Changes in Skin Temperature and Physiological Reactions in Murrah Buffalo During Solar Exposure in Summer

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ABSTRACT : Six adult female Murrah buffaloes of about 12 years were exposed to solar radiation during summer when minimum and maximum ambient temperatures were 27.1 and 44.1℃, respectively. The skin surface temperature at forehead, middle pinna, neck, rump, foreleg, hindlegs were recorded using non-contact temperature measuring instrument and respiration rate and rectal temperature were measured throughout the 24 hours starting from 6:30 AM. The diurnal fluctuations and temperature gradients have been reported for buffaloes. During summer when ambient temperature and solar radiation was maximum, adult buffaloes were not able to maintain their thermal balance even after increasing the pulmonary frequency 5-6 times. The changes in skin temperature at various sites indicate that the temperature of skin surface not only varies in relation to exposure but also due to water diffusion and evaporation.
(**Key Words**: Buffalo, Summer, Skin Temperature, Respiration Rate, Rectal Temperature)

INTRODUCTION

In homeotherms the body temperature remains almost constant within relatively narrow limits. The ability to maintain homeothermy despits repeated challenges due to variation in external enviroment has been of great importance for establishing the higher forms of animal life. Most homeotherms maintain an equilibrium between the heat production and heat loss, together with any heat absorbed from the surroundings. To maintain the 'internal milieu' particularly in stressful conditions, number of physiological and behavioral changes occur and they vary in intensity and duration of the environmental stress in relation to the genetic make-up. Buffalo (*Bubalus bubalis*) is well adapted to hot-humid conditions and changes that occur during heat exposure have been documented (Hafez et al., 1955; Nair and Benzamin, 1963; Cockrill, 1981; Benzamin, 1982; Chikamune, 1986; Chaiyabutr, 1993). The changes that occur during exposure to heat in chamber qualitatively are observed to be different from heat exposure under natural environment and the variations due to unexposure of different portions.

The ability of large domestic animals to tolerate high environmental temperature depends primarily on the capacity to dissipate heat. In buffaloes, the ability to sweat is deficient and the body attempts compensatory measures such as increased respiration rate and panting. This compensation is not full and animals are not able to dissipate body heat and animals are distressed. The magnitude of changes in thermal load of buffaloes have been measured (Chaiyabutr, 1993) but information on skin surface temperature changes during sun exposure in summer is not available. At high environmental temperature the buffalo has to dissipate the heat absorbed from the surroundings as well as the heat produced metabolically. In this paper attempt has been made to describe skin temperature changes during a 24 hours period particularly to know the level of stress on buffalo. This information on skin temperature and physiological reaction is likely to further help in alleviation of stress in buffaloes and also in proper shelter management during summer when direct exposure of animal could be avoided.

MATERIALS AND METHODS

Six adult females Murrah buffaloes of about 12 years, weighing 540-700 kg were used for the study. These animals were appeared to be adapted to local environmental conditions and were maintained in loose housing system. On the day of experiment all animals were housed in an open paddock for exposure to the ambient conditions as observed during summer when minimum and maximum temperature was 27.1℃ and 44.1℃, respectively. The feeding consisted of green fodder and water was available *ad libitum*. The physiological reaction and

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skin temperature changes were monitored continuously for 24 hours at an hourly interval.

Meteorological conditions

The maximum ambient temperature recorded during the study was 44.1℃ at 3.00 PM and minimum temperature was 27.1℃ at 6:00 AM. The relative humidity was 64% at 7:30 AM and 19% at 2:22 PM. The minimum wind velocity was 2.7 km/hr. at 7:00 AM and maximum was 13.2 km/hr. at 3:00 PM and direction was North-West.

The rainfall was nil on the day of experiment. The maximum average solar intensity was 2.64 MJ/M²/hr. at 12:00 noon and minimum was after the sun set. The weather conditions as prevailed during the experiment were measured on a data logger system (Solomat, U. K.) (figure 1). The monthly average air temperature and relative humidity have been presented in the form of climograph (figure 2).

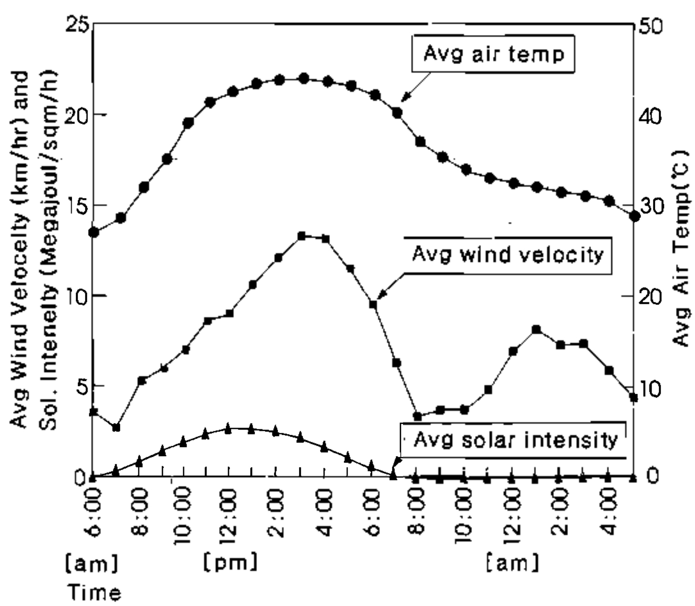

Figure 1. Ambient temperature, wind velocity and solar intensity during experimental period.

The skin temperature at different sites viz. a) forehead, b) middle pinna, c) middle neck, d) rump, e) forelegs, upper and lower sites, f) hindlegs, upper and lower sites were recorded using non-contact temperature measurement instrument (Raytek[R], model Raynger ST 2L). The skin temperature was recorded by keeping the instrument about 6 inches away directing towards the specific site where temperature was to be measured. The rectal temperature (RT) was recorded with a mercury in glass type clinical thermometer, inserted 2-3″ in rectum for at least 2 minutes and the rectal mucosa was in contact with the bulb of thermometer. The respiration rate (RR) of animals was recorded by counting the flank movement, one inward and one outward movement as one respiration.

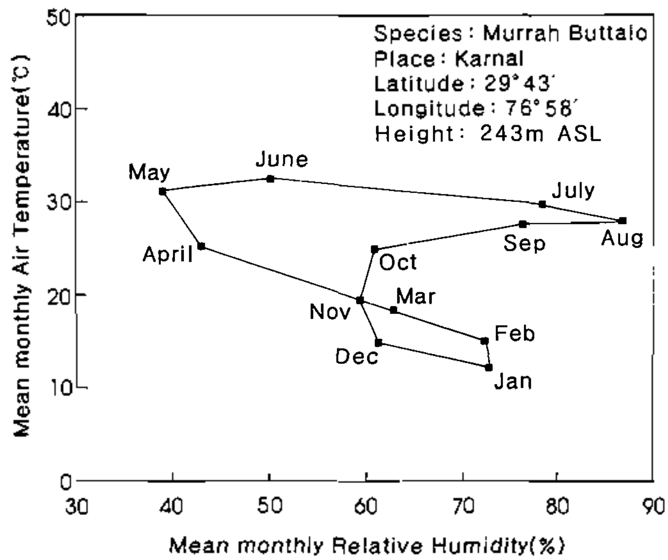

Figure 2. Climograph.

RESULTS AND DISCUSSION

The changes in physiological reactions and skin temperature over a period of 24 hours have been presented in table 1 and 2 (figure 3, 4). The resting respiration rate (RR) of buffaloes at the beginning of experiment was 11 per minute at 6:30 AM. The skin temperature increased as the intensity of solar radiation increased. Solar radiation is the radiant energy that comes from the sun which is received at the earths surface. An animal grazing in an open field is exposed to (1) direct radiation (visible and short infrared waves) from the sun, part of which is reflected according to color and other properties of the coat and the reminder absorbed as heat, (2) solar radiation reflected from clouds and other particles in the sky part of which may be reflected by the hair coat and (3) solar radiation reflected from the horizon. Of the total radiant heat that an animal is subject to out in the sun approximately 50% comes from the first two sources and the remainder from the third. Heat normally passes by conduction from the warm skin (about 33℃) of most species of livestock to the cooler air around it. But as air temp. rises above the comfort range (13-18℃), the heat loss diminishes and if air temperature exceeds skin temperature, heat will flow in a reverse direction. This can become a serious problem in hot, dry areas (McDowell et al., 1972). The pattern of temperature

Table 1. Mean temperature(℃) variation (surface & core) and respiration rate of female Murrah buffaloes during the experimental period

Sl. No.	Time of observation	Forehead	Middle Pinna	Middle Neck	Middle Back	Rump	Udder	Foreleg (upper)	Foreleg (lower)	Hindleg (upper)	Hindleg (lower)	Rectal Temp.	Respiration Rate (breath/min)
1.	6.30 am	28.50±1.30	28.25±1.89	29.66±0.17	27.41±0.83	27.25±0.77	31.25±0.72	29.83±0.54	30.33±0.49	30.00±0.29	30.50±0.50	38.70±0.21	11.25±0.38
2.	7.30 am	34.42±0.78	32.58±0.46	33.58±0.54	31.33±1.07	32.08±0.79	32.33±0.80	32.50±1.09	33.25±1.11	33.58±0.98	33.25±0.01	38.72±0.21	12.33±0.33
3.	8.30 am	39.66±1.57	36.33±0.21	35.41±0.76	35.00±0.89	35.08±0.86	33.41±0.42	34.91±0.35	36.25±0.46	36.25±0.53	37.41±0.57	39.08±0.15	14.25±0.31
4.	9.30 am	45.58±0.79	39.25±0.66	37.58±0.70	38.91±0.74	37.16±0.65	36.66±0.59	37.16±0.81	37.75±0.46	36.75+0.44	38.00±0.62	39.45±0.10	17.75±0.17
5.	10.30 am	49.91±1.79	40.58±0.72	40.16±0.63	42.08±0.24	40.83±0.70	38.81±0.51	40.33±0.86	41.33±0.79	38.58±0.37	40.91±0.64	39.78±0.08	23.75±0.50
6.	11.30 am	49.66±1.11	41.50±0.41	40.91±0.47	42.66±0.38	41.75±0.50	38.83±0.28	40.25±0.63	41.50±0.26	38.91±0.20	42.08±0.69	39.80±0.06	47.91±1.80
7.	12.30 pm	49.58±1.56	42.00±0.48	40.25±0.34	43.58±0.51	41.91±0.44	40.66±0.82	39.83±0.28	42.66±0.90	39.50±0.13	41.75±0.38	40.00±0.80	51.91±1.58
8.	1.30 pm	50.83±0.69	42.25±0.42	41.08±0.58	43.25±0.42	41.58±0.33	40.25±0.63	40.91±0.45	43.08±0.80	39.91±0.24	42.50±0.63	40.00±0.10	50.66±1.15
9.	2.30 pm	48.25±0.73	41.90±0.30	40.41±0.38	42.41±0.24	41.58±0.44	39.58±0.40	40.83±0.46	42.83±0.36	39.91±0.45	43.25±0.79	39.83±0.25	48.66±1.26
10.	3.30 pm	45.50±0.71	40.08±0.47	39.50±0.34	41.66±0.36	39.91±0.84	39.16±0.40	39.66±0.42	42.08±0.61	39.08±0.35	41.08±0.61	39.87±0.06	48.25±1.54
11.	4.30 pm	43.42±0.60	39.08±0.20	39.50±0.32	39.25±0.31	38.50±0.41	37.75±0.74	38.50±0.45	40.25±0.90	37.66±0.36	40.25±0.93	39.55±0.17	48.41±2.96
12.	5.30 pm	40.50±0.41	38.00±0.13	38.33±0.33	37.91±0.44	37.75±0.42	36.66±0.57	38.00±0.39	38.75±0.68	37.08±0.27	39.08±1.36	39.07±0.09	30.83±3.10
13.	6.30 pm	37.25±0.54	36.00±0.22	35.75±0.38	36.16±0.70	35.25±0.62	35.33±0.56	35.75±0.67	36.83±0.74	34.66±0.42	35.83±0.83	38.91±0.19	19.00±1.48
14.	7.30 pm	33.42±0.72	32.25±0.66	33.91±0.51	33.08±0.77	32.33±0.69	31.83±0.56	33.41±0.40	34.33±0.82	32.66±0.48	34.41±0.27	38.82±0.07	16.50±1.13
15.	8.30 pm	32.25±0.31	30.66±0.40	32.08±0.44	29.91±0.24	30.08±0.60	30.75±0.38	30.91±0.47	32.08±0.35	31.33±0.48	31.75±0.36	38.85±0.05	14.08±0.79
16.	9.30 pm	32.25±0.87	30.58±0.87	31.33±0.42	29.66±0.46	29.75±0.42	30.80±1.14	31.41±0.54	32.50±0.32	32.00±0.29	32.08±0.33	38.72±0.09	13.41±0.58
17.	10.30 pm	30.50±0.45	29.41±0.74	30.33±0.57	28.00±0.43	28.66±0.76	29.50±0.45	29.16±0.49	30.66±0.53	30.41±0.37	31.41±0.95	38.76±0.05	12.08±0.66
18.	11.30 pm	30.17±0.38	30.17±0.54	30.08±0.20	27.66±0.36	27.70±0.93	30.75±0.72	30.42±0.49	30.91±0.45	30.08±0.75	30.91±0.30	39.04±0.34	11.58±0.24
19.	12.30 am	30.33±0.87	31.00±1.80	29.91±0.27	29.00±0.26	28.50±0.77	30.83±0.33	30.66±0.56	30.41±0.81	30.41±0.45	31.00±0.48	38.72±0.03	11.50±0.36
20.	1.30 am	29.58±0.69	28.50±0.52	30.08±0.44	27.41±0.37	27.75±0.65	30.25±0.75	30.75±0.42	31.66±0.38	30.66±0.48	31.25±0.63	38.48±0.15	11.00±0.31
21.	2.30 am	28.75±0.62	28.42±0.46	30.08±0.24	27.75±0.54	26.00±0.50	30.75±0.60	30.00±0.79	30.50±0.67	30.33±0.95	31.58±0.51	38.58±0.11	11.00±0.41
22.	3.30 am	29.83±0.28	29.17±1.05	30.66±0.69	28.66±0.80	27.42±0.44	29.75±0.78	29.83±0.49	31.00±0.45	30.33±0.85	31.75±0.63	38.61±0.08	11.16±0.23
23.	4.30 am	28.83±0.40	28.08±0.71	29.83±0.76	28.50±0.43	27.33±0.25	30.25±0.53	31.00±0.52	31.58±0.58	29.49±0.61	30.33±0.64	38.39±0.10	10.83±0.10
24.	5.30 am	27.66±0.53	27.58±0.81	28.33±0.46	27.00±0.87	27.50±0.89	30.50±0.63	30.08±0.57	29.41±0.79	30.50±0.18	30.16±0.64	38.51±0.09	11.08±0.37

Table 2. Correlation matrix for surface, core temperature and respiration rate in relation to environmental temperature and wind velocity

	Forehead	Middle Pinna	Middle Neck	Middle Back	Rump	Udder	Foreleg (upper)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	1.0000						
2.	0.9875	1.0000					
3.	0.9795	0.9871	1.0000				
4.	0.9871	0.9909	0.9908	1.0000			
5.	0.9842	0.9906	0.9910	0.9934	1.0000		
6.	0.9715	0.9786	0.9711	0.9840	0.9756	1.0000	
7.	0.9770	0.9831	0.9870	0.9915	0.9883	0.9853	1.0000
8.	0.9767	0.9812	0.9889	0.9916	0.9877	0.9825	0.9924
9.	0.9797	0.9869	0.9853	0.9850	0.9904	0.9746	0.9843
10.	0.9786	0.9850	0.9891	0.9877	0.9866	0.9746	0.9872
11.	0.9599	0.9505	0.9294	0.9447	0.9366	0.9508	0.9292
12.	0.8576	0.8698	0.8797	0.8844	0.8792	0.9081	0.8848
13.	0.7756	0.8119	0.8436	0.8344	0.8311	0.8190	0.8341
14.	0.6162	0.6679	0.6930	0.6894	0.6614	0.7181	0.7239

	Foreleg (lower)	Hindleg (upper)	Hindleg (lower)	Rectal Temp.	Respira-tion Rate	Environmental temp.	Wind velocity
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.	1.0000						
9.	0.9854	1.0000					
10.	0.9907	0.9911	1.0000				
11.	0.9414	0.9334	0.9414	1.0000			
12.	0.9086	0.8794	0.9020	0.8968	1.0000		
13.	0.8520	0.8022	0.8307	0.7775	0.8335	1.0000	
14.	0.7315	0.6789	0.7243	0.6212	0.7883	0.7876	1.0000

changes at middle neck, pinna, middle back, rump, foreleg, hindleg and forehead reflected that skin temperature changes took place in relation to the environ-mental temperature and correlations were highly significant ($p < 0.05$, table 2). The magnitude of changes in skin temperature were highest at forehead and lowest at hindleg (upper). The temperature gradient between air temperature and skin temperature of forehead, pinna, middle back and rump were very sharp but the temperature gradient of middle neck, udder, foreleg and hind leg were small. The forehead, pinna, middle neck, back, foreleg and hindleg temperatures were observed to be minimum in early hours of the day and these changes occured when the ambient temperature was less. The temperature fluctuation of udder was not parallel to the ambient temperature changes because of topographic location of udder in posterior part of the body and between hindlegs.

The effects of heat exposure on cardio-pulmonary activities of buffaloes have been reported in acute and short term exposure. Heart rate (HR), RR and RT are little affected by temperature upto 30℃ (Chaiyabutr et al., 1987; Chikamune, 1986). The change in RR occur more when air temperatures increase and animals begin to pant

(Chikamune, 1986). During the course of heat exposure (41℃/31℃, DB/WB) the RT of buffaloes has been observed to rise at a mean rate of 0.0033℃/340 kg wt., however, heart rate was observed to be less affected (Chaiyabutr et al., 1987).

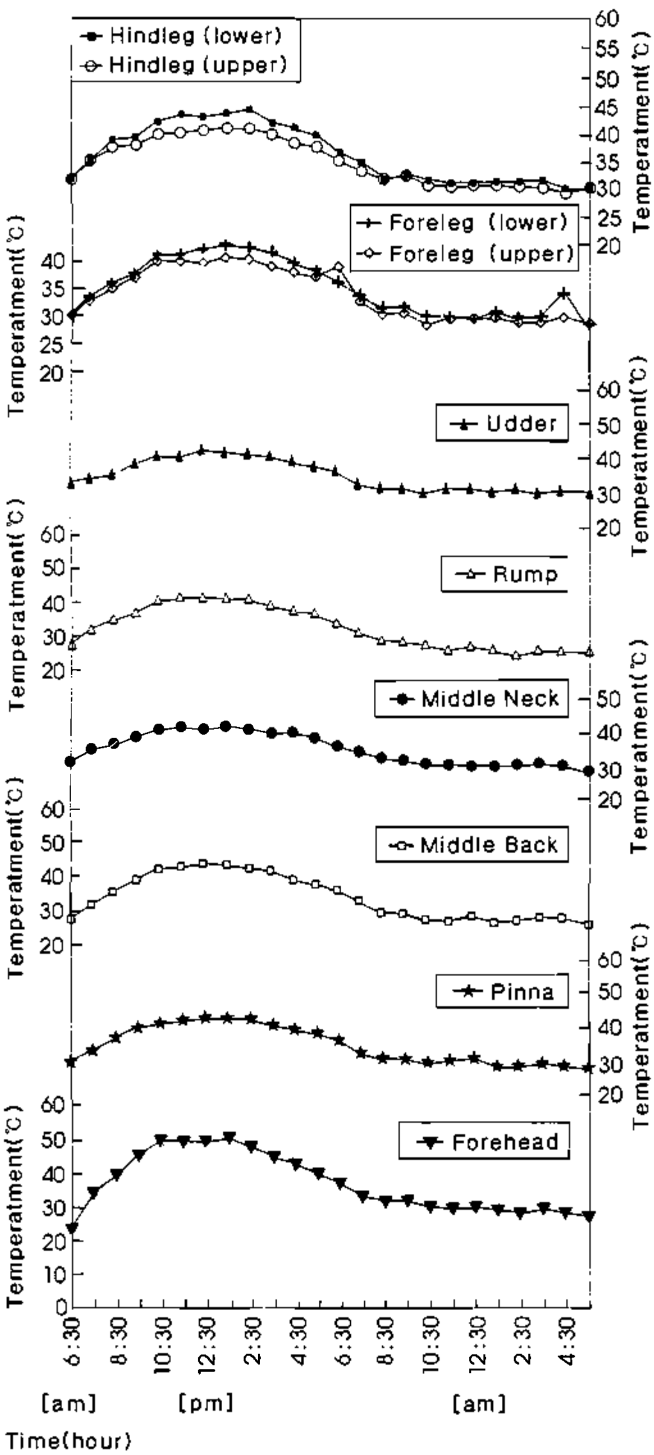

Figure 3. Skin surface temperature changes in experimental animals.

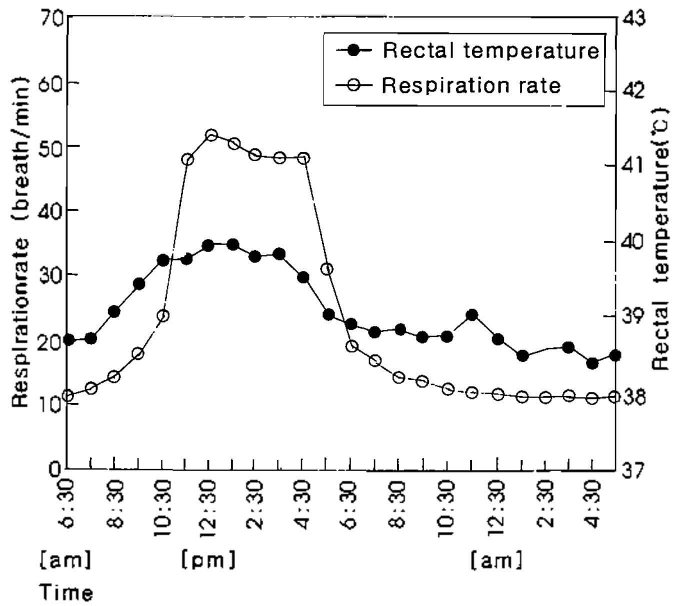

Figure 4. Physiological reactions changes in experimental animals.

Effect of heat stress under direct solar radiation exposure has been observed to change physiological reactions to variable levels. Acute solar exposure cause more marked heart rate and respiratory changes than heat exposure in hot room at 41℃ (Chaiyabutr et al., 1983b, 1987). These changes have been attributed to the differences in nature of the skin of the buffaloes. During present study buffaloes exhibited distinct changes in the pattern of skin temperature and rise and fall were related to the magnitude of changes in ambient conditions. When ambient temperature was highest the body gained heat load of animals increased. During summer when ambient conditions were harsh and solar radiation was maximum, adult buffaloes were not able to maintain their thermal balance even after increasing pulmonary frequency 5-6 times. Inadequate sweating mechanism and skin cover put buffaloes to disadvantage under solar conditions as enhanced reabsorption of solar radiation interfere with heat loss resulting in a higher heat storage. The changes in skin temperature at various sites indicate that the temperature of skin surface not only varies in relation to exposure but also due to water diffusion and evaporation from the skin. Evaporation is the vaporization of water from the body surface and respiratory tract, which aids in the cooling process. One gram of water vaporized at 20℃ will release 0.6 kcal of heat energy. Evaporation depends on the humidity of air and air flow. If the humidity is low evaporation takes place very rapidly, but if it is high evaporation will be slow or nil and the system try to maintain the skin temperature. The sweat glands stimulated by thermal stress, usually produce a film of water on the skin, which if evaporated rapidly restores body heat to near normal levels (McDowell et al., 1972). The sweat glands of buffaloes have surfaces of 0.247 cm^2 of each and the glandular surface per cm^2 of skin surface is about 1.07 (Hafez 1968). In high temperature animal compensates through vasodilation of the smallest arteries (arterioles) near the skin. Increase the blood flow the periphery takes place very rapidly. The degree of dilation depends upon the level of stimuli and location on the body. The ventral portin of the body was able to dissipate heat, however, dorsal surface exchange heat due to direct exposure. It is evident from these results that during cooler part of the day animals were able to loose heat and RT and RF returned to normal. Therefore, it appears that buffaloes have capacity to withstand moderate heat and solar exposure and they employ heat storage mechanism during solar exposure.

The heat gained was relieved at later stage, when gradient between body temperature and environment started increasing. Buffaloes sweat limitedly and prefer wallowing in water due to specific heat of water and capacity of water to absorb far greater heat and readily heat exchanging power. The low hair density on skin helps in readily exchange of heat to water. The thickness of buffalo skin helps in protection against overheating of the body through reduction of thermal conductivity, however, it hinders heat dissipation through convection and radiation (Pant and Roy, 1972) but this limitation is overcomed while wallowing.

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