Thermoregulatory Responses of Swamp Buffaloes and Friesian Cows to Diurnal Changes in Temperature

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ABSTRACT : Several reports have indicated that a rectal temperature of buffaloes is easily influenced by their surroundings. To clarify an effect of changing environmental temperature on thermoregulatory responses of buffaloes, an environment with diurnal temperature changes of 25℃ to 35℃ was created using an artificial climate laboratory. Three swamp buffaloes and three Friesian cows were exposed to three different experimental periods as follows: Period 1 (constant temperature of 30℃), Period 2 (diurnally changing temperature) and Period 3 (diurnally changing temperature and fasting). Heat production, rectal temperature, respiration rate, heart rate and respiration volume were measured during each period. Rectal temperature of the buffaloes fluctuated diurnally with the changing temperature (Periods 2 and 3), but remained constant in cows. Mean heat production was significantly lower in buffaloes than in cows in Period 2 and 3. However, the maximum rectal temperature and the increment of heat production were not always lower in buffaloes than in cows during Period 2. These results show that a rectal temperature and heat production in buffaloes are markedly influenced by the diurnal changes in temperature. Compared with *Bos taurus* cows, the differences may be attributed to the physiological features of buffaloes including a high heat conductivity of their bodies and a lower heat production. (***Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 8 : 1273-1276***)

Key Words : Buffaloes, Diurnally Changing Temperature, Thermo-Lability, Thermoregulation

INTRODUCTION

There have been stated in several reports that a rectal temperature of buffaloes increases rapidly during exposure to hot conditions (Badreldin and Ghany, 1952; Moran, 1973). Chikamune et al. (1987) reported that a rectal temperature of buffaloes increased rapidly as compared with cattle when buffaloes were abruptly exposed to conditions of 35℃. The rectal temperature of buffaloes fluctuated from 1.4 to 2.0℃ in rest conditions with seasonal changes of air temperature, while that of cattle remained a constant in the same conditions (Chikamune et al. 1986; Koga et al. 1991a). In the latter study, the rectal temperature of buffaloes decreased to 36.8℃ at an air temperature of 7.0℃, while rectal temperature of cattle remained at 38.5℃.

Thermo-lability allows conservation of energy in cold and famine conditions by avoiding the necessity to increase heat production, and conservation of water in hot and arid conditions by avoiding the necessity to increase evaporative heat loss (Johnson, 1971). On the other hand, thermo-lability has also been suggested as one of the main indicators for disadaptability in cattle (Moran, 1973). Buffaloes which live in a hot-humid climate and have a unique behaviour, namely wallowing, also have a physiological mechanism supporting heat dissipation when they wallow, viz, an increase in the blood volume and rate of blood flow to the skin surface in hot conditions (Koga et al., 1998). Therefore it is possible that thermo-lability in buffaloes also has a role in their particular heat dissipation system.

The present study was undertaken to clarify an effect of a diurnally changing environmental temperature on thermoregulatory response of buffaloes and to suggest the role of thermo-lability in buffaloes

MATERIAL AND METHODS

Three female swamp buffaloes (estimated to be 13 to 19 years old) and three Holstein- Friesian cows (2 years old) in dry and non-pregnant were used in this study. Their average body weights at beginning of the experiment was 510 and 650 kg, respectively. Estrus behaviour was not observed on the day of body temperature measurement.

The animals were maintained in an artificial climate laboratory (Zootron) at the National Institute of Animal Industry, Japan. For the first 7 days they were maintained at 20℃, 60% relative humidity (RH), allowing the animals to acclimatize before the experimental phase. The experiment consisted of three successive periods: a period of 7 days of constant temperature (30℃, 60 RH) [Period 1]; a period of 7 days of diurnally changing temperature [Period 2] when temperature fluctuated between 25℃ and 35℃ (mean 30℃) with a constant 60% RH and a period of

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5 days when temperature and humidity were the same as Period 2 but fasting [Period 3].

During Period 2 and Period 3, the temperature changed sinusoidly from 25℃ at 00:00 to 35℃ at 12:00 and then back to 25℃ at 24:00. Measurements were done 9 times every three hours on the last day of each Period (0:00, 3:00, 6:00, 9:00, 12:00, 15:00, 18:00, 21:00 and 24:00). Measurements of rectal temperature, respiration rate and heart rate were recorded using the methods described previously by Koga et al. (1991a, 1991b). After recording physiological parameters, exhaled gas was collected through a face mask for measurements of respiration volume and heat production and was analyzed by the metabolic energy analyzer (Zoontron, Shimadzu, Kyoto). The heat production of the animals the was measured by indirect calorimetry using Brouwer's formula (Brouwer, 1965) to calculate heat from the amounts of oxygen consumed, carbon dioxide produced, and methane production.

After each measurement, food was given as one of nine equal meals, except in Period 3 when the animals were fasted. The amount of food (hay wafer) was calculated based on the Japanese Feeding Standard for dairy cows. Water and salt mixture (Kohen, Nihon Zenyaku Co. Ltd., Tokyo) were supplied *ad libitum* through the experimental period.

The data obtained were subjected to t-test for 2 species and to Duncan's multiple range tests after AOV had revealed a significant ($p<0.05$) effect for the comparison of three experimental periods (Snedecor and Cochran, 1980). The relation between the diurnally changing temperature and rectal temperature was analyzed as follows. The rectal temperatures of buffaloes and cows over 24 hours were repeatedly correlated against air temperature noted from a lag time of 3 hours before the air temperature was recorded until 9 hours after the air temperature was recorded.

RESULTS

The mean values for heat production, rectal temperature, respiration rate, heart rate and respiration volume are presented in table 1. Heat production in buffaloes was lower than in cows for three periods and was significantly different in Period 2 and 3 ($p<0.05$). As the environmental temperature fluctuated, significant difference ($p<0.05$) appeared between species in Period-2 reflecting a lower increment of heat production in buffaloes (Buffaloes: 1.03% vs. Cows: 5.64%) (table 1).

Rectal temperature was not significantly different between species although the rectal temperature in buffaloes fluctuated markedly. There was, however, significant difference ($p<0.05$) between Period 2 and Period 3 in mean rectal temperature of buffaloes, but not for cows. The respiration rate and heart rate were significantly lower ($p<0.05$) in buffaloes than in cows during each period.

The changes in environmental and rectal temperature during Period 2 are shown in figure 1-1. The amplitude of diurnal changes was greater in buffaloes than in cows during Period 2 (Buffaloes: 1.2 ±0.03℃ vs. Cows: 0.7±0.02℃). The maximum rectal temperature was not always lower in buffaloes than in cows during Period 2 (Buffaloes: 39.3±0.18℃ vs. Cows: 39.2±0.29℃). The correlation coefficients to each lag time are shown in figure 1-2. Significant correlations for buffalo were observed for a lag times of +2 to +8 hours ($p<0.05$); no significant correlation was observed for cows.

Changes of the environmental temperature and heat production during 24 hours periods are shown in figure 2. The heat productions in Period 2 and Period 3 were lower in the buffaloes than in cows over the whole time. While the values of cows were higher than the dotted line which signifies the mean values of heat production during Period 1 for cows, except for 24:00, the values for buffaloes were lower than

Table 1. Mean values of physiological responses during a day

	Buffaloes			Cows		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
Heat production (cal/min/$kg^{0.75}$)	67.9 ±2.6^{b}	68.6 ±2.6^{b}*	34.9 ±3.2^{a}*	76.2 ±2.3^{b}	80.5 ±2.4^{b}	51.2 ±1.9^{a}
Rectal temperature (℃)	38.6 ±0.2^{ab}	38.8 ±0.2^{b}	38.1 ±0.1^{a}	38.5 ±0.0^{a}	38.8 ±0.1^{b}	38.9 ±0.3^{b}
Respiration rate (counts/min)	38.3 ±1.9^{b}*	51.3 ±1.3^{c}*	28.3 ±1.0^{a}*	58.6 ±4.5^{a}	72.6 ±1.3^{b}	57.2 ±5.0^{a}
Heart rate (counts/min)	54.3 ±2.0^{b}*	62.1 ±3.5^{b}*	37.5 ±0.9^{a}*	70.8 ±5.2	73.2 ±1.9	67.6 ±3.7
Respiration volume (l/min/$kg^{0.75}$)	0.95±0.0^{b}	1.11±0.1^{b}*	0.47±0.1^{a}*	1.12±0.1^{b}	1.38±0.1^{c}	0.84±0.1^{a}

Values are means±SE.

a,b,c Value having the same or no letters in the same row are not significantly different within species ($p>0.05$: Duncan's multiple range test).

* Significant difference from cows ($p<0.05$: t-test)

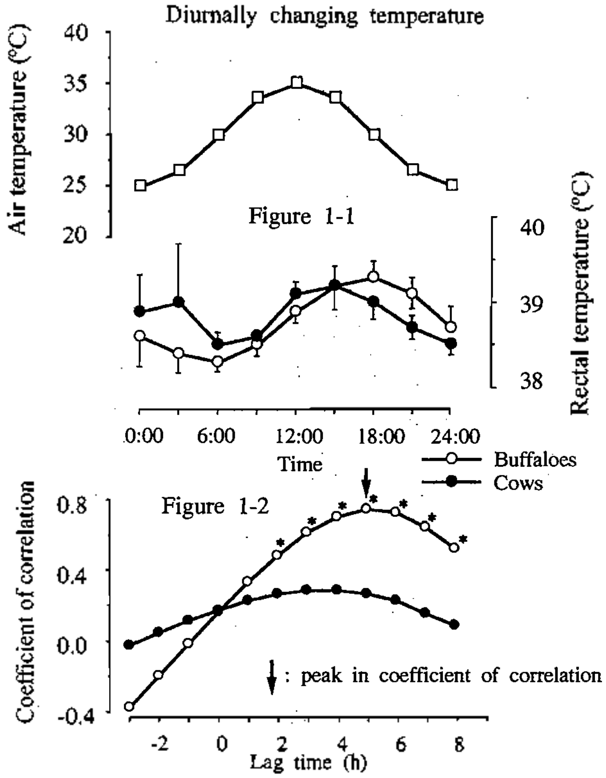

Figure 1-1. Change of rectal temperature in buffaloes and cows in Period-2; **Figure 1-2.** Coefficients of correlation of rectal temperature in Period-2 against the respective air temperature 3 hours before until 9 hours after the air temperature was recorded (*: Significant correlation, $p<0.05$)

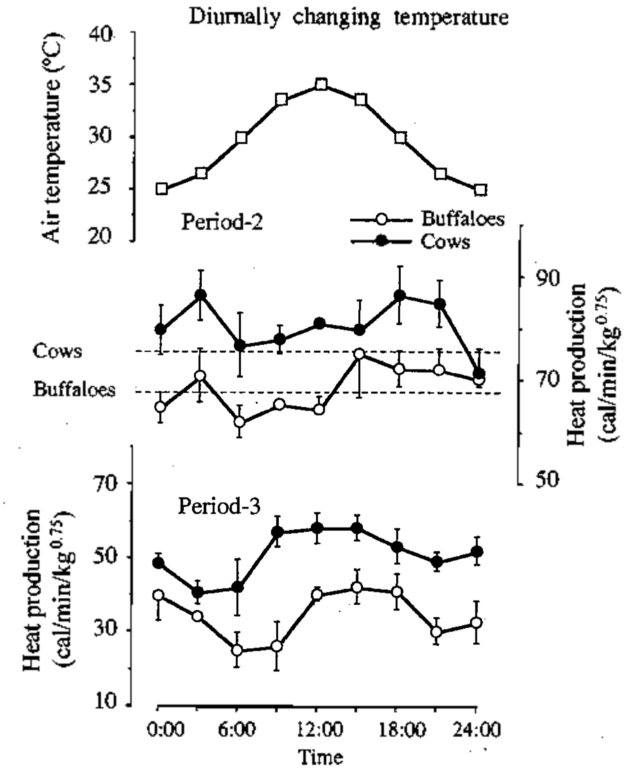

Figure 2. Change of heat production in buffaloes and cows during Period-2 and Period-3 (---- : The level of mean value of heat production during Period-1)

their dotted line during the morning which were the latter half of a lower environmental temperature. The increments of heat production were not always lower in buffaloes than in cows during Period-2 (Buffaloes: 27.7±8.42% vs. Cows: 24.5±6.10%) and Period-3 (Buffaloes: 74.0±26.7% vs. Cows: 19.8±5.0%)

DISCUSSION

Rectal temperature in buffaloes was significantly correlated with the changing temperature, but not in *Bos taurus* cows (figure 1-1). The cycle of rectal temperature in buffaloes was 5 hours out of phase with temperature changes (figure 1-2).

According to the well known observations of Schmidt-Nielsen et al. (1957), camels utilize thermolability and an effective coat to delay a rise in the rectal temperature in the daytime by decreasing the body temperature at night. Compared with camels, buffaloes also have a similar phase of the rectal temperature, but fall easily into hyperthermia because the buffalo's body, which has sparse hair and dark skin, absorbs much more solar heat under open field conditions (Badreldin and Ghany, 1952). In fact, the rectal temperature of buffaloes was a lower value at 6:00, but increased until 18:00. The maximum value for buffaloes was not always lower than that of cows. Therefore the fluctuation of rectal temperature in buffaloes is suggestive of a direct reflection of the change of environmental temperature rather than the utilization of environmental temperature for avoiding hyperthermia.

Heat production in buffaloes also fluctuated with temperature changes (figure 2). This may be attributable to the lower base of heat production of buffaloes. Furthermore, the physiological mechanism in buffaloes may tolerate the decrease of rectal temperature without an increase of heat production. Therefore, during low environmental temperatures, buffaloes can decrease their own heat production to a lower level than cows. This suggestion is supported by the observation that the rectal temperature of buffaloes decreased significantly from Period 2 to Period 3, that the significant difference between species appeared in Period 2, and that there was not a significant difference between species in Period 1. The former may indicate that the heat production of buffaloes decreases simultaneously with the decrease in rectal temperature. In Period 2 heat production by buffaloes during the morning was lower than in Period 1 while the values in cows throughout the day were almost always higher than in Period 1. Even in buffaloes, however, the total heat production during a whole day increased slightly from Period 1.

From these results, buffaloes may have a high heat conductivity between internal- and external-environment. Previous reports have also reported results similar to this physiological feature. Chikamune et al. (1987) reported that buffaloes avoid hyperthermia when they received a water-spray. Badreldin and Ghany (1952) indicated that buffaloes have a better cooling mechanism than cows under shade. In our observations, the difference in rectal temperature between species vanished in the controlled conditions, while rectal temperature in buffaloes was lower than in cattle under shade in natural conditions (Koga et al., 1991).

When the rectal temperature of buffaloes is increased their blood volume and blood flow in the skin increases for heat transportation to the skin surface. Accordingly, buffaloes appear to have the advantage for heat dissipation of the decrease in temperature difference between rectum and skin surface and an increase in the temperature difference between skin surface and environment (Koga et al., 1998).

In conclusion, the heat production and rectal temperature in buffaloes fluctuated with environmental temperature. This physiological features of buffaloes may reflect a high heat conductivity of their bodies, including an unfortified skin surface against heat, and the lower heat production. Because thermo-lability in buffaloes is not always available for the effective heat dissipation, it may contribute towards heat dissipation during wallowing which increases sensible heat loss via water and mud. This heat dissipative system may be the quick and simple adaptation, given the existence of available swamp, in spite of the liability to hyperthermia under open field conditions.

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REFERENCES

Badreldin, A. L. and M. A. Ghany. 1952. Adaptive mechanisms of buffaloes to ambient temperature. Nature. 170:457-458.

Brouwer, F. 1965. Report of sub-committee on constants and factors. In: Energy Metabolism: Proc. 3rd Symp., Troon, pp. 441-443, Publ. Eur. Ass. Anim. Prod., No. 11, Ed Baxtey K. L. Academic Press, London.

Chikamune, T., Y. Kanai, T. Ichikawa, H. Homma and H. Shimizu. 1987. Influence of solar radiation and effects of water spray on thermoregulatory responses and heat production in swamp buffalo. Jpn. J. Trop. Agr. 31:1-5.

Chikamune, T., Y. Kanai and H. Shimizu. 1986. Comparison of the effects of seasonal-climatic changes on thermoregulatory responses and plasma concentrations of thyroid hormones in swamp buffaloes and cattle. Jpn. J. Zootech. Sci. 57:778-784.

Johnson, K. G. 1971. Body temperature lability in sheep and goats during short-term exposures to heat and cold. J. Agric. Sci. 77: 267-272.

Koga, A., K. Kurata, R. Furukawa, M. Nakajima, H. Homma, Y. Kanai and T. Chikamune. 1998. Rectal-skin temperature difference regulated by blood volume in Swamp Buffaloes in hot conditions: Comparative study of thermo-regulation in buffaloes and cattle. Anim. Sci. Technol. (Jpn.) 69:81-89.

Koga, A., N. Ishikawa, A. Tajima, H. Homma, Y. Kanai and T. Chikamune. 1991a. Characteristics of physiological responses and blood constituents in relation to seasonal changes for the environment in buffaloes compared with cattle. Jpn. J. Trop. Agr. 35:283-288.

Koga, A., T. Chikamune, Y. Kanai, H. Homma, A. Tajima, N. Ishikawa, R. Furukawa, T. Ueno, M. Nakajima and T. Watanabe. 1991b. Effects of high environmental temperatures on some physicochemical parameters of blood and heat production in swamp buffaloes and Holstein cattle. Anim. Sci. Technol. (Jpn.) 62:1022-1028.

Moran, J. B. 1973. Heat tolerance of Brahman cross, buffalo, Banteng and Shorthorn steers during exposure to sun and as a result of exercise. Aust. J. Agric. Res. 24:775-782.

Schmidt-Nielsen, K., B. Schmidt-Nielsen, S. A Jarnum and T. R Houpt. 1957. Body temperature of the camel and its relation to water economy. Am. J. Physiol. 188: 103-112.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical Methods. 7th Ed. Iowa State University Press. Ames.