Research article

Effective Heat Dissipation in Hot-humid Climates: the Hypothesis Formulated by the Results in Swamp Buffaloes

ARATA KOGA
University of Veterinary and Animal Sciences, Lahore, Pakistan
Email: arkoga@uvas.edu.pk

MAKHDOOM ABDUL JABBAR
University of Veterinary and Animal Sciences, Lahore, Pakistan

TALAT NASEER PASHA
University of Veterinary and Animal Science, Lahore, Pakistan

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Abstract Most countries of Southeast Asia belong to hot-humid climates with high humidity and small diurnal changes in air temperature throughout the year. These conditions are harsh for large livestock ruminants because the conditions prevent evaporative heat loss (panting and sweating). Swamp buffaloes are distributed widely throughout this climatic zone as a large livestock ruminant, and traditionally provide power to plough farm fields. Buffaloes are also valuable for small farmers as these animals show a good digestibility to low quality roughage. For animal production in hot-humid climates, crossbred cattle have been exploited as an efficient tool for blending the adaptability of tropical cattle accompanying with high sweating rate. But effective heat dissipation is still a major problem in this area. Buffaloes easily sustain heat stress under solar radiation as compared to tropical cattle, but they quickly recover after moving into shade or spraying with water. Therefore these adapted animals must have an effective physiological system for heat dissipation under hot-humid conditions. Several comparative experiments have been conducted comparing thermo-regulatory responses between swamp buffaloes and cattle. Hormone and blood parameters were also compared between the two species in terms of blood volume and distribution in the body. The results show active heat transport through blood flow and water turnover in buffaloes as compared to temperate or tropical cattle. In hot-humid climates, there is usually high water availability with a large amount of precipitation. Therefore the effective heat dissipation in buffaloes may be developed through water utilization rather than evaporative heat loss. The observed physiological system suggests that the adapted heat dissipation is combined with behavioral heat dissipations such as wallowing.

Keywords: Swamp buffaloes, heat dissipation, hot-humid climates, Southeast Asia

INTRODUCTION

For large livestock animals living in hot climates it is very important, though difficult, to dissipate excessive internal heat through sweating and panting. There are some instances in which animals living in severe environments have shown distinctive thermo-regulatory responses. Schmidt-Nielsen et al. (1957) reported that the rectal temperature of camels fluctuates within a large range, allowing these animals to avoid heat stress without body-water loss through sweating and panting. Although the low humidity in hot-dry climates lends itself to evaporative heat loss, it is very difficult to find water in this climate. Thus the adaptation to dissipate heat without body-water loss is achieved using the large diurnal change in air temperature. Among hot climates the difficulty of heat dissipation varies between hot-dry and hot-humid climates. In hot-humid climates high humidity is generally paired with a small diurnal change in air temperature and thus evaporative heat loss is not as effective for body-heat dissipation. However, there is usually an abundance of water in hot-humid climates which may be effectively used for body-heat dissipation.

Swamp buffaloes are found in hot-humid climates and are an important livestock ruminant for East and Southeast Asia. Despite being endemic to this habitat, rectal and skin temperatures in buffaloes increase rapidly under solar radiation and the rate of sweating is lower than in cattle. Respiratory evaporation is ineffective because panting in buffaloes induces an increase in blood pH and causes respiratory alkalosis. In contrast, panting does not cause blood pH changes in cattle (Koga et al., 1991a). Regardless of the inefficacy of evaporative heat loss, the rectal temperature in buffaloes decreases rapidly when they are moved into the shade or sprayed with water following heat stress. A large fluctuation in rectal temperature was observed in buffaloes exposed to artificial controlled temperature that fluctuated diurnally between 25 and 35˚C (Fig. 1; Koga et al., 1999b). Under natural conditions, the rectal temperature in buffaloes was correlated with seasonal changes in environmental temperatures, but the same was not true for Friesian cattle in temperate zones (Koga et al., 1991b) or tropical cattle in tropical zones (Koga et al., 2004). Furthermore, under natural conditions, haematocrit (Ht) in buffaloes was correlated with seasonal changes in environmental temperatures, but the same was not true for Friesian cattle in temperate zones (Fig. 2; Koga et al., 1991b). A correlation was detected between rectal temperature and Ht in buffaloes, but not in cattle (Koga et al., 1991b; 2004). These results suggest that thermo-regulation in buffaloes is more reliant upon heat transport through blood flow than in cattle.

Water turnover is generally higher in temperate cattle than in tropical cattle (Siebert and Macfarlane, 1969), because the retention of body water is very important for dissipating heat through blood circulation in hot conditions. Although buffaloes are endemic to the tropics, the water turnover in these animals is higher than in temperate cattle (Siebert and Macfarlane, 1969). Moreover, Chaiyabutr et al. (1987) reported that water turnover increases when buffaloes are exposed to hot conditions, which contradicts the findings in cattle. This increase in water turnover is accompanied by high water requirements and body water content, especially in hot conditions (Siebert and Macfarlane, 1969). In previous experiments water intake in buffaloes increased markedly with increased air temperature, and it was significantly higher than in Friesian cattle at 35˚C (Koga et al., 1999a). The volume of urine and the water content of the faeces were also higher in buffaloes than in Friesian cattle under normal conditions (Koga et al., 2002). These results suggest that water excretion contributes to heat dissipation in the thermo-regulatory system of buffaloes.

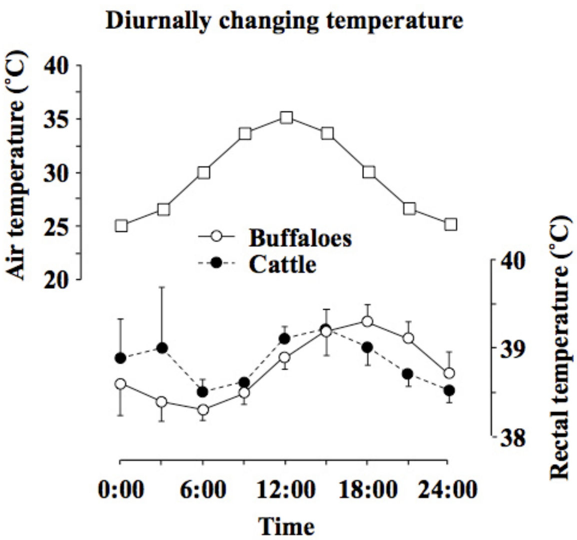

Fig.1 Change of rectal temperature with diurnally changing temperature

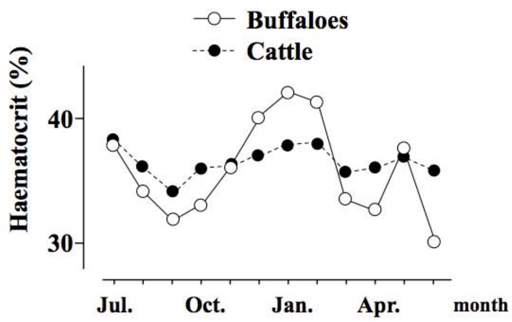

Fig.2 Monthly mean values of haematocrit during the course of one year

On the basis of these reports the physiological system in buffaloes suggests that the adaptive thermo-regulatory functions use internal and external water in hot-humid climates. Because of plentiful rainfall in these climates an abundant supply of water is available. Therefore, in this short review two distinctive physiological systems in buffaloes are discussed with the results obtained from several experiments.

RESULTS AND DISCUSSION

Marked increase in blood volume and blood flow to the skin surface

In animals the redistribution of cardiac output generally arises from the necessity to dissipate heat under hot conditions, which is facilitated by sending more blood to the surface of the body. Excessive heat is left in the subcutaneous tissues and skin temperature increases (Hales, 1973). Consequently the internal heat gradient between the rectal and skin temperature is narrowed and the external heat gradient between the skin and the surrounding air is widened, thus promoting body-heat dissipation from the skin surface. On the basis of published reports, we compared the changes in blood and plasma volume, rectal and skin temperature, and blood flow to the skin surface before and after heat exposure in both buffaloes and temperate cattle. From the results of several experiments the blood volume, especially plasma volume, increased more in buffaloes than in cattle after heat exposure. The increase in skin temperature and blood flow to the skin surface was also larger in buffaloes than in cattle after heat exposure (Koga et al., 1999a). In addition, the difference of rectal and skin temperature (R-S difference) was calculated, and a relationship between R-S difference and blood volume (as indicated by Ht) was compared in both species (Koga et al., 1998). The R-S difference was significantly smaller in buffaloes than in cattle. And Ht in buffaloes decreased significantly as the surrounding temperature increased, while the Ht in cattle was almost stable during the same period (Fig. 3; Koga et al., 1998). Conversely, as the surrounding temperature decreased the R-S difference and the Ht in buffaloes increased, and the any significant difference between the animals vanished after that point (Koga et al., 1998).

Distinctive arginine vasopressin response to a decrease of blood volume in buffaloes

MacFarlane et al. (1967) reported that body-water regulation, which involves the renin-angiotensin axis and arginine vasopressin (AVP), is influenced by the availability of water in the native habitat of animal species. Based on this work, the correlation between plasma AVP concentrations and Ht (as an index of plasma volume) were investigated between swamp buffaloes and Friesian cattle after 3 days of water deprivation (Fig. 4; Koga et al., 2002). An increase in AVP concentration and Ht was finally larger in buffaloes (3267% in AVP and 30.5% in Ht) than in cattle (886% in AVP and 19.0% in Ht) on day 3. But the initial response in AVP was distinctive in buffaloes. From day 0-1, the AVP/Ht ratio, (as an index of AVP sensitivity) was lower in buffaloes (2.51) than in cattle (3.40), although the increase in Ht was larger in buffaloes (16.0%) than in cattle (4.8%) during the same period. From Days 1-2 and 2-3, the AVP/Ht ratio was higher in buffaloes than in cattle (the values are shown in Fig. 2), although there was a similar increase in Ht in both species (7.1% and 5.1% in buffaloes, and 9.2% and 3.9% in cattle, respectively).

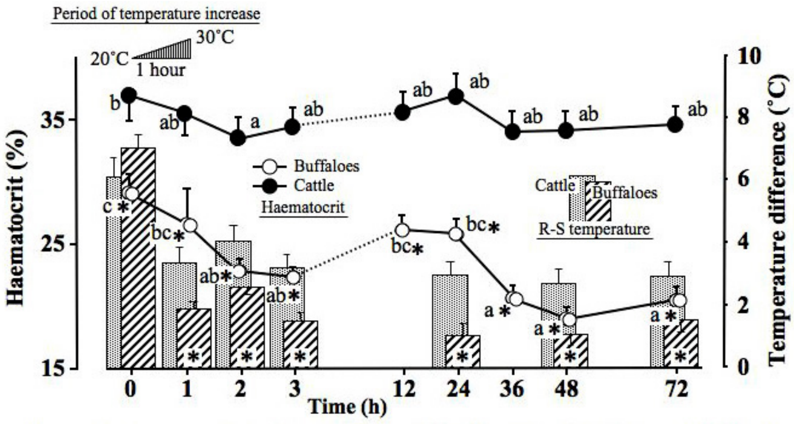

Fig.3 Change in rectal-skin (R-S) temperature and haematocrit following a temperature increase from 20 ˚C to 30 ˚C during one hour

** Significant difference from cattle (p<0.05)*
a, b, c: Values having same letters in the same line are not significantly different (p<0.05) (Modified from Kogo et al., 1998)

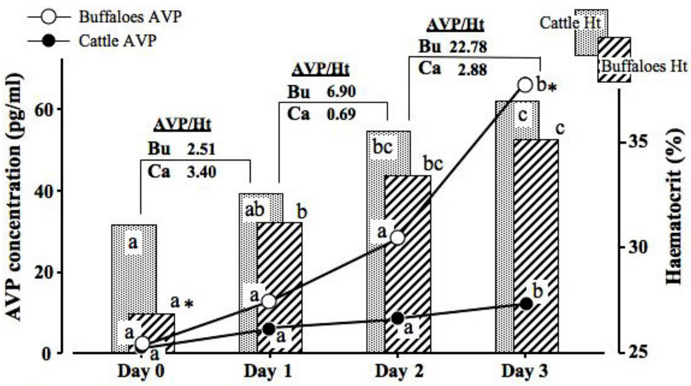

Fig.4 Change in AVP and haematocrit over 3 days following water deprivation

** Significant difference from cattle (p<0.05)*

CONCLUSION

This research has shown that heat transport through blood flow is more active in buffaloes than in cattle, and that the initial AVP sensitivity is lower in buffaloes than in cattle, as indicated by a decrease in plasma volume. The increase in blood volume in buffaloes maintains an elevated skin temperature under hot conditions, thus facilitating the dissipation of heat from the surface of skin when buffaloes wallow in the mud or move into the shade. The initial decreased AVP sensitivity observed in buffaloes permits a decrease in body water through urine excretion, within certain limits, and appears to be a typical response for animals living in habitats with high water availability. Our findings in swamp buffaloes contradict the findings in temperate and tropical cattle in that buffaloes, unlike cattle, use body-water for heat dissipation. In hot-humid climates there is generally an abundance of water as well as high humidity and a narrow diurnal range in air temperature. Therefore, the physiological responses observed in buffaloes demonstrate that the heat dissipation system via body-water circulation is more adaptive than evaporative heat loss in these climates. For animal production systems in hot-humid climate areas, this animal species may be expected a good potential with the adapted heat dissipation system as well as good digestibility of low quality roughage (Homma, 1994).

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