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Full Length Research

Effect of seasons on physiological responses, milk production and composition in Indigenous cows

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ABSTRACT: The present investigation was carried out to find the effect of seasons on milk production and composition in indigenous Sahiwal, Tharparkar and Gir cows maintained under the intensive management practices at the institute livestock farm. Fifteen lactating cows of Tharparkar (TP), Sahiwal (SW) and Gir breed were selected in early lactation. The experiment was conducted for a period of 10 months and the seasons were categorized as hot-humid, hot-dry, autumn and winter season. Blood and milk samples collected at fortnightly intervals were analysed for minerals and plasma hormones. Physiological responses-respiration rate (RR), pulse rate (PR) and rectal temperatures (RT) were recorded. The results showed that the milk fat, solid not fat SNF and urea levels were higher in TP cows in comparison to SW and Gir cows ($p<0.01$), however, protein % was lower ($p<0.01$) in TP cows. Milk Mg, Ca and Na levels were lower in hot-humid season than in winter season ($p<0.05$) in TP cows in comparison to SW and Gir. Plasma cortisol level was higher and aldosterone level was lower in hot-humid and hot-dry season in all the breeds of cows ($p<0.05$) than the values observed in winter season. TP cows were found to have higher aldosterone level as compared to SW and Gir cows in all the seasons. The cows response to ambient temperature in terms of RR, RT and PR was higher in hot-humid season and lowest in winter season ($p< 0.01$) in all the breeds, however changes in RT were of less magnitude in TP cows than SW and Gir cows in hot-hot humid season. It was concluded that TP cows have higher plasma aldosterone, milk urea and sodium levels and less diurnal variation in RT, PR and RR in comparison to SW and Gir cows in hot-dry and hot humid season which makes TP cows more heat tolerant than SW and Gir.

Keyword: Hot dry season, hot humid season, hormones, indigenous cows, milk yield, physiological reactions.

INTRODUCTION

India has the distinct 20 agro-ecological zones with varying climate of tropical to temperate regions in 8 different agro-climatic zones. The temperature in tropical regions of the country rises between 40 to 48°C in summer season and dips to less than 0°C during the winter season. This diverse range of low to very high ambient temperature adversely influences the physiological and endocrinological profile of animals causing the stress. The stress represents reaction of the body to external stimuli that disturbs normal homeostasis (Adamczyk et al., 2015; Hill and Wall, 2015) resulting in adverse impact on growth, lactation, reproductive performance and immune functions of the animals (Kadokawa, 2012). Sahiwal and Gir cows are specialized milch cattle breed while Tharparkar is a dual-purpose cattle breed and is very well adapted to extremely hot-dry climate in the deserts of Rajasthan and Gujarat (Iqbal et al., 2019). Heat stress during hot dry and hot humid season decrease feed intake (Aggarwal and Singh, 2006), milk production, metabolic hormone levels (thyroid hormone), increases cortisol level and alters milk composition (Chanda et al., 2017). Due to dynamic changes in the climate, the extremes of high and low temperature incidences are now happening at a very fast rate. It is expected that the temperature will rise 1.5^0 C (warming) between 2030 and 2050 and will further increase to more than 3 to 4^0C causing intense global warming by 2100 (IPCC, 2018). In such situations indigenous cows breeds being more heat tolerant than the crossbred cows, which have higher metabolic heat production could play immense role in mitigation of summer stress and milk production (Das et al., 2016). Thus, the present study was undertaken to assess the comparative performances of indigenous cow breeds to summer and winter stress by measuring physiological reactions, milk production, composition, plasma energy metabolites and hormone levels.

MATERIALS AND METHODS

Selection of animals and management

The plan of the experiment was duly approved by the Institute Animal Ethic Committee (IAEC) of the institute during June 2017. Fifteen lactating cows, five each of Sahiwal, Tharparkar and Gir breed in II parity, yielding average milk yield of 9.5, 9.7 and 10 kg/day, respectively, were selected from the livestock herd of the institute at av.50 ±10 days of lactation. The cows were managed in an asbestos roof shed during hot humid (July- September), autumn (Oct-Nov.), spring (March), hot dry (April-May) and winter season (December–February). During the experiment period of 10 months, all the cows were maintained in an asbestos roof shed and were fed on a ration consisting of roughages (berseem, oats, maize or jowar fodder) and concentrate mixture (60:40). Meteorological data viz., dry bulb temperature, wet bulb temperature; relative humidity was recorded during the experiment period. The temperature humidity index was calculated ($THI = 0.72(T_{db} + T_{wb}) + 40.6$).

Sampling and analysis

Experimental cows were hand milked twice a day in the morning (7 am) and eveninghour (6 pm) and the milk yield of individual cow was recorded. Milk samples (200 ml) were collected at fortnightly intervals at the time of milking. In fresh milk samples, milk fat, SNF, protein and lactose was determined using a Milko tester. Milk casein, whey protein, non-protein nitrogen (NPN), urea and ash content of milk were estimated by standard analytical methods. Mineral content of milk (Ca^{++}, Mg^{+}, Na^{+} and K^{+}) were determined by Flame Atomic Absorption Spectrometry (Model AA-7000; Shimadzu corporation, Japan**)**. To determine the plasma energy metabolites and hormones level, blood samples were collected from the jugular vein

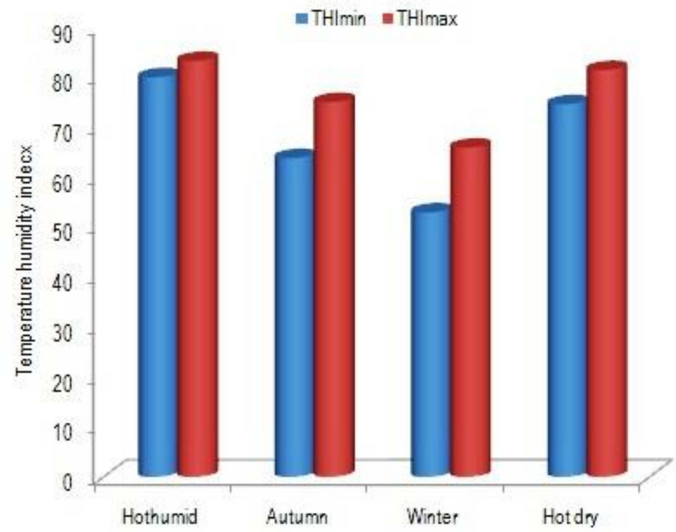

Figure 1. Mean maximum and minimum THI during different seasons of the experiment.

at 8 am in sterile heparinised vacutainer tubes. Plasma cortisol and aldosterone levels were determined by bovine specific enzyme immunoassay kits (M/S. Bioassay Technology Limited, China). The copper soap solvent extraction method modified by Shipe et al. (1980) was used for the estimation of plasma non esterified fatty acids (NEFA). Blood glucose and total protein were estimated by analytic kits (M/S Span Diagnostics Ltd.).

Physiological responses like rectal temperature (RT), respiration rate (RR) and pulse rate (PR) of the cows were recorded at fortnightly intervals. Rectal temperature (^{0}F) was recorded by clinical thermometer while respiration rate was recorded by observing flank movement and is expressed as breaths/minute. Pulse rate was counted by observing the pulsation of middle coccygeal artery at the base of the tail and expressed as beats/minute. Experimental data was analysed statistically by 3-way ANOVA with interactions using Sigma Stat Software program. Mean values were compared for statistical significance at 5% and 1% level.

RESULTS

Mean THI_{min} value was more ($p<0.05$) during hot-humid season than the hot-dry season (Figure 1), however, THI_{max} was higher in hot-humid season ($p<0.05$) and the lowest THI_{max} of 52.90 was recorded in winter season of the experiment ($p<0.05$). Average maximum and minimum temperatures during the experiment ranged between 18.37 to 35.66 and 5.76 to 26.40°C, respectively.

Table 1. Mean milk yield and composition changes in different breeds of cows.

Breed	Seasons of experiment									
	Hot humid season			Autumn season		Winter season			Hot dry	
Milk yield (kg)										
SW	$241.10^{x}\pm18.88$	$265^{x}.50\pm22.46$	$256.90^{x}\pm35.13$	$256.0^{x}\pm33.00$	$290.50^{x}\pm50.70$	$197.20^{y}\pm30.66$	$132.40^{zy}\pm37.28$	$93.80^{z}\pm29.96$	$55.30^{z}\pm36.21$	$30.30^{z}\pm19.80$
TP	$208.30^{y}\pm45.27$	$261.50^{x}\pm15.49$	$247.30^{x}\pm8.44$	$126.30^{yz}\pm22.10$	$131.0y^{z}\pm32.15$	$106^{zy}.20\pm26.36$	$190.40^{xy}\pm19.94$	$105.40^{z}\pm23.08$	$112.80^{z}\pm24.13$	$66.70^{z}\pm41.43$
GR	$133.90^{z}\pm14.04$	$116.20^{z}\pm22.82$	$118.80^{z}\pm19.39$	$126.30^{yz}\pm22.10$	$131.0y^{z}\pm32.15$	$106.20^{zy}\pm26.36$	$66.10^{z}\pm29.33$	$31.0^{z}\pm24.40$	$17.10^{z}\pm16.36$	$16.69^{z}\pm15.35$
Fat %										
SW	$3.42^{x}\pm0.058$	$3.5^{x}\pm0.054$	$3.6^{x}\pm0.083$	$4.34^{x}\pm0.081$	$4.5^{x}\pm0.070$	$4.68^{x}\pm0.106$	$4.7^{x}\pm0.063$	$4.66^{x}\pm0.050$	$4.58^{x}\pm0.037$	$4.52^{x}\pm0.083$
TP	$4.08^{y}\pm0.308$	$4.44^{y}\pm0.107$	$4.46^{y}\pm0.050$	$4.64^{y}\pm0.040$	$4.96^{y}\pm0.097$	$4.84^{x}\pm0.116$	$4.94^{x}.3\pm0.04$	$4.78^{x}\pm0.066$	$4.66^{x}\pm0.124$	$4.64^{x}\pm0.074$
GR	$3.20^{z}\pm0.089$	$3.16^{z}\pm0.112$	$3.20^{z}\pm0.094$	$3.68^{z}\pm0.165$	$3.74^{xz}\pm0.102$	$3.96^{y}\pm0.092$	$4.18^{y}\pm0.086$	$4.28^{y}\pm0.058$	$4.18^{y}\pm0.091$	$4.26^{y}\pm0.050$
Protein %										
SW	$3.46^{x}\pm0.024$	$3.50^{x}\pm0.031$	$3.56^{x}\pm0.024$	$3.58^{x}\pm0.037$	$3.64^{x}\pm0.04$	$3.68^{x}\pm0.037$	$3.68^{x}\pm0.037$	$3.70^{x}\pm0.031$	$3.7^{x}\pm0.031$	$3.64^{x}\pm0.024$
TP	$3.50^{x}\pm0.025$	$3.54^{x}\pm0.020$	$3.56^{x}\pm0.020$	$3.60^{x}\pm0.025$	$3.64^{x}\pm0.020$	$3.66^{x}\pm0.020$	$3.68^{x}\pm0.030$	$3.70^{x}\pm0.025$	$3.68^{x}\pm0.054$	$3.50^{x}\pm0.058$
GR	$3.44^{x}\pm0.050$	$3.46^{xy}\pm0.24$	$3.54^{x}\pm0.024$	$3.60^{x}\pm0.031$	$3.62^{x}\pm0.020$	$3.64^{x}\pm0.024$	$3.66^{x}\pm0.050$	$3.68^{x}\pm0.048$	$3.66^{x}\pm0.024$	$3.64^{x}\pm0.050$
Lactose %										
SW	$5.26^{x}\pm0.103$	$5.27^{x}\pm0.073$	$5.27^{x}\pm0.132$	$5.29^{x}\pm0.054$	$5.30^{x}\pm0.064$	$5.37^{x}\pm0.181$	$5.40^{x}\pm0.332$	$5.21^{x}\pm0.149$	$5.14^{x}\pm0.250$	$5.00^{x}\pm0.037$
TP	$5.22^{x}\pm0.057$	$5.23^{x}\pm0.025$	$5.24^{x}\pm0.070$	$5.28^{x}\pm0.240$	$5.30^{x}\pm0.029$	$5.31^{x}\pm0.115$	$5.31^{x}\pm0.025$	$5.29^{x}\pm0.031$	$5.21^{x}\pm0.043$	$4.94^{x}\pm0.217$
GR	$5.18^{x}\pm0.040$	$5.17^{x}\pm0.070$	$5.19^{x}\pm0.030$	$5.25^{x}\pm0.034$	$5.29^{x}\pm0.19$	$5.30^{x}\pm0.052$	$5.25^{x}\pm0.092$	$5.23^{x}\pm0.008$	$5.25^{x}\pm0.032$	$4.96^{x}\pm0.04$
SNF %										
SW	$8.88^{x}\pm0.025$	$8.89^{x}\pm0.026$	$8.89^{x}\pm0.026$	$8.92^{x}\pm0.024$	$8.94^{x}\pm0.011$	$8.95^{x}\pm0.55$	$8.95^{x}\pm0014$	$8.99^{x}\pm0.013$	$9.01^{x}\pm0.042$	$8.99^{x}\pm0.016$
TP	$8.89^{x}\pm0.112$	$8.90^{x}\pm0.094$	$8.93^{x}\pm0.087$	$8.95^{x}\pm0.090$	$8.98^{x}\pm0.032$	$9.00^{x}\pm0.028$	$9.03^{x}\pm0.061$	$9.04^{x}\pm0.069$	$9.04^{x}\pm0.050$	$9.03^{x}\pm0.038$
GR	$8.80^{x}\pm0.064$	$8.84^{x}\pm0.040$	$8.85^{x}\pm0.023$	$8.85^{x}\pm0.048$	$8.86^{x}\pm0.37$	$8.89^{x}\pm0.148$	$8.91^{x}\pm0.017$	$8.92^{x}\pm0.095$	$8.94^{x}\pm0.038$	$8.96^{x}\pm0.68$

Values with difference superscripts $^{x, y, z}$ differ in a column ($p<0.05$); Sw-Sahiwal, TP-Tharparkar, GR-Gir cow.

Milk production and composition

Milk yield of cows varied between the breeds ($p<0.01$) and was higher in Sahiwal cows in comparison to Tharparkar and Gir cows (Table 1). Sahiwal cows attained peak milk yield of 9.80 kg than 8.70 and 4.30 kg/d in Tharparkar and Gir cows, respectively. Mean milk fat percentage showed variation between breed and season ($p<0.01$) and was more in TP cows than SW and Gir cows. Furthermore, milk fat and protein content decreased in all the breeds in hot humid season and increased in winter season ($p<0.05$). Llactose percent was non-significant between the breed, animal and season, however SNF and casein content was influenced by breed and season ($p<0.001$). SNF was higher in Tharparkar cows followed by Sahiwal and Gir cows ($p<0.001$) during all the seasons. Casein in all the breeds showed increasing trend from hot humid season to winter season. Whey protein varied between season ($p<0.01$) and was non-significant between Sahiwal and Tharparkar cows. However, Gir cow milk has numerically low whey protein content than Sahiwal and Tharparkar cows. Also, Sahiwal cows exhibited greater variability in whey protein content as compared to Tharparkar and Gir cows. Mean

Table 2. Mean milk casein, whey protein, NPN, urea level and ash content of milk in different breeds of cows.

Breed	Months of experiment									
	Hot humid season			**Autumn season**		**Winter season**			**Hot dry**	
Casein %										
SW	2.83±0.023	2.87±0.036	2.94±0.021	2.97±0.036	3.03±0.041	3.070±0.042	3.06±0.040	3.10±0.028	3.08±0.032	3.02±0.025
TP	2.88±0.029	2.92±0.020	2.94±0.015	2.94±0.008	3.03±0.026	3.050±0.044	3.08±0.049	3.102±0.031	3.081±0.065	3.015±0.040
GR	2.84±0.053	2.84±0.023	2.93±0.023	3.01±0.027	3.048±0.014	3.066±0.022	3.075±0.060	3.099±0.049	3.060±0.026	3.031±0.053
Whey protein %										
SW	0.622±0.003	0.620±0.003	0.618±0.003	0.612±0.003	0.608±0.004	0.606±0.004	0.608±0.005	0.610±0.005	0.612±0.002	0.610±0.007
TP	0.61±0.004	0.612±0.003	0.612±0.003	0.610±0.003	0.612±0.002	0.60±0.008	0.610±0.004	0.604±0.004	0.602±0.003	0.60±0.003
GR	0.602±0.006	0.606±0.002	0.604±0.005	0.606±0.002	0.604±0.004	0.600±0.003	0.602±0.005	0.602±0.002	0.604±0.005	0.606±0.004
NPN (%)										
SW	0.295±0.002	0.297±0.002	0.288±0.002	0.277±0.004	0.253±0.003	0.239±0.002	0.234±0.002	0.230±0.004	0.231±0.002	0.243±0.004
TP	0.304±0.002	0.297±0.002	0.289±0.04	0.280±0.04	0.255±0.002	0.249±0.003	0.232±0.002	0.231±0.002	0.235±0.003	0.244±0.002
GR	0.283±0.003	0.282±0.005	0.279±0.004	0.259±0.002	0.247±0.003	0.232±0.005	0.227±0.004	0.214±0.002	0.228±0.001	0.238±0.001
Urea (mg/ml)										
SW	0.37±0.002	0.36±0.003	0.36±0.002	0.35±0.001	0.33±0.003	0.33±0.001	0.33±0.002	0.33±0.002	0.35±0.002	0.36±0.003
TP	0.37±0.004	0.36±0.003	0.36±0.002	0.35±0.003	0.34±0.003	0.34±0.002	0.33±0.003	0.35±0.002	0.36±0.006	0.36±0.005
GR	0.35±0.002	0.35±0.002	0.35±0.007	0.35±0.003	0.33±0.002	0.33±0.004	0.33±0.006	0.34±0.003	0.34±0.001	0.35±0.002
Ash (%)										
SW	0.69±0.025	0.70±0.031	0.70±0.018	0.715±0.014	0.719±0.018	0.72±0.024	0.72±0.022	0.72±0.015	0.72±0.024	0.71±0.009
TP	0.69±0.022	0.69±0.031	0.71±0.01	0.72±0.030	0.72±0.017	0.72±0.033	0.72±0.012	0.72±0.029	0.71±0.036	0.70±0.015
GR	0.70±0.019	0.70±0.03	0.71±0.02	0.70±0.02	0.70±0.03	0.71±0.014	0.71±0.020	0.71±0.022	0.71±0.030	0.70±0.021

NPN content of milk varied between Sahiwal, Tharparkar and Gircows ($p<0.05$).

Minerals profile of milk

Ash content of milk did not vary between the breed, animal and season during the experiment. The reference value of milk ash content was 0.70 to 0.73% in Sahiwal, Gir and Tharparkar cows. Mean milk sodium level was higher in Tharparkar cows ($p<0.001$) than the Sahiwal and Gir cows, however, Na level did not vary between GR and SW cows (Table 2). Furthermore, mean sodium level was lower in hot humid season and maximum in spring season in SW, TP and Gir cows. Potassium levels decreased ($p<0.05$) during hot dry season in TP cows in comparison to SW and GR cows. Milk calcium level was low in hot-humid season and was higher in winter season ($p<0.001$). Milk Mg level showed remained non-significant in different seasons.

Physiological responses

Mean RR in the morning hour varied significantly between the breed ($p<0.01$), season and intervals (morning and evening). Mean RR and PR was maximum in hot-humid season and was lowest in

Table 3. Mean milk Na, K, Ca and Mg levels in different breeds of cows.

Breed	Seasons of experiment									
	Hot humid			Autumn		Winter			Hot dry	
Sodium(mg/L)										
SW	484.6^{x}±4.46	489.2^{x}±2.67	493^{x}±8.51	495.6^{x}±1.20	498.8^{x}±0.66	503.6^{x}±0.24	505.6^{x}±0.68	507^{x}±0.71	508.6^{x}±0.51	499.6^{x}±0.51
TP	491.4^{y}±1.98	496.6^{y}±0.60	501.2^{y}±0.86	502.4^{y}±0.40	504.4^{y}±0.40	505.2^{y}±0.58	507.4^{y}±0.51	507.6^{y}±0.51	505.6^{y}±0.50	499.6^{x}±0.51
GR	482^{z}±6.32	491.4^{z}±0.51	493.8^{z}±0.73	500.4^{z}±0.68	502.2^{z}±0.49	503.4^{z}±0.24	504.6^{xz}±0.51	504.6^{y}±0.40	503.8^{z}±0.49	488.6^{y}±0.68
Potassium(mg/L)										
SW	1532.2^{x}±8.8	1531.8^{x}±5.2	1532.2^{x}±2.9	1526.8^{x} ±2.7	1523.0^{x}±1.5	1525.4^{x}±2.9	1521.0^{x}±2.4	1519.4^{x}±2.3	1518.4^{x}±0.9	1522.2^{x}±4.2
TP	1528.0^{x}±0.9	1527.4^{x}±2.1	1528.2^{x}±2.1	1526.4^{x}±0.9	1522.2^{x}±4.1	1525.2^{x}±2.1	1521.8^{x}±4.0	1520.2^{x}±3.5	1517.4^{x}±2.7	1517.4^{x}±2.7
GR	1527.4^{x}±1.6	1525.6^{x}±3.1	1527.4^{x}±1.2	1526.8^{x}±1.65	1523.8^{x}±1.6	1525.0^{x}±2.0	1521.0^{x}±4.0	1519.2^{x}±2.92	1520.0^{x}±5.64	1516.2^{x}±1.2
Calcium(mg/L)										
SW	1203.2^{x}±3.5	1206.6^{x}±1.5	1208.4^{x}±1.4	1208.4^{x}±1.8	1210.2^{x}±2.0	1212.2^{x}±0.7	1212.4^{x}±1.7	1212.8^{x}±0.9	1212.2^{x}±1.1	1212.8^{x}±0.5
TP	1205.6^{x}±1.6	1206.2^{xy}±1.5	1207.4^{x}±0.8	1208.2^{x}±0.9	1210.0^{x}±1.1	1212.0^{x}±0.9	1212.8^{x}±0.4	1213.0^{x}±0.7	1212.4^{x}±0.9	1213.2^{x}±1.7
GR	1204.0^{x}±31	1204.0^{yz}±31	1207.2^{x}±1.8	1208.6^{x}±1.2	1210.2^{x}±1.2	1211.8^{x}±1.0	1212.6^{x}±0.5	1213.6^{x}±0.2	1212.0^{x}±0.8	1211.6^{x}±0.4
Magnesium(mg/ml)										
SW	129.2^{x}±0.86	129.6^{x}±0.68	129.8^{x}±1.65	130.0^{x}±0.83	130.6^{x}±0.51	131.2±0.37	131.2^{x}±0.37	130.4^{x}±1.53	130.2^{x}±1.65	129.2^{x}±1.52
TP	129.0^{x}±1.48	129.8^{x}±0.97	130.0^{x}±0.77	130.4^{x}±0.04	130.8^{x}±0.49	131.0^{x}±0.32	130.8^{xy}±0.37	130.8^{x}±0.58	130.8^{x}±0.48	130.2^{x}±0.37
GR	128.6^{x}±0.50	129.4^{x}±2.35	129.4^{x}±1.36	130.4^{x}±0.87	130.6^{x}±0.40	130.8^{x}±0.37	136.6^{z}±0.24	130.0^{x}±0.71	130.2^{x}±0.58	129.8^{x}±0.86

Values with difference superscripts $^{x, y, z}$ differ in a column (p<0.05); Sw-Sahiwal, TP-Tharparkar, GR-Gir cow.

the winter season (p<0.05) in TP cows (Figure 2). Morning pulse rate averaged 67.08, 62.12 and 61.46 pulse/minute in SW, TP and GR cows respectively and were non-significant, however, evening PR value was higher in all the breeds of cows (p<0.05) in comparison to morning. PR was significantly influenced by season in all the breeds of cows (p<0.05) and averaged 70.06, 65.08 and 66.24 pulse/minute in SW, TP and GR cows, respectively. Mean morning RT was significant between the breed and season (p<0.001), the respective values were 101.80, 101.40 and 101.20^{0}F in SW, GR and TP cows. Mean RT during evening time was more in hot-humid and hot-dry season than the winter season, Figure 4 (p<0.01). Rectal temperature of SW and Gir cows in the evening time was higher in comparison to TP cows (Figure 5).

Plasma Hormones and energy metabolites

Mean plasma aldosterone level was higher in TP and GR cows than SW cows (p<0.05) with the respective values of 82.12, 81.4 and 79.06 ng/L (Figure 6). Plasma cortisol was non-significant and numerically higher in SW cows than GR and TP cows with the respective mean values of 4.33, 4.20 and 4.28 ng/ml. Cortisol level remained high in hot-dry and hot-humid season and the minimum level were observed in winter season (p<0.05). Mean aldosterone level decreased in hot and hot-humid season and was higher in winter season in all the breeds (Figure 7). Plasma protein did not vary between breed and animals and was lower in summer in comparison to winter season (p<0.01).

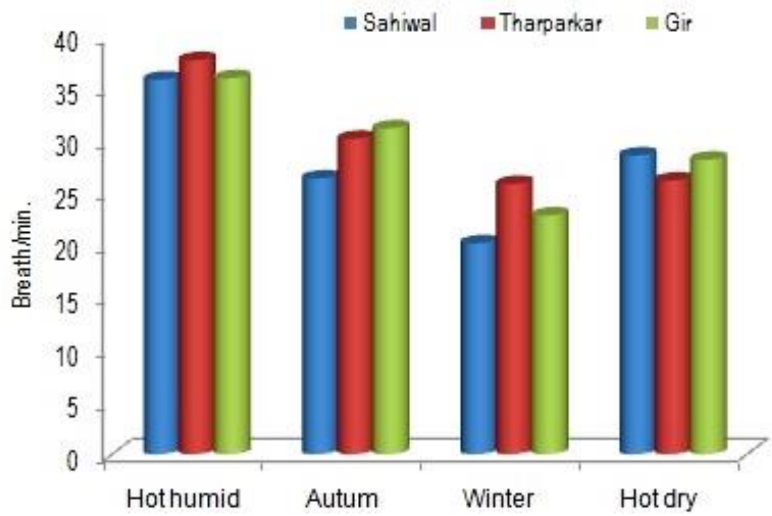

Figure 2. Effect of season on morning respiration rate in different breeds of cows.

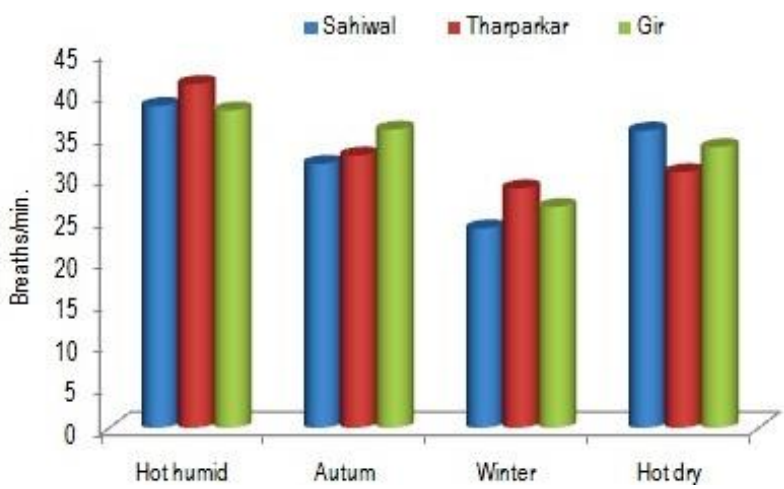

Figure 3. Effect of season on evening respiration rate in different breeds of cows.

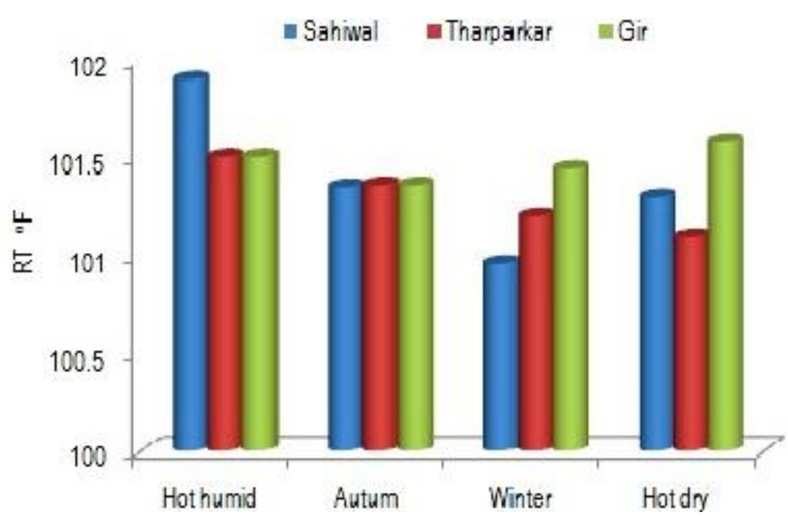

Figure 4. Effect of season on morning rectal temperature in different breeds of cows.

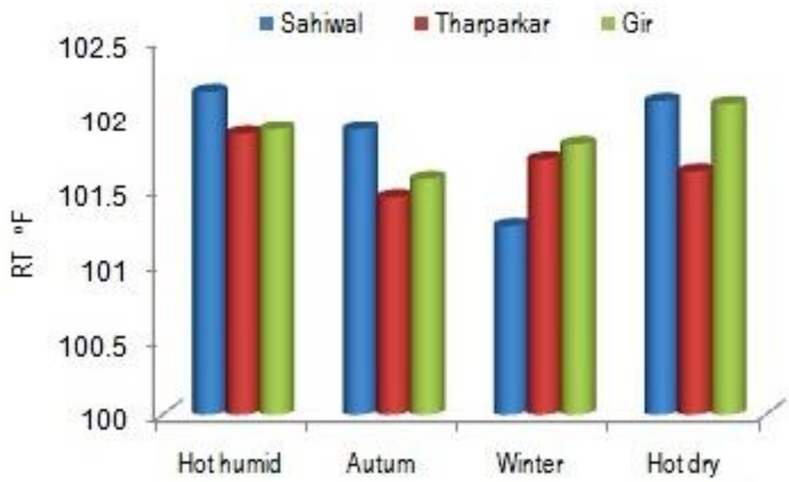

Figure 5. Effect of season on evening rectal temperature in different breeds of cows.

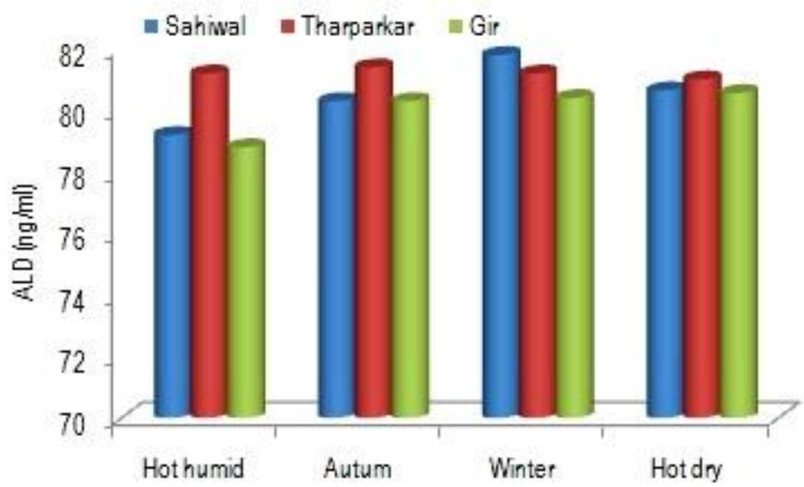

Figure 6. Mean plasma aldosterone level during different seasons of experiment in cows.

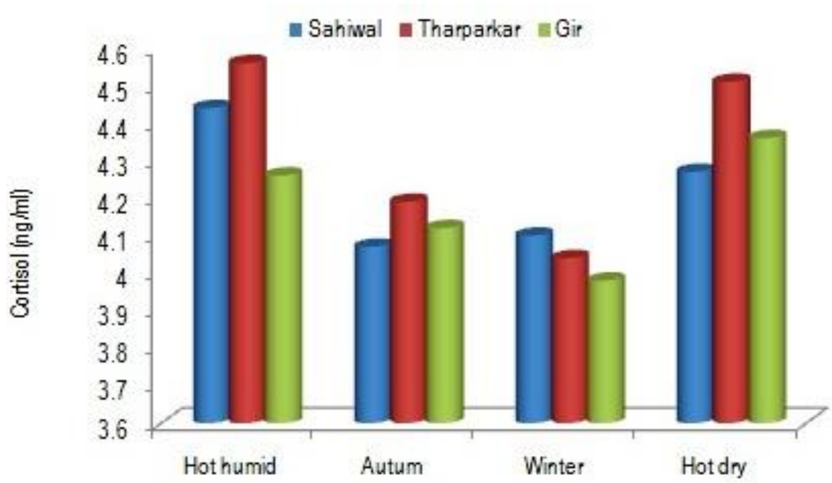

Figure 7. Mean plasma cortisol level during different seasons of experiment in cows.

Plasma glucose level was non-significant between the breed with mean values of 53.37, 52.77 and 52.41 mg/dl in GR, TP and SW cows, respectively. Plasma glucose and NEFA levels were higher in winter than in summer season ($p<0.01$). Mean plasma NEFA level were 0.34, 0.34 and 0.31 mM/ml in SW, TP and GR cows, respectively.

DISCUSSION

The results of the study demonstrated that Tharparkar cows are more heat tolerant in comparison to the SW and Gir cows due to less impact of THI on milk production, physiological responses and higher circulatory aldosterone level which regulates the ionic concentration of sodium and potassium in milk (Choudhary et al., 2019). The loss of potassium in the sweat is very high during the summer season. Potassium is essentially required to maintain the normal function of cell by maintaining its level across the cell membrane. Long-term maintenance of potassium homeostasis is achieved by alterations in renal excretion of potassium in response to variations in intake (Palmer, 2015). Indigenous breed of cows like Tharparkar, Sahiwal and Gir are the most important milch breed of the western arid region of India (Choudhary et al., 2019). Because of heat tolerance characteristics features, all the three breeds have now been focussed to upgrade them extensively for high milk production and reproductive efficiency (Singh, 2016). Gir cows can withstand high temperature by raising the rectal temperatures in hot-dry condition contrary TP cows in which increase in RT was less consistent in this study. It has been found that grading-up of local cattle by temperate breeds for greater performance results to increase the sensitivity to heat stress (Chanda et al., 2017). The reason for better adaptability in TP cows could be attributed to its habitation in desert area of the country where adrenal secretion of both cortisol and aldosterone hormone due to the reduction in hepatic blood flow which reduces aldosterone metabolic clearance rate. Marked rises in plasma cortisol during heat stress are always accompanied by simultaneous rises in aldosterone, but rises in aldosterone sometimes also occur in the absence of a rise in cortisol (Collins et al., 1979). Dehydration under heat caused a sharp increase in antidiuretic hormone ADH levels and a significant increase in plasma protein as observed in this study (El-nouty et al., 1980). It has been reported that high temperature humidity index (THI) during hot humid decreases feed efficiency, DM intake (DMI), body weight, plasma T4, glucose and NEFA levels in comparison to winter session (Singh et al., 2014a,b). Other factors like quality of feed and season also influenced homeorhetic mechanisms in the rearrangement of metabolism (Vujanac et al., 2012). The diurnal variation in the RT, PR and RR also indicated adverse effect of high THI during hot-dry and hot-humid season. The low values of RR in morning and high values in the afternoon in SW and GR cows as compared to TP cows suggest that later can withstand the rigors of high ambient temperature (Pandey, 2017). Furthermore, the rise in physiological responses indicated thermoregulatory and adaptive responses of cows which lead to a significant increase in rectal temperature, respiration rate, sodium and cortisol level (Wankar et al., 2014; Cardoso et al., 2015).

It has been reported that summer heat stress reduced milk yield and DMI, altered milk composition and influenced the physiological functions of confined lactating Holstein cows managed under Mediterranean climatic conditions (Bouraoui et al., 2002) as THI was negatively correlated to milk yield ($r = -0.76$) and feed intake ($r = -0.24$). Protein percentage and protein yield decreased beyond THI 68 for both THI measurements (test-day THI and THI from previous week) however THI effects on milk urea level were less obvious in Holstein cows (Gernand et al., 2019). Bernabucci et al. (2015) found lowest values of all the main milk components (fat, protein, total solids, and solids-not-fat) in the summer and the greatest values in the winter in Holstein cows which was observed in the present study. The altered composition of milk during heat stress are attributed to higher internal metabolic heat production during lactation which reduces the resistance of cattle to bear the thermal stress (Pragna et al., 2017). However, mist and fan cooling during hot-dry season provide better comfort by alleviating environmental stress as physiological responses such as RT, RR, PR, and forehead and mid-dorsal temperatures significantly ($p<0.05$) reduces as compared to control, which subsequently resulted higher ($p<0.001$) milk yield by 4.44 % (Haque et al., 2016). The higher value of physiological responses in the evening for respiration rate, pulse rate and rectal temperature suggest that these parameters could be used as indicators of heat stress in lactating cows. The polymorphism at HSP70 could also be explored as potent determinant for heat tolerance in cattle, which may aid in selection for thermotolerance in cattle (Bhat et al., 2016). The milk fat, protein and lactose were significantly higher ($p<0.05$) in winter season due to lower THI values and comfortable environment for animals (Chanda et al., 2017). In-housed buffaloes in winter season experienced better comfort by alleviating environmental stress and the physiological responses viz., respiration rate and pulse rate were significantly reduced ($p<0.01$) leading to higher milk yield by 9.92% (Haque et al., 2018). Such buffaloes have higher concentration of milk plasminogen (10.6 vs. 8.05 μg/ml; $p < 0.01$) and β-casein ($p < 0.05$), and lower plasmin level (0.299 vs. 0.321 μg/ml; $p < 0.05$). The higher aldosterone level in the TP cows supports this fact as aldosterone is responsible for controlling the electrolyte balance of body mainly sodium and potassium level. This fact was also evident from less magnitude of change in RT in TP cows in comparison to SW and GR cows. RT has been used as index of stress condition and any type of infection involved. However, microclimate alteration by providing mist and fan in the buffaloes shed augmented feed intake and more milk yield in buffaloes (Anjali and Singh, 2010; Reddy et al., 2015). During winter season also the in-house management of buffaloes helps in maintaining the physiological responses to normal level (Aggarwal and Singh, 2005). Parameters like respiration rate, pulse rate, blood pressure, skin surface temperature and blood flow give an immediate response about comfort level to a climatic stress as summer season is more stressful as compared to winter (Aggarwal et al., 2019). Since cows were producing moderate quantity of milk, the plasma levels of energy metabolites- NEFA and glucose were in normal range, however, high producing crossbred cows' meets energy requirement by mobilisation of the body reserves resulting in higher NEFA concentration. Although these changes are normal adaptive process in high yielding cows, when a cow fails to adapt, several metabolic and infectious disorders occur (Wankhade et al., 2017).

Conclusions

The results of the study revealed that adverse effects of heat stress on milk production, composition and physiological reactions are more severe in hot-humid season than the hot-dry season due to higher cortisol and aldosterone levels. Tharparkar cows exhibit more heat tolerant capacity over the Sahiwal and Gir cows due to least changes in physiological reactions (RR, RT and PR), high milk urea, sodium and plasma aldosterone levels during heat stress. Furthermore, summer stress leads to decline in milk production and adversely influenced protein, whey protein and mineral content of milk which could be maintained by adopting suitable feeding and management strategies. The findings of the study could be of great interest in strategic planning for genetic improvement of the indigenous livestock's and their preservation.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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