Internal Changes of Blood Compartment and Heat Distribution in Swamp Buffaloes under Hot Conditions : Comparative Study of Thermo-Regulation in Buffaloes and Friesian Cows

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ABSTRACT : From previous studies, there is a strong possibility in buffaloes that the marked increase in blood volume (BV) under hot conditions contributes to heat transportation from the rectum to the skin. The present study was done to clarify changes with environmental temperature on water-shift between blood and extracellular fluid (ECF), heat distribution between the rectum and the skin, and blood flow rates (BFR) at the hind legs (reflecting the skin surface). Four buffaloes and four Friesian cows were successively exposed to three different temperatures of 20℃, 30℃ and 35℃. BV and ECF volume were measured with Evans' blue and sodium-thiocyanate dilution methods, respectively. Rectal and subcutaneous (as the skin) temperatures were measured by copper-constantan thermocouples. BFR were measured by a supersonic blood flow meter. With an increase in environmental temperature, skin temperature in buffaloes increased significantly than cows, but rectal temperature was not significantly different between two species. BV, especially plasma compartment, increased significantly in only buffaloes, while ECF volume did not change in both species. BFR increased significantly in buffaloes, but not in cows. From these results, the increase of BV may be caused by water flowing from ECF compartment. The water-shift may induce the increase of BFR and skin temperature. It is suggested in the present study that internal changes of blood compartment in buffaloes contribute to transfer of heat to the skin surface. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 6 : 886-890)*

Key Words : Buffaloes, Blood Compartment, Rectal-Skin Temperature Difference, Blood Flow Rate, Thermoregulation

INTRODUCTION

It has previously been reported in buffaloes that blood volume rises and hematocrit (Ht) decreases during summer and they appear in the reverse during winter (Koga et al., 1991; Pandey and Roy, 1969). This phenomenon observed in buffaloes resembles to the changes observed in animals under heat stress (Koga et al., 1998; Chaiyabutr et al., 1997; 1990). On the other hand, some researchers have also reported that skin temperature was higher in buffaloes than in cattle when they were exposed to hot conditions (Chikamune, 1987; Moran, 1973). From the previous results, there is a strong possibility that the blood volume in buffaloes increases greatly with an increase in environmental temperature, and is sent to the body surface by means of a redistribution of cardiac output. As a result, much heat in the body core is transported to body surfaces, and skin temperature increases greatly in buffaloes. Because of this, the internal temperature distribution in buffaloes is advantageous for heat dissipation, because the increase in skin temperature can reduce the temperature gradient between the rectum and skin (Internal temperature gradient), and increase the temperature gradient between the skin and environment (External temperature gradient). Therefore, thermo-regulation of buffaloes may depend on sensible heat loss such as wallowing, which increase heat conductivity between the body surface and its surroundings.

The present study was undertaken to find the relationship between the increase of blood volume and the increase of skin temperature and clarify the feature of thermoregulation mechanism in buffaloes in comparison with cows. The present study consist of two experiments. Experiment I was done to find an effect of environmental temperature on the ratio of plasma volume to blood volume, the ratio of blood volume to extracellular fluid and rectal-skin temperature difference under hot conditions. In Experiment II, leg blood flows were measured by a supersonic blood flow meter for each of the two animals.

MATERIALS AND METHODS

Experiment I

Four female swamp buffaloes (estimated to be 13-19 years old) and four female Friesian cows (2 years old) were used in this study. The animals were non-pregnant and dry. Their average body weights at

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the beginning of the experiment were between 510 and 650 Kg, respectively. Estrus behaviour was not observed at least on the day of body temperature measurements. The animals were maintained in an artificial climate laboratory (Zootron) at the National Institute of Animal Industry, Japan. The conditions of the first 7 days were 20℃, 60% relative humidity (RH) allowing the animals to acclimatize prior to the experiment. The experiment consisted of three successive periods as follows: 7 days at 20℃, 60% RH, 7 days at 30℃, 60% RH and 7 days at 35℃, 60% RH. The feed was given in two equal portions at 9:00 and 18:00 hours each day. The amount of feed (hay wafer) was calculated by the Japanese Feeding Standard for dairy cows. Water and salt mixture (Kohen, Nihon Zenyaku Co. Ltd., Tokyo) was supplied *ad libitum* throughout the experimental period.

Respiration rate, heart rate and water intake were recorded on the last day of each period before an injection of pigment by a method described previously (Koga et al., 1991). Rectal and subcutaneous temperatures (as the skin temperature) were recorded with copper-constantan thermocouples which was fitted with needle tips. The needle tips for subcutaneous temperature measurement had been inserted subcutaneously to a skin depth which had an abundance of blood vessels (approximately 5 mm) (Hafez et al., 1954). The mean subcutaneous temperatures were measured at five body locations: back sacral, rear haunch, rear leg, fore flank and back thoracic (McLean, 1963). Before the experiments, a polyethylene catheter was inserted into a jugular vein for the collection of blood and also to inject the pigment. The plasma volume was measured by the Evans' blue dilution method. The blood volume was calculated from the Ht value and plasma volume. A concentration of pigment were measured by a spectrophotometer (UV-160A, Shimadzu, Kyoto).

T-test and Duncan's multiple range test were used to estimate the statistical significance of differences between buffaloes and cows, and among three periods (20, 30 and 35℃), respectively (Snedecor and Cochran, 1980).

Experiment II

Two swamp buffaloes and two Friesian cows were used in Experiment II. The animals used were the same as for Experiment I. They were maintained in an artificial climate laboratory (Zootron) during 54 days. The conditions of the first 10 days were 20℃, 60% RH allowing the animals to acclimatize. The two treatment periods were as follows: 15 days at 20℃, 60% RH and 7 days at 35℃, 60% RH. The treatments were repeated again. Feeding and management of the animals were the same as for Experiment I.

Flow probes (6 mm: cows, 4 mm: buffalo) were fitted at the dorsal artery of the hind legs (arteria dorsalis pedi) by surgery after calmness by tranquilizer. Six days were allowed for the animals to recover from surgery. For the measurement of blood flow rate, flow probes were connected to a supersonic blood flow meter (Transonic T101). Rectal and subcutaneous temperatures were measured by same method as Experiment I.

As Experiment II was supplied with two animals in each species, we applied statistical analysis as four values from two bodies and two periods. The t-test (Snedecor and Cochran, 1980) was used to estimate the statistical significance of differences between an increment from control (20℃) to hot conditions (35℃) in both species.

RESULTS

Experiment I

Results of respiration rate and heart rate were similar to previous reports (Chaiyabutr et al., 1987; Hales, 1973; Ingram and Legge, 1971) and showed the physiological features of buffaloes well (data not shown). Results under the 20℃, 30℃ and 35℃ conditions for rectal, subcutaneous, internal and external temperatures in both species are presented in table 1. In the 20℃ period, rectal and subcutaneous temperatures of buffaloes were significantly ($p<0.05$) lower than cows. As environmental temperature increased, both rectal and subcutaneous temperatures of buffaloes increased significantly ($p<0.05$), and subcutaneous temperature was significantly ($p<0.01$) higher in buffaloes than in cows at 30℃ and 35℃. As a result, internal temperature significantly ($p<0.05$ and 0.01, respectively) decreased in buffaloes than in cows at 30℃ and 35℃, and external temperature significantly ($p<0.01$ respectively) increased in buffaloes than in cows at both periods.

Results under the 20℃, 30℃ and 35℃ conditions for extracellular fluid volume, blood volume, plasma volume and water intake in both species are presented in table 2. Extracellular fluid volume was higher in buffaloes than in cows and the value in both species remained the same through three periods. As environmental temperature increased, blood and plasma volumes of both species increased in spite of the unchanged of extracellular fluid, but both volumes were significantly ($p<0.01$ and 0.05, respectively) higher in buffaloes than in cows at 30℃ and 35℃. Especially, plasma volume in buffaloes markedly increased from 78.2% to 86.0% of blood volume. Water intake in both species significantly ($p<0.05$) increased, but the extent of the increase was higher in buffaloes than in cows. At 35℃, water intake was significantly ($p<0.01$) higher in buffaloes than in cows.

Table 1. Mean values of rectal and subcutaneous temperatures and their differences in buffaloes and cows for each period

		20℃	30℃	35℃
Rectal temperature (℃)	Buffalo	37.90±0..09^{a}*	39.00±0.13^{b}	39.50±0.10^{c}
	Cows	38.30±0.01^{a}	38.70±0.39^{a}	40.10±0.30^{b}
Subcutaneous temperature (℃)	Buffalo	30.75±0.38^{a}*	37.50±0.39^{b}**	37.65±0.21^{b}**
	Cows	32.10±0.44^{a}	34.80±0.27^{b}	36.55±0.19^{c}
Internal temperature gradient[1] (℃)	Buffalo	7.15±0.39^{b}	1.45±0.30^{a}*	1.80±0.16^{a}**
	Cows	6.20±0.37^{b}	3.88±0.59^{a}	3.53±0.21^{a}
External temperature gradient[2] (℃)	Buffalo	10.57±0.38^{c}*	7.50±0.39^{b}**	2.65±0.21^{a}**
	Cows	12.10±0.37^{c}	4.80±0.27^{b}	1.55±0.19^{a}

Values are means±SE.

[1] Internal temperature gradient=Rectal temperature - Subcutaneous temperature.

[2] External temperature gradient=Subcutaneous temperature - Environmental temperature.

*, ** Signigicant difference from cows at 5% and 1% level, respectively.

[a,b,c] Values having same letters in the same row are not significantly different ($p>0.05$).

Table 2. Mean values of extracellular fluid, blood and plasma volumes and water intake in buffaloes and cows for each period

		20℃	30℃	35℃
Extracelluar fluid volume (ml/kg)	Buffalo	600.3±12.1	608.5±19.5*	603.9±20.8
	Cows	486.3±20.8	477.9±25.0	505.0±14.6
Blood volume (ml/kg)	Buffalo	47.9±4.3 (8.0%)	51.0±1.6** (8.4%)	55.8±5.0* (9.2%)
	Cows	42.8±1.0 (8.8%)	43.3±0.5 (9.1%)	44.1±1.1 (8.7%)
Plasma volume (ml/kg)	Buffalo	37.5±0.4 (78.2%)	42.8±0.2** (84.0%)	48.0±4.3* (86.0%)
	Cows	30.0±0.1 (70.1%)	31.0±0.1 (71.7%)	29.8±0.1 (67.6%)
Water intake (ml/kg)	Buffalo	6.7±0.8^{a}	10.3±1.3^{a}	15.2±1.3^{b}**
	Cows	5.4±0.3^{a}	6.3±0.2^{ab}	6.8±0.4^{b}

Values are means±SE.

Values in parentheses of blood volume are for the ratio of blood volume to extracelluar fluid.

Values in parentheses of plasma volume are for the ratio of plasma volume to blood volume.

*, ** Signigicant difference from cows at 5% and 1% level, respectively.

[a,b] Values having same letters in the same row are not significantly different ($p>0.05$).

Table 3. Mean values of rectal and leg subcutaneous temperatures and increment of leg blood flow in buffaloes and cows at 20℃ and 35℃

	Buffaloes		Cows	
	20℃	35℃	20℃	35℃
Rectal temperature (℃)	37.9±0.15	39.0±0.17** (+2.9%)	38.2±0.13	40.2±0.13** (+5.2%)
Leg subcutaneous temperature (℃)	32.5±1.30	40.0±0.08** (+23.1%)	34.8±0.23	41.0±0.08** (+17.8%)
Increment of leg temperature (%)	55.5±11.61*		20.6±6.81	

Values are means±SE.

Values in parentheses are for the ratio of value on 35℃ period to value on 20℃ period.

*,** Significant difference from 20℃ treatment at 5% and 1% level, respectively.

Experiment II

Results under the 20℃ and 35℃ conditions for rectal and leg subcutaneous temperatures and increment of leg blood flow are presented in table 3. Rectal and subcutaneous temperatures increased significantly ($p<0.01$) in both species, and the extent of the increase of subcutaneous temperature was 23.1% in buffaloes and 17.8% in cows. Leg blood flows were expressed by the percentage of the increment from 20℃ to 35℃. The increments of leg blood flow were significantly ($p<0.05$) higher in buffaloes than in cows.

DISCUSSION

The present study was undertaken to find the relationship between the increase of blood volume and the increase of skin temperature and clarify the feature of thermoregulation mechanism in buffaloes in comparison with cows.

In the present study, the subcutaneous temperature (as the skin temperature) of buffaloes increased significantly with the increase of the environmental temperature and the extent of the increase was significantly higher in buffaloes than in cows. Blood and plasma volumes of buffaloes also increased with the increase of environmental temperature, while the values for cows remained the same over three periods. Furthermore the increment of leg blood flow, which reflects the blood flow to the skin surface, was significantly higher in buffaloes than in cows.

The redistribution of cardiac output arise from the necessity of heat dissipation under hot conditions and contribute to sending more blood towards the body surface (Hales, 1973). There are many arterio-venous anastomoses (AVA's), which plays an important role for the regulation of heat exchange in tissues important to heat exchange, viz., the nasal mucosa, tongue, external pinnae and skin of the legs and body (Hales, 1978). The heat transferred by arterial blood is left at AVA's and increases the subcutaneous temperature. Then the heat is dissipated from the skin surface through various systems (Hales et al., 1978; Ingram and Legge, 1971). For example, the plasma volume in human, which depends on sweat for heat dissipation, increased markedly under hot conditions (Senay et al., 1976) and support sweating effects from the skin surface.

From these results and above mentioned reference, it is suggested in buffaloes that the increase of skin temperature is caused by the increase of the blood flow to the skin surface and blood volume.

The increase of blood volume in buffaloes was due to the increase of plasma compartment which includes more water. The source of water might be drinking water, or the water coming from other compartments. Water intake of buffaloes did increase, however, the extracellular fluid volume of buffaloes did not change with the increase of environmental temperature. Chaiyabutr et al. (1987) reported that the flow rate of liquid from the rumen, as well as body water turnover, of buffaloes significantly increases during 5h of acute heat exposure (41℃). Because we did not measure the urine volume we can not state with certainty, however, it is possible that buffaloes discharged a larger amount of urine which could be the cause of the fast whole body water turnover rate. Thus we suggest that the increase in blood volume in buffaloes under hot conditions was largely not caused by an increase in whole body water, but possibly by the shift of water from other compartments (especially the rumen) to blood vessels.

Heat tolerance of buffaloes has previously been lower than in cows, because their rectal and skin temperatures increase easily under hot conditions (Moran, 1973). But it was clarified in this study with regard to skin temperature that the increase of skin temperature in buffaloes is the product of active heat transportation from the rectum to the skin. Indeed the internal heat distribution of buffaloes under hot conditions could be the advantageous for sensible heat loss, viz. internal temperature difference was significantly lower in buffaloes than in cows, and external temperature difference was significantly higher in buffaloes than in cows. Ruminants mainly depend on insensible heat loss, such as panting, because, especially buffaloes, sweating rate is very low (Koga et al., 1991) in comparison with other animals, such as horses or humans. Still, buffaloes may depend on sensible heat loss, because they have behavioral heat dissipation; namely wallowing which increase heat conductivity as well as increasing evaporative heat loss. Indeed it is well known that the rectal temperature of buffaloes decreases rapidly when they were moved under the shade or sprayed with water after heat stress (Badreldin and Ghany, 1952; Chikamune et al., 1987).

In conclusion, the shift of water from extracellular fluid compartment to blood compartment with the increase of environmental temperature increased the blood flow to the skin surface and provided advantageous conditions for heat dissipation. The heat dissipation system of buffaloes mainly depends on sensible heat loss by wallowing. To support sensible heat loss, buffaloes perhaps make up their internal heat distribution by means of blood flow. This physiological feature of buffaloes have been perhaps acquired through the adaptation to hot-humid climates which have abundant water.

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