RESEARCH ARTICLE

Geothermal Energy: Revolutionary Initiative in Indian Dairy Sector and Its Effect on Physiological Parameters of Growing Murrah Buffaloes

Nikita Bhalakiya[1]*, Sohan Vir Singh[1], Pawan Singh[2], Gaurav Kumar[1], Jaskiran Kaur[1], Apeksha Ukey[1]

Abstract

Renewable energy derived from the core of earth is known as geothermal energy. It originates from heat produced during the radioactive decay of elements. The temperature at 2-3 meters below the surface of earth remains almost the same in a special range (24°-28°C) throughout the year. This temperature can be used to control the temperature of the animal habitat in a comfortable range during the summer and winter seasons by applying geothermal system. Geothermal system was developed through results obtained of a pilot study conducted in LRC, NDRI, Karnal in which various temperature sensors were used to detect temperature at various underground depth, *i.e.,* 12, 8, 6, 4, and 2 meter. The effect of surface (environmental) temperature was found negligible on underground temperature beyond 4 m depth. Therefore, geothermal heat exchanger/pipes can be placed at 4 m depth below. The efficiency of this geothermal system was determined for cooling and warming of shed and its impact on physiological parameters of 18 growing female Murrah buffalo-heifers (10-14 month) divided into 3 equal groups during winter and summer seasons at ICAR-NDRI, Karnal. Animals of first group (experimental) were housed under shed provided with geothermal system, those of second group (control-I) were housed in the shed which was replica of group I, except geothermal system, and third group of animals (control-II, herd) were reared under normal existing managemental conditions. The system was operated during coldest 12 hours of the day (night time) during winter season and hottest 12 hours of the day (day time) during summer season. Temperature difference among experimental shed, control-I, control-II and duct were recorded throughout the study at every 2 h interval by temperature sensing probe. Samplings were done at fortnight intervals. During the experimental period we found significant ($p<0.05$) increase in temperature of experimental shed during winter season, and significant decrease ($p<0.05$) during summer season as compared to environmental temperature and control shed. This effect was reflected in terms of significantly ($p<0.05$) higher physiological parameters, *viz.,* respiration rate, rectal temperature and skin temperature during winter season and lower during summer season in experimental shed as compared to herd and control group.

Key words: Geothermal energy, Murrah buffaloes, Physiological responses, Seasonal stress.

Ind J Vet Sci and Biotech (2025): 10.48165/ijvsbt.21.4.21

Introduction

In the recent scenario of global warming and energy crisis many new methods came into existence to reduce pollution but renewable energy has attracted the attention of people and scientists globally. One of these methods is the use of geothermal energy, one of the best gifts by nature. It is the heat received within the subsurface of the earth. In the core of earth, rocks and liquids contain this thermal energy. Geothermal energy is renewable as decay of naturally existing radioactive elements replenishes the heat that is emitted from the interior of the earth and will continue in future also without getting exhausted. This energy can be used without bringing any unwanted changes in the environment. The underground (below the surface 2-3 meters) temperature of the earth remains almost the same in a special range (24°C-28°C) throughout the year. This temperature can be used to control the temperature of the animal shed in a comfortable range during the summer and winter seasons. Generally, to control the temperature of the shed, geothermal energy is extracted from the depth of 2-3 meters of the earth. It has a very low environmental impact, emits almost no greenhouse gases, and offers continuous access to clean, renewable energy. It also provides a low-carbon method of cooling and heating buildings (Mahbaz *et al.*, 2020). Geothermal energy is

[1]Animal Physiology Division, ICAR-National Dairy Research Institute, Karnal-132001, Haryana, India

[2]Livestock Production and Management, ICAR-National Dairy Research Institute, Karnal-132001, Haryana, India

Corresponding Author: Dr. Nikita Bhalakiya, Assistant Professor, Department of Physiology & Biochemistry, College of Veterinary Science, Kamdhenu University, Rajpura (Nava), Himmatnagar, Gujarat, India. e-mail: nikitabhalakiya59@gmail.com

How to cite this article: Bhalakiya, N., Singh, S V., Singh, P., Kumar, G., Kaur, J., & Ukey, A. (2025). Geothermal Energy: Revolutionary Initiative in Indian Dairy Sector and Its Effect on Physiological Parameters of Growing Murrah Buffaloes. Ind J Vet Sci and Biotech, 21(4), 109-115.

Source of support: Nil

Conflict of interest: None

Submitted 17/04/2025 **Accepted** 10/05/2025 **Published** 10/07/2025

continuously transferred from core of the earth to its surface due to the difference in temperature between the core and its surface. Some of the core rocks melt at temperatures over 4000°C to generate hot, molten rocks known as magma. Since the mantle is lighter than the underlying rock, it also exhibits plastic behaviour under this temperature, causing some of it to go upward.

Almost anywhere in the world, geothermal heat can be accessed and used immediately as a source of heat called low-temperature geothermal energy. It is obtained from pockets of heat about 150°C (302° F). Most pockets of low-temperature geothermal energy are found just a few meters below the ground, and can be used for heating greenhouses, homes, fisheries and industrial processes. It is most efficient when used for heating, although it can sometimes be used to generate electricity (Zhiyin *et al.,* 2012; Colin *et al.,* 2019). As environmental temperature has negligible effect on underground temperature and it is constant throughout the year around 25°C or so, geothermal system was design to utilize this underground temperature for conditioning of environmental air. This conditioned environmental air is again blown back into shed which changes the temperature of shed towards comfortable.

India is a tropical country and experiences huge variation in temperature throughout the year, *i.e.,* from below minus 2°C to above 48°C. These drastic changes in temperature affect every living being including dairy animals adversely. Though in India, dairy animals which are habitant of particular region are well adapted, still these temperature changes affect adversely in terms of immune status, growth and production. Extreme environmental conditions consistently threaten the productive and reproductive success of livestock. Buffaloes are well-adapted to such climatic extremes, as shown by their large population in such varied climatic conditions. Despite of this, it is widely assumed that buffaloes are susceptible to heat stress due to their sparse hair coat and thick black skin, which absorbs more solar radiation. Buffalo skin has less (nearly 1/6th) sweat glands than zebu skin, compromising heat dissipation through evaporative heat loss. These unique morphological and anatomical characteristics make them poor thermo-regulators, causing internal body heat to rise, affecting food intake, growth, productivity and reproductive efficiency. When the ambient temperature exceeds the upper critical temperature, the body temperature will increase which compromise health, productive and reproductive performance of animals. Choi *et al.* (2010, 2012) used geothermal heating pump for cooling and warming of pig house and broiler house but in India, utilization of geothermal energy is still in an immature stage where only a few scientist have tried to explore the geothermal energy potential for space conditioning of houses but geothermal energy is not utilized to maintain the comfortable microenvironment in buffalo shed till date. Hence, this study was designed to mitigate the environmental stress effects on buffaloes and to provide comfortable micro-environment.

Materials and Methods

Development of Geothermal System and Its Components

For development of geothermal system pilot study was carried out for assessing the subsurface temperature and to standardize the depth at which the underground temperature remains same devoid of changes in environmental temperature. Underground temperature was monitored round the year recorded at 2 hourly intervals during 24 h of the day at different depths. Five temperature sensing probes (PT-100) were installed at different depth (2m, 4m, 6m, 8m and 12m) to monitor the underground temperature and based on results obtained geothermal heat exchanger pipes were placed.

The system is a practical and inexpensive method for cooling and heating of animal shed using geothermal energy. Two major subsystems or components of geothermal system are shown in the Figure 1 (Sketch) and Figure 2 (Actual photo animal shed). (1) Atmospheric air suction pump: The air is sucked from environment which passes through the

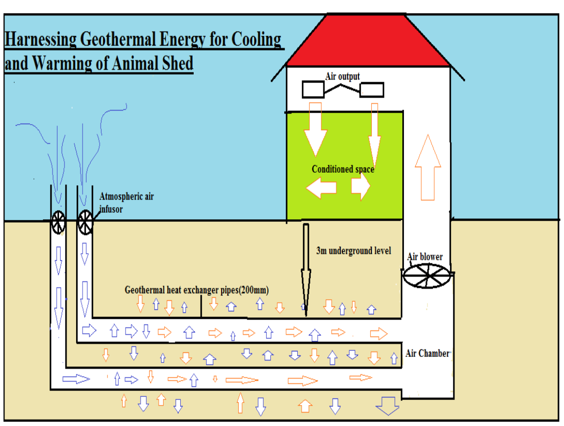

Fig. 1: Major components of geothermal system

Fig. 2: Major components of geothermal system (Inside view of animal shed)

geothermal heat exchanger pipes and blown into animal shed. (2) Geothermal heat exchanger pipes in which heat exchange occur between air present in the pipes and the earth, where the air tries to equilibrate with the deep earth temperature.

Functioning of Geothermal System

Since the temperature of the atmosphere is higher than the temperature of the ground during the summer season, atmospheric hot air is sucked by atmospheric air suction pump into underground geothermal heat exchanger pipes, where heat exchange occurs between the earth and the hot atmospheric air in the pipes, and they attempt to equilibrate in terms of temperature. Air in the pipes becomes cooler than atmospheric air as a result of heat exchange when it travels through pipes, and this cooler air is exhausted into the shed, allowing the temperature of shed to cool down. In comparison, since the temperature of the atmosphere is lower than the temperature of the underground during the winter, atmospheric cold air is sucked by atmospheric air suction pump into underground geothermal heat exchanger pipes, where heat exchange occurs between the earth and the air in the pipes, and they attempt to equilibrate in terms of temperature. While passing through pipes air become relatively warmer than atmospheric air as a result of heat exchange and this relatively warm air is exhausted into shed and shed temperature shifts toward more comfortable.

Selection of Animals

Following approval of the Institutional Animal Ethics Committee, 18 growing female Murrah buffalo-heifers (10 to 14 months) were selected from LRC, ICAR-NDRI, Karnal (India) and further divided equally (six each) into three groups based on their body weight. Animals of first group (experimental) were housed under shed provided with geothermal system, those of second group (control-I) were housed under the shed which was replica of experimental shed, except geothermal system, and those of third group (control-II, normal shed) were reared under normal existing managemental conditions. All the experimental animals were fed as per ICAR (2013) with available green fodder and concentrate mixture. Deworming and vaccination was done before the start of experiment and at appropriate time throughout the experiment.

Measurement of Physiological Responses

Rectal temperature was recorded using digital thermometer, respiration rate was recorded by flank method, and the peripheral skin temperature of the experimental animals at forehead region was recorded using non-contact body infrared thermometer using standard procedures. All the parameters were measured at fortnight interval during winter season (Pre-adaptive + December to February) and during summer season (Pre-adaptive + April to June).

Statistical Analysis

Statistical analysis of the data obtained was performed using software version 16.0 of the SPSS system and Prism 5 for window to find mean ± SE, and one-way analysis of variance was done to find out the significant difference among three groups. The means were compared using Duncan's multiple range tests to draw scientific interferences. Paired 't' test was used to compare between seasons. Evaluation of the correlation between the factors in respective set of animals was made by using a correlation coefficient at the level of probability $p \leq 0.05$.

Results and Discussion

Effect of Geothermal Energy on Temperature (°C) of Experimental Shed

The temperature (°C) varied from 12.40±0.18 to 13.51±0.22 in experimental sheds. It varied from 8.50±0.15 to 11.52±0.22 in Control-I, and from 7.13±0.43 to 10.42±0.81 in control-II (environment), whereas temperature of duct varied from 15.11±0.41 to 16.14±0.49 during winter season. The overall mean values of temperature (°C) of experimental shed (12.98±0.63), control-I (10.15±1.06), duct (15.67±0.64) and

Table 1: Effect of geothermal energy on temperature (°C) of experimental shed (mean ± SE, n=6)

Fortnight	Control-II	Duct	Control-I	Experimental shed
15 Dec	8.31±0.73	15.27±0.72	9.62±016	12.72±0.16
30-Dec	7.13±0.43	15.11±0.41	8.50±0.15	12.40±0.18
15-Jan	10.42±0.81	16.00±0.82	11.52±0.22	13.33±0.23
31-Jan	8.90±0.42	15.91±0.51	10.26±0.17	13.00±0.17
15-Feb	8.31±0.50	15.62±0.51	9.70±0.19	12.94±0.17
28-Feb	10.14±0.58	16.14±0.49	11.35±0.17	13.51±0.22
Winter	**8.86^{ax}±1.11**	**15.67^{bx}±0.64**	**10.15^{cx}±1.06**	**12.98^{dx}±0.63**
15-April	38.80±0.46	30.50±0.22	37.10±0.31	33.20±0.30
30-April	40.50±0.45	30.90±0.38	39.20±0.42	35.90±0.52
15-May	37.10±0.62	29.30±0.59	35.90±0.35	32.30±0.33
31-May	35.30±1.04	27.10±0.91	34.40±0.25	30.00±0.36
15-June	36.10±0.31	27.30±0.32	35.20±0.40	30.20±0.32
30June	37.20±0.18	28.10±0.24	36.00±0.34	32.50±0.50
Summer	**37.50^{ay}±0.76**	**28.86^{by}±0.66**	**36.30^{ay}±0.68**	**32.35^{cy}±0.88**

Means with superscripts (a,b,c,d) in a row for groups and (x,y) in a column for seasons differ significantly (p<0.05).

control-II (8.86±1.00) differed significantly from each other during winter season. During summer season, the respective temperatures (°C) varied from 30.00±0.36 to 35.90±0.52 in experimental shed, from 34.40±0.25 to 39.20±0.42 in Control-I, 27.10±0.91 to 30.90±0.38 in duct and from 35.30±1.04 to 40.50±0.45 in control-II. The overall mean values of temperature (°C) of experimental shed (32.35±0.88), control-I (36.30±0.68), duct (28.86±0.66) and control II (37.50±0.76) differed significantly from each other during summer season (Table 1).

Significantly higher and lower temperature of experimental shed noted during winter and summer season, respectively, occurred due to warming effect of geothermal energy during winter and cooling effect during summer, as during winter season chilled environmental air passed through underground pipes to higher underground temperature where heat exchange occurred between underground temperature and environmental air and this warm conditioned environmental air again blown back to experimental shed causing for warming of shed, whereas during summer season environmental hot air passed through underground pipes where underground temperature is significantly lower than environmental temperature and thus heat exchange occurred which was responsible for lowering of environmental air temperature which was blown back to experimental shed so this cool conditioned air is responsible for lowering the temperature of shed as compared to control-I and control-II .

The values recorded during present study in different groups were in accordance with those of Mun *et al.* (2021), who reported GHP (geothermal heat pump) system to increase the inside temperature of the pig barn in the severe winter season. The increased temperature showed the efficiency of the GHP system that it can provide enough heat to maintain the required temperature for piglets by converting geothermal energy to heat.

Respiration Rate (breaths/min)

The respiration rate (RR, breaths/min) of growing Murrah buffalo-heifers varied from 28.00±0.58 to 30.33±0.49 in experimental group, whereas it varied from 27.17±0.48 to 29.33±0.56 in Control-I and from 25.17±0.60 to 30.00±0.52 in control-II during winter season. The overall mean values of respiration rate (breaths/min) of growing Murrah buffalo-heifers in experimental group was higher ($p<0.05$) *i.e.* 29.02±0.21 compared to control-II (27.48±0.33) during winter season The respiration rate of growing heifers varied from 31.00±0.77 to 33.33±0.67 breaths/min in experimental group, whereas it varied from 31.67±0.42 to 34.33±0.33 breaths/min in Control-I and from 32.00±0.77 to 37.50±0.43 breaths/min in control-II during summer season. The overall mean values of respiration rate (breaths/min) of growing Murrah buffalo-heifers in experimental group was lower ($p<0.05$) *i.e.* (32.00±0.29) compared to control-I (33.25±0.19) and control II (36.02±0.31) during summer season (Table 2). The overall mean values of respiration rate of growing Murrah buffalo-heifers were significantly higher during summer season in all the groups as compared to winter season.

The significantly higher and lower respiration rate of growing buffalo-heifers noted during winter and summer season, respectively, in experimental group was due to warming effect of geothermal energy during winter and cooling effect during summer. The values recorded during the present study in different groups were in accordance with those of Seerapu *et al.* (2015), who reported a lower respiration rate among the animals provided with foggers and foggers plus fans during the summer season than the animals of the control group (without foggers and/or fans). In addition, Ambulkar *et al.* (2011) reported that the provision of fogger during summer seasons markedly lowered the respiration rate in Murrah buffaloes, which is mainly due to lowering of microclimatic temperature by foggers and fans. Kumar *et al.* (2009) found lower respiration (11 breaths/min) in lactating buffaloes kept under cooling system (fan cum mist system) for 6 h (10.00 to 16.00 h) compared to their counterpart kept under natural climatic conditions. Similar findings were reported by Singh and Upadhyay (2009), who reported lower physiological responses (RR, PR, RT & ST) in protected compared to exposed group of dairy animals.

Dandage (2009) reported that there was increased in respiration rate of Sahiwal, Karan Fries and Murrah buffaloes at the end of 4 h exposure in climatic chamber at 40°C and 50% RH and also during summer seasons. Respiratory rate increases as stressors cause an animal to maintain homeothermy by dissipating excessive heat when other avenues (conduction, convection and radiation) becomes inadequate. Respiration rate is influenced by ambient temperature, solar radiation, relative humidity and wind speed. Among these, ambient temperature has been found to be the most influential factor. Elevated respiration is a strive to increase heat loss by evaporative cooling. These results were in conformation with Singh *et al.* (2014) in buffaloes and Sailo *et al.* (2017) in cattle, who also reported increased respiration rate during summer as compared to winter season in cattle. This increased respiration rate in summer might be due to the increased demand of oxygen by the tissues in stressed condition. Respiration rate is increased during hot-humid to increase loss of heat through skin and respiratory evaporation. The response ensures direct heat stimulation of peripheral receptors which transmit nervous impulse to the heat centre in the hypothalamus. The cardio-respiratory center is stimulated to send impulses to respiratory activity.

Skin Temperature (°C)

The skin temperature (ST, °C) of growing Murrah buffalo-heifers varied from 30.17±0.30 to 30.83±0.79 in experimental group, whereas it varied from 29.17±0.60 to 30.67±0.33 in Control-I and from 28.50±0.34 to 30.67±0.67 in control-II during winter season. The overall mean values of skin temperature (°C) of growing heifers in experimental group was significantly higher

($p<0.05$), *i.e.* 30.60±0.20 compared to control-I (30.00±0.19) and control-II (29.08±0.18) during winter season. During summer season, the skin temperature (°C) of growing buffalo-heifers varied from 31.00±0.58 to 33.33±0.42 in experimental group, whereas it varied from 30.83±0.87 to 34.83±0.65 in Control-I and from 31.33±0.61 to 35.33±0.21 in control-II. The overall mean values of skin temperature (°C) in experimental group was significantly lower ($p<0.05$) *i.e.* 32.35±0.24 compared to control II (34.00±0.28) during summer season, and it was significantly ($p<0.05$) higher during summer season in all the groups as compared to winter season (Table 2).

Significantly higher and lower skin temperature (°C) of growing buffalo-heifers recorded during winter and summer season, respectively, in experimental group might be due to warming effect of geothermal energy during winter and cooling effect during summer in experimental shed. The values recorded during present study in different groups were in accordance with those of Shibu *et al.* (2008), who reported a rise in ST in heifers due to rise in ambient temperature. Das *et al.* (2016) and Singh and Upadhyay (2009) also reported the similar trend, *i.e.* higher ST in heat exposed group compared to protected group of animals.

Rectal Temperature (°C)

The rectal temperature (RT, °C) of growing Murrah buffalo-heifers varied from 37.81±0.17 to 38.31±0.17 in experimental group, whereas 37.43±0.10 to 37.70±0.08 in Control-I and 36.99±0.12 to 37.27±0.11 in control-II during winter season. The overall mean values of rectal temperature (°C) in experimental group was significantly higher ($p<0.05$) *i.e.* 38.11±0.06 compared to control-I (37.59±0.04) and control-II (37.10±0.04) during winter season. During summer season, the rectal temperature (°C) of growing heifers varied from 38.06±0.18 to 38.51±0.15 in experimental group, whereas from 38.43±0.27 to 38.83±0.13 in Control-I and 38.83±0.23 to 39.19±0.12 in control-II. The overall mean values of rectal temperature (°C) of growing buffalo-heifers in experimental group was significantly lower ($p<0.05$) *i.e.,* 38.32±0.07 compared to control-I (38.65±0.09) and control II (39.05±0.08) during summer season (Table 2), and these values were significantly ($p<0.05$) higher as compared to values in winter season.

The significantly higher and lower rectal temperature of growing buffaloes recorded during winter and summer season, respectively, in experimental group was normally due to warming effect of geothermal energy during winter and cooling effect during summer. The values recorded during present study in different groups were in accordance with those of Singh and Upadhyay (2009), who found that heat protected dairy cows had lower physiological responses (RR, PR, RT, and ST) than heat exposed groups. According to Das *et al.* (2016), washing buffaloes twice, three times, and four times a day during the summer months have a positive impact on reducing physiological reactions.

Rectal temperature alteration from the physiological norm has been used as a measure of discomfort. Even though

Table 2: Effect of geothermal energy on respiration rate, skin temperature and rectal temperature of growing Murrah buffalo-heifers during winter and summer seasons

Season	Interval (days)	Respiration rate (breaths/min)			Skin Temperature (°C)			Rectal Temperature (°C)		
		Experiment	Control-I	Control-II	Experiment	Control-I	Control-II	Experiment	Control-I	Control-II
Winter	0	30.00±0.60	29.17±0.79	30.00±0.52	30.83±0.48	30.17±0.60	28.50±0.43	37.81±0.17	37.43±0.10	37.01±0.06
	15	29.00±0.37	28.33±0.42	28.00±0.68	30.67±0.33	29.17±0.60	28.83±0.40	37.93±0.19	37.50±0.13	36.99±0.12
	30	28.17±0.48	27.50±0.67	27.17±0.60	30.50±0.61	29.67±0.76	28.67±0.33	38.01±0.14	37.57±0.13	37.02±0.11
	45	28.00±0.58	27.17±0.48	25.17±0.60	30.17±0.31	29.00±0.52	28.83±0.40	38.15±0.10	37.59±0.16	37.06±0.12
	60	28.33±0.42	27.83±0.70	26.33±0.99	30.83±0.79	30.33±0.33	28.50±0.34	38.17±0.10	37.60±0.10	37.09±0.13
	75	28.83±0.60	28.17±0.87	27.17±0.48	30.67±0.62	30.50±0.43	28.67±0.33	38.25±0.13	37.66±0.09	37.15±0.12
	90	29.50±0.67	29.33±0.56	27.67±1.23	30.67±0.71	30.50±0.43	30.00±0.58	38.29±0.13	37.69±0.08	37.19±0.14
	105	30.33±0.49	29.17±0.31	28.33±1.12	30.83±0.76	30.67±0.33	30.67±0.67	38.31±0.17	37.70±0.08	37.27±0.11
	Overall	**29.02^{ax}±0.21**	**28.33^{ax}±0.23**	**27.48^{bx}±0.33**	**30.60^{ax}±0.20**	**30.00^{bx}±0.19**	**29.08^{cx}±0.18**	**38.11^{ax}±0.06**	**37.59^{bx}±0.04**	**37.10^{cx}±0.04**
Summer	0	31.00±0.77	31.67±0.42	32.00±0.77	31.00±0.58	31.17±0.79	31.33±0.61	38.06±0.18	38.43±0.27	38.83±0.23
	15	32.00±1.15	32.83±0.48	34.33±0.80	31.17±1.01	30.83±0.87	32.67±0.95	38.16±0.15	38.53±0.20	38.91±0.33
	30	31.17±0.60	33.00±0.58	36.33±0.33	31.83±0.70	31.83±0.79	33.17±0.79	38.24±0.12	38.56±0.30	38.98±0.29
	45	31.50±0.99	33.33±0.67	36.83±0.31	32.50±0.62	32.50±0.76	34.00±0.73	38.34±0.21	38.64±0.21	39.06±0.16
	60	32.17±0.79	33.50±0.43	36.67±0.42	32.67±0.61	33.33±0.49	35.33±0.33	38.41±0.15	38.73±0.34	39.13±0.28
	75	32.83±0.79	33.83±0.48	37.17±0.31	33.17±0.40	34.00±0.26	35.17±0.31	38.43±0.09	38.76±0.27	39.18±0.16
	90	32.00±0.68	33.50±0.43	37.33±0.49	33.33±0.42	34.67±0.33	35.00±0.26	38.45±0.30	38.79±0.15	39.19±0.06
	105	33.33±0.67	34.33±0.33	37.50±0.43	33.17±0.40	34.83±0.65	35.33±0.21	38.51±0.15	38.83±0.13	39.19±0.12
	Overall	**32.00^{ay}±0.29**	**33.25^{by}±0.19**	**36.02^{cy}±0.31**	**32.35^{ay}±0.24**	**32.90^{ay}±0.30**	**34.00^{by}±0.28**	**38.32^{ay}±0.07**	**38.65^{by}±0.09**	**39.05^{cy}±0.08**

Means within the parameter with superscripts (a,b,c,d) in a row for groups and (x,y) in a column for seasons differ significantly ($p<0.05$).

there is a significant change in the core body temperature in different parts of the body at different times of the day, rectal temperature is still regarded as a reliable indicator of body temperature (Srikandakumar and Johnson, 2004). RT measures thermal balance and may be useful in determining harsh thermal environment (Silanikove, 2000). These results are also in line with earlier studies that reported positive effect of water sprinkling and airflow to reduce heat stress in dairy buffaloes (Kumar and Gupta, 1991; Vijayakumar *et al.,* 2011). The RT and RR were significantly ($p<0.05$) lower in misting and wallowing group as compared to control during the experimental period (Yadav *et al.,* 2016). The rectal temperature in present study was consistent with that of Joshi and Tripathy (1991), who noticed an increase in rectal temperature from 102.0 °F to 103.8 °F when buffalo calves were exposed to 40.5 °C for 8 h daily for three months. Sethi *et al.* (1994) recorded 2.6 °C rise in rectal temperature in buffaloes when exposed to direct sun rays in the months of June and July. The rectal temperature and respiration rates of buffaloes were significantly higher during direct sun exposure than the values obtained when the animals were kept under shade in the barn (Gudev *et al.,* 2007). Moran (1973) also noted that under solar radiation, skin temperature and rectal temperature of buffaloes both rise, but when they are transferred into the shade, their rectal temperatures quickly fall. The findings of the current study are consistent with those of Singh *et al.* (2008), as Tmax and THI had a positive correlation with RT in buffaloes maintained in sheds and exposed environments. Ambulkar *et al.* (2011) and Yadav *et al.* (2016) reported that sprinkle and misting of cool water on buffaloes and wetting or wallowing of buffaloes during the summer season can effectively reduce body temperature through evaporative cooling.

The underground temperature variation during different months of the year was minimum at around 4 m depth and it remained almost constant throughout the year besides the fact that variation in environmental temperature was very drastic during winter and summer season. Based on results of pilot study, geotheramal system was developed and used for warming and cooling of shed during winter and summer season, respectively. These changes in micro-environment helped in maintaining the normal physiological responses. Therefore, the geothermal system could be used effectively for providing the comfortable micro-environment to dairy animals for enhancing production and welfare.

Conclusion

Geothermal energy has efficient cooling effect during summer season as well as warming effect during winter season in experimental shed as compared to control-I and control-II, which provide comfortable micro-environment to the animal during extreme cold and extreme hot weather conditions. Use of environment friendly geothermal energy might bring some revolutionary changes in dairy sectors in near future.

Acknowledgement

The authors are thankful to the Director, as well as Head, LPM Division, ICAR-National Dairy Research Institute, Karnal for providing the necessary facilities to conduct this study.

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