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Comparison of the thermoregulatory response of buffaloes and tropical cattle, using fluctuations in rectal temperature, skin temperature and haematocrit as an index

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SUMMARY

In previous comparative studies of buffaloes and temperate cattle, a greater increase in rectal temperature (RT) and skin temperature (ST), and a greater decrease in haematocrit (Ht) have been observed in buffaloes than in temperate cattle with an increase in ambient temperature (AT). Our series of previous experiments suggested that great changes in RT, ST and Ht are induced in buffaloes by a marked increase in blood flow from the body core to the surface, which accelerates dissipation of heat from the skin surface. On the basis of these suggestions, the present study was undertaken to compare fluctuations in RT, ST and Ht between buffaloes and tropical cattle. Fluctuations in the aforementioned parameters, particularly RT and Ht, were greater in buffaloes than in cattle. Moreover, the correlation for RT or Ht *v.* AT was significant for buffaloes ($r = 0{\cdot}33$ and $-0{\cdot}37$, respectively) but not for cattle. The correlation coefficient for ST *v.* AT was significant in both species, but was greater in buffaloes ($r = 0{\cdot}63$) than in cattle ($r = 0{\cdot}56$). These results demonstrate that with changes in ambient temperature, RT, ST and Ht fluctuate much more in buffaloes than in tropical cattle, as found previously for temperate cattle. Therefore, the distinctive thermoregulatory responses of buffalo are confirmed as being specific to this species.

INTRODUCTION

Swamp buffaloes are distributed widely throughout South-East and East Asia. In the Philippines, smallholders rely on buffaloes for traditional farming practices, including ploughing, hauling and carrying heavy loads. Smallholders usually maintain two buffaloes and some raise buffaloes to supplement their income from the sale of milk and of live animals for slaughter. To further improve the production potential of swamp buffaloes, the Philippine Carabao Center implements continuous crossbreeding of the Philippine carabao (swamp-type buffalo) with river-type buffaloes, which are used for dairy farming in South Asia and Europe. Crossbred buffaloes grow faster and produce more milk than the Philippine carabao. In this case, an additional measure against heat stress is required for improved farming in the Philippines (particularly for milk production, which elevates the resting metabolic rate).

Despite the historical association of buffaloes with hot-humid habitats, thermoregulation in these animals has been estimated to be less effective than in cattle with regard to their tolerance of heat. Previous studies have revealed that the rectal and skin temperatures of buffaloes increase readily under solar radiation (Moran 1973) and that buffaloes sweat less

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than cattle (Joshi *et al*. 1968; Koga *et al*. 1991 *a*). By contrast, the rectal temperature of buffaloes decreases rapidly when they are moved into the shade (Badreldin & Ghany 1952) or sprayed with water (Chikamune *et al*. 1987), following heat stress. The results of a series of experiments that were carried out to compare thermoregulation in buffaloes with that of temperate cattle revealed that the rectal temperature of buffaloes fluctuated with diurnal changes in air temperature (Koga *et al*. 1999 *b*). This fluctuation was the result of active transport of heat through increased blood flow from the core of the body to its surface (Koga *et al*. 1999 *a*). Such an increase of blood flow is induced by an increase in the distribution of body water into the blood with a decrease in haematocrit (Koga *et al*. 1999 *a*). However, the aforementioned studies of swamp buffaloes and temperate cattle leave the question of whether the distinctive fluctuation in rectal temperature and haematocrit in buffaloes is particular to this species or whether this might be a feature that is common to thermoregulation in buffaloes and tropical cattle that inhabit hot climates. If the latter were true, one would expect to see the same thermoregulatory responses in tropical cattle that are observed in buffaloes. Alternatively, the thermoregulatory responses of buffaloes to heat might be unique to this species. The purpose of this study was to characterize the distinctive thermoregulatory responses of buffaloes in relation to tropical cattle. In this study, the following three environmental variables were defined as the influential factors for the thermoregulatory responses: ambient temperature (°C), relative humidity (%) and temperature–humidity index (THI). The THI is calculated by combining ambient temperature and relative humidity into one value and used to quantify heat stress in cattle (Ravagnolo 2000).

MATERIALS AND METHODS

Six crossbred buffaloes (about 2·5 years old) and six Brahman grade cattle (2·5 years old) were used in this study. The mean body weight of the buffaloes and cattle at the final stage was $433 \cdot 5 \pm 15 \cdot 2$ and $373 \cdot 9 \pm 10 \cdot 3$ kg, respectively. No animals were pregnant or lactating. The experiment was conducted at the Philippine Carabao Center, at the University of the Philippines at Los Baños. The animals were housed indoors in individual pens and were fed corn silage supplemented with brewer's spent grain and a commercially available concentrate compound. The amount of feed given to each animal was calculated according to the feeding standard for water buffaloes (Kearl 1982). Animals were fed at 08.00 h and 15.00 h, after collecting data. Data were acquired from each animal (12 head) over at least 2 experimental days, and gained weekly during 13 weeks. On each day of the experiment, ambient, rectal and skin temperature, as well as relative humidity, respiration rate and pulse rate were measured at four different times (07.00, 10.30, 14.00 and 16.00 h). To measure haematocrit, 5 ml of blood was collected twice daily (at 07.00 and 14.00 h) from the jugular vein into an evacuated tube that contained sodium heparin. The respiration rate and pulse rate of each animal was measured by conventional methods. The rectal and skin temperature of each animal was recorded with a digital thermometer (Model SK-1250MC; Sato Keiryo-Seisakujyo, Japan). Rectal temperature was measured by inserting the thermometer sensor about 10 cm into the rectum. Skin temperature was measured by placing the thermometer sensor on the shaved surface of the skin. The mean skin temperature at three locations was calculated (sacral and thoracic region of the back and mid-flank; cf. McLean 1963). The temperature–humidity index (THI) was calculated as $\mathrm{THI} = ((9/5 \times \mathrm{temperature}) + 32) - (11/2 - (11/2 \times \mathrm{humidity})) \times ((9/5 \times \mathrm{temperature}) - 26)$, with temperature in °C (Ravagnolo *et al*. 2000).

The study was arranged as a split-plot design and data were analysed as randomized complete blocks using StatView (version 4.02, Abacus Concepts, Berkeley, CA). The mean values and coefficients of variability were calculated for each parameter, and differences between the two species were assessed using Student's *t*-test (Snedecor & Cochran 1980). The correlation coefficients between each of the measured variables (rectal and skin temperature ($n = 52$) or haematocrit ($n = 26$)) and the environmental variables (ambient temperature, humidity and THI) were calculated to assess interrelationships.

RESULTS

The mean ambient temperature, relative humidity, and temperature–humidity index (THI) within the facility were 31·1 °C, 65·5%, and 82·2, respectively, and ranged between 36·0 and 26·0 °C, 92·0 and 46%, and 91·2 and 75·3, respectively, during the study. Under these conditions, animals were exposed to heat stress throughout the study, as the minimum THI was >74 throughout this period, which was high enough to cause heat stress (Ravagnolo *et al*. 2000).

The mean rectal temperature and respiration rate were significantly ($P < 0 \cdot 05$) higher in buffaloes than in cattle (Table 1). By contrast, the mean pulse rate was significantly ($P < 0 \cdot 05$) lower in buffaloes than in cattle. The mean skin temperature and haematocrit were not significantly different between the two species. The coefficients of variability for rectal and skin temperatures, haematocrit, and respiration rate were larger in buffaloes than in cattle, particularly for rectal temperature and haematocrit. By contrast, the coefficient of variability for pulse rate was smaller in buffaloes than in cattle. The correlation coefficients for rectal temperature *v*. ambient temperature or

Table 1. *Mean values of thermoregulatory responses and haematocrit in buffaloes and cattle through the experimental period*

	Buffaloes		Cattle	
	Means	CV(%)	Means	CV(%)
Rectal temperature (°C)	$39{\cdot}3 \pm 0{\cdot}37$*	0·93	$39{\cdot}1 \pm 0{\cdot}20$	0·51
Skin temperature (°C)	$36{\cdot}5 \pm 1{\cdot}43^{NS}$	3·92	$36{\cdot}3 \pm 1{\cdot}41$	3·88
Haematocrit (%)	$35{\cdot}3 \pm 3{\cdot}46^{NS}$	9·81	$34{\cdot}7 \pm 2{\cdot}68$	7·72
Respiration rate (cpm)	$42{\cdot}8 \pm 21{\cdot}3$*	49·7	$29{\cdot}6 \pm 11{\cdot}3$	38·4
Pulse rate (cpm)	$68{\cdot}9 \pm 9{\cdot}1$*	13·2	$74{\cdot}8 \pm 15{\cdot}5$	20·7

Values are means ± S.D. (D.F. = 51 for rectal and skin temperature, respiration rate and pulse rate; D.F. = 25 for haematocrit). CV, coefficient of variability; *, significant difference from cattle ($P < 0{\cdot}05$; Student *t*-test); NS, not significant difference from cattle.

Table 2. *Correlation coefficients of rectal, skin temperature and haematocrit against the ambient conditions in buffaloes and cattle through the experimental period*

	Buffaloes			Cattle		
	Rectal temperature	Skin temperature	Ht	Rectal temperature	Skin temperature	Ht
Ambient temperature (°C)	0·33*	0·63*	−0·37*	−0·24	0·56*	−0·27
Humidity (%)	−0·32*	−0·66*	0·43*	0·12	−0·56*	0·32
THI	0·07	0·33*	−0·14	−0·28*	0·45*	−0·22

*, Significant difference ($P < 0{\cdot}05$; correlation coefficient test).
D.F. = 52 and 26 for rectal and skin temperature, and haematocrit, respectively.
Ht, Haematocrit; THI, temperature–humidity index.

humidity were significant for buffaloes, but not for cattle (Table 2). Similarly, the correlation coefficients for haematocrit *v*. the same environmental parameters were significant for buffaloes, but not for cattle. The correlation coefficients for rectal temperature *v*. ambient temperature and for haematocrit *v*. humidity were positive for buffaloes. By contrast, the correlation coefficients for rectal temperature *v*. humidity and for haematocrit *v*. ambient temperature were negative for buffaloes. The correlation coefficients for skin temperature *v*. ambient temperature or humidity were significant for both species, but larger for buffaloes than for cattle. By contrast, there was a significant negative correlation for rectal temperature *v*. THI for cattle, but not for buffaloes. Finally, the correlation coefficient for skin temperature *v*. THI was significant in both species, but was larger in cattle.

DISCUSSION

The objective of the current study was to compare the thermoregulatory responses of buffaloes with those of tropical cattle. Buffaloes were observed to have distinctive thermoregulatory responses; these responses are probably specific to this species, as the coefficient of variability in rectal temperature and haematocrit of buffaloes was greater than in cattle, and the correlation coefficient for these two parameters *v*. various environmental parameters was significant for buffaloes, but not for tropical cattle. By contrast, rectal and skin temperatures *v*. THI were closely correlated in cattle, but not in buffaloes. The cause of the poor correlation in buffaloes may be due to a greater influence of ambient temperature on thermoregulation in these animals.

Regarding the fluctuation of rectal temperature in buffaloes, we reported previously (Koga *et al*. 1999*a*) that there was a significant correlation between rectal and ambient temperatures in buffaloes, but not in Friesian cows, when animals were exposed to diurnal changes in temperature in a climate-controlled laboratory. In that study, the cycle of rectal temperature in buffaloes was 5 h out of phase with ambient temperature, which was changed systematically from 25 °C at 00.00 h to 35 °C at 12.00 h, and back to 25 °C at 24.00 h. Moreover, the rectal temperature in buffaloes was lower than that in

Friesian cows during the period in which ambient temperature was low (between 00.00 and 09.00 h), and it was higher than that in Friesian cows after the period of high ambient temperature (between 15.00 and 24.00 h). Based on these results and those of the present study, it would appear that rectal temperature in buffaloes is affected greatly by ambient temperature.

We suggested in a previous report that the fluctuation of rectal temperature in buffaloes is induced by active internal heat transport through changes in blood flow (Koga *et al.* 1999*a*). A seasonal change in haematocrit has been reported in buffaloes (Pandey & Roy 1968, 1969; Koga *et al.* 1991*b*), which probably affects the thermoregulatory responses of these animals. Consequently, we compared changes in the volume of extracellular fluid, blood and plasma in buffaloes and Friesian cows when the animals were exposed successively to ambient temperatures of 20, 30 and 35 °C (Koga *et al.* 1999*a*). As the ambient temperature increased, blood volume increased greatly in buffaloes (from 47·9 to 55·8 ml/kg), but increased only slightly in Friesian cows (from 42·8 to 44·1 ml/kg), while there was no change in extracellular fluid volume during the same period. During the increase in blood volume, the ratio of plasma to blood volume increased greatly in buffaloes (from 78·2 to 86·0%), but was almost constant in Friesian cows (70·1–67·6%). These results suggested that the increased volume of blood in buffaloes was induced by an increase in the distribution of body water into the blood from other body compartments, rather than by an increase in water ingestion. In that study (Koga *et al.* 1998), the correlation coefficient for haematocrit *v.* blood volume was −0·73 for buffaloes and 0·40 for Friesian cows, respectively. The significant negative correlation between haematocrit and ambient temperature observed in the present study suggests that blood volume in buffaloes increases with an increase in ambient temperature.

There have been previous reports that the marked increase in blood volume in buffaloes contributes greatly to the dissipation of heat from the body core to the skin surface (Koga *et al.* 1998, 1999*a*). The increased rate of blood flow in the dorsal artery of the hind leg was compared between buffaloes and Friesian cows when the animals were exposed to an increase in ambient temperature (from 20 to 35 °C at 60% relative humidity; Koga *et al.* 1999*a*). As the shunting of heat from the body core to the skin is associated with an increase in arterial blood flow to the nose, tongue, and limbs, and these organs include numerous arteriovenous anastomoses, these regions are important for heat exchange (Hales 1973; Hales *et al.* 1978). In the study of Koga *et al.* (1999*a*), blood flow to the hind leg increased by 55·5% in buffaloes and by 20·6% in Friesian cows, respectively. Such active heat transport probably contributes to the reduction of the difference between the temperature of the body core and that of the subcutaneous tissue, and to the increased difference between the temperature of the skin surface and the environment (Koga *et al.* 1999*a*). Moreover, these changes in the distribution of body heat are induced rapidly, along with a change in haematocrit (within 3 h of the change in ambient temperature; Koga *et al.* 1998). In the present study, a significant positive correlation between rectal and ambient temperatures and a significantly higher positive correlation between skin and ambient temperatures was observed in buffaloes, as compared with tropical cattle. These observations indicate that buffaloes take advantage of effective internal heat distribution to dissipate heat from the body core to the skin, thereby accelerating heat loss, particularly when they are sprayed with water or moved into the shade.

In conclusion, rectal temperature and haematocrit in buffaloes exhibit a marked fluctuation relative to tropical cattle, which suggests that buffaloes have a distinctive mechanism for dissipating heat in hot-humid climates, as hypothesized by Koga *et al.* (1998, 1999*a*, *b*). This physiological heat-reduction system probably protects buffaloes against heat stress more effectively, as compared with cattle, and it may be possible to utilize this trait to benefit milk production in hot-humid climates.

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