CHAPTER II

BACKGROUND INFORMATION

Many information concerning climatic physiology of swamp buffalo has been reported especially about the heat tolerance compared with any other domestic animals. Some morphological characteristics are responsible for the ability of animal to survive in hot climate for example : number of sweat gland, body conformation, density of hair coat and pigment of the skin. Buffalo is considered not to be the heat tolerance animal because it has only one sixth of the sweat gland population density compare with Bos taurus cattle (Hafez, Badreldin & Shafie, 1955a). Moreover, the surface area of the sweat gland, and the low sweating rate of buffalo under high environmental temperature indicated that sweating is less important in thermoregulation than in cattle (Joshi, McDowell & Sadhu, 1964; Chikamune. 1986) On the other hand, the body conformation; thickness of the body. deep belly and large proportional surface area (surface/weight) facilitate dissipation of excess body heat especially through radiation. Since hair is justified to be an insulating coat, the low density of hair follicle facilitate heat dissipation by convection and radiation. The black skin of buffalo protects the deeper layers of the skin against ultraviolet ray while it permits free convection over the body surface. All of these morphological features make its ability to thrive in the hot and arid environment (Shafie, 1985). However the relative lower evaporative heat loss in buffalo indicated that it was not heat tolerance animal so that the wallowing is one of the most important adaptive behavior of buffalo under hot climate to dissipate heat by non-evaporative cooling.

Effect of heat exposure on circulatory system

The most obvious effect of heat exposure on cardiovascular function is an increase in heart rate. An increase in heart rate is consistent with an increase in cardiac output in ox (Whittow, 1965, 1968) but not in sheep (Hales, 1973). On the other hand, arterial blood pressure will increase or decrease that depends on total peripheral resistance affected by severity of heat exposure. Some factors that alter heart rate have an influence on sino-atrial node, the area of pacemaker. The increase in heart rate of heat stress condition is considered by two reasons; first, the increase in temperature acts directly at the SA node and second, because of catecholamine produced during stress condition (Hafez, 1968). It has been reported that severe heat stress which caused deep temperature to rise by 2.4° C increased blood flow to the adrenal gland and probably increased catecholamine level (Rübsamen & Hales, 1985). In buffalo, the normal value of heart rate is quite low when compare with any other domestic ruminant. The previous reports shown that at the temperature of 10-15° C, (the zone for temperate cattle) 15-20°C (the zone for buffalo) and 20-25°C (the zone for subtropical cattle), the heart rate of buffalo was lower than Egyptian, Dairy Shorthorn and their crossbred. Although buffalo had a lower cardiac rhythm than the cattle breeds, it was demonstrated that there was a higher magnitude of increase in heart rate by an approximate of 30% compare with 9, 26 and 13% in Egyptian, Dairy Shorthorn and their crossbred respectively in direct solar heat exposure for 2 hrs. (Shafie, 1985). The similar response was also reported by Chaiyabutr et al. (1987) who showed a marked increase in heart rate of buffalo from 40 to 56 beats/min after heat exposure for 6 hrs. However, a very slight increase in heart rate of buffalo and native cattle with a much higher value in Dairy Shorthorn and Holstein has been reported (Badreldin & Ghany, 1954; Chikamune, 1986). Thus, the conclusion can not be established depending on the experimental condition and probably the genetic variation of the individual animal.

Effect of heat exposure on respiration

The moisture is evaporated from the body by respiration and the increase in frequency known as panting will increase excess heat loss by respiratory evaporation. At a higher ambient temperature about 35^{o} C there is an increase in respiratory evaporative moisture for an apprioximately threefold which is about 60% of total heat loss in sheep (Brockway, Mc Donald & Pullar, 1965) and 32% in steer. (Mc Lean & Calver, 1972)

Buffalo has a lower respiratory rate than cattle (Alim & Alimed, 1956; Fahimuddin, 1975; Chikamune, 1986 ; Shafie, 1985). The respiratory rate markedly increases in Holstein cow greater than in buffalo in contrary to the higher tidal volume of buffalo when exposed to heat in climatic chamber (Chikamune, 1986). The lower respiration volume was associated whith a high ratio of oxygen uptake in buffalo suggesting the more efficient mechanism of energy saving for respiratory exercise in this species than in cattle (Chikamune, 1987). However, the controversy of the faster and greater increase in respiration rate in buffalo than native cattle and Dairy shorthorn during direct exposed to solar radiation has been demonstrated (Shafie, 1985).

Effect of heat exposure on body temperature

The ambient temperature has an effect on thermoregulation and body temperature. Zone of thermal neutrality is the range of temperature that the animal can persist with comfortable. Zone of thermal neutrality in buffalo was considered to be 13 to 24° C (Goswanui & Narian, 1962) while the value which was reported by Shafie (1985) was 15-20° C. When the temperature decreases until reach lower critical temperature, the metabolic rate and oxygen consumption will increase to maintain body temperature by increase in heat production. If the ambient temperature falls further, heat loss will be greater than heat production. The animal is in the state of hypothermia and finally, fatal. When animal exposed to heat until reach upper critical temperature, it will increase evaporative heat loss by both sweating and respiration to increase heat loss from the body until maximal rate of evaporative heat loss is reached. If the ambient temperature further increase, the body temperature will rise according to the increase in heat production plus heat gain from the environment which are greater than heat loss from the body. The core temperature will increase and animal is in the state of hyperthermia. The previous report showed that in buffalo the upper critical ambient temperature is 36.1° C (Misra, Sen Gupta & Roy, 1963) whereas Chikamune (1986) reported the range between 35° C and 38° C. Several studies proved that buffalo has the lower norm of body temperature than cattle (Fahimuddin, 1975; Chikamune, 1986 ; Shafie, 1985). The rises in rectal temperature has a greater magnitude in Holstein cattle than in the buffalo (Chikamune, 1986) exposed to heat in climatic chamber in contrary to the report in buffalo exposed to direct solar radiation (Shafie, 1985).

Effect of heat exposure on plasma volume, water content and water turnover rate.

Many previous reports showed that blood and plasma volume increased both in cattle and buffalo exposed to hot environment. Kamal and Shebaita (1972) reported an increase in plasma volume with a concomittant increase in plasma solids by 13.5% and 15.6% in buffalo and Friesian respectively. The results was the same as that reported in buffalo exposed to heat at 42^{o} C in climatic chamber for 5 hrs. in which there was an increase in plasma solid by 12.8%, plasma volume 7.1% and blood volume 6.5% with a decrease of packed cell volume and a higher rate of liquid flow from the rumen. The increase in plasma volume might probably due to an increase in water reaborption at the intestine which could be observed by the decrease of rumen retention time. Moreover, plasma protein and glucose concentration of buffalo exposed to heat increased significantly which produced an osmotic force facilitating the water flow into intravascular compartment (Chaiyabutr et al., 1987). These possible role was also supported previously in sheep (Macfarlane & Howard, 1970).

In the dry and hot tropic condition, cattle and sheep contained more water than in temperate zone. Moreover, the extracellular fluid increased when exposed to heat in camel, goat, boran cattle and fat tailed Ogaden sheep in summer greater than in winter (Hafez, 1968). The increase in water content is a part of mechanism for evaporative cooling perhaps it is due to an increase in water intake during exposed to hot conditions (Mullick, 1962; Misra et al., 1963). Water turnover is justified to be one factor responsible for acclimatization. It determines rate of water loss and replacement from the animal. Hafez (1968) showed that buffalo had the higher rate of water turnover than cattle. Bos indicus requires less water than Bos taurus and pure European breed in the same environment (Siebert & Macfarlane, 1969). Goat uses less water than sheep while camel has the lowest of water turnover rate (Macfarlane & Howard, 1970). In these studies it was shown that the animal which has lower water turnover rate survied better in the hot and arid environment.

Water turnover rate as well as the total body water of buffalo increased in summer (Kamal & Seif. 1969). The total body water of buffalo increased significantly from 1787 ml/kg dry body weight at 18^{o} C. 52% RH to 2328 ml/kg at high ambient temperature (32^{o} C, 36% RH). The similar results were also reported by Chaiyabutr et al. (1987) with an increase in water turnover rate from 43.8 to 82.53 litre/day when buffalo exposed to heat (41^{o} C, 44% RH) compared with natural environmental temperature (30^{o} C, 46% RH). However, water turnover rate is affected by many factors such as temperature. season, food intake and many physiological states. Thus, the values obtained cannot be compared between each of these experiment.

Effect of heat exposure on body metabolism

Very little information was obtained concerning the effect of high environmental temperature on body metabolism. Macfarlane (1964) suggested that when the body temperature elevated from absorption of the heat of ambient air and solar energy, the metabolic rate would increase proportionally. However, in dry season energy production is considered to be depressed because of the decrease of thyroxin output (Johnson, Ragsdale & Cheng, 1957; Premachandra, Pipes & Turner, 1960). The ^{131}I uptake per 24 hr at 22^{o} C air temperature was 10.13% in buffalo but its value was 8.91% at 35^{o} C. The reduction is quite lower than Friesians (Kamal, Kotby and El-Fouly, 1972). The serum content of T_4 in summer was also lower than that in winter : 11.16 $\pm$ 2.04 VS 11.36 $\pm$ 1.55 ng/ml (Dixit, Agrawal, Agrawal & Dwaraknath, 1982). The reduction of thyroid function was related to the decrease of feed intake or the direct effect of the temperature on thyroid gland. Many researchs showed that high environmental temperature had a direct influence on decreasing thyroid activity in cattle (Yousef, Kibler & Johnson, 1967b) and sheep (Thompson, 1973). Furthermore, Yousef and Johnson (1965) showed that the changes of thyroid activity would occur 60 hrs. after heat exposure and its required 108 hrs. for readjustment. Thus, it does not play a major role in acute heat experimental study. During summer and experimental heat,the excretion of 17-hydroxysteroid and 17-ketosteroid were reduced suggesting the low production of cortisol resulted in low protein and carbohydrate metabolism (Robinson & Morris, 1960). Short term exposure to heat increased plasma cortisol which was the response to stress reaction while long term exposure to heat decreased plasma cortisol and turnover rate (Christison & Johnson, 1972). Yousef and Johnson (1967a) suggested that this was the part of acclimatization to reduce metabolic and heat production. Short term exposure to heat or cold increased plasma levels of catecholamine in the ungulate (Thompson, Christopherson, Hamond & Hills, 1978; Barrand, Dauncey & Ingram, 1981; Young, 1981). The data of Davis (1978) indicated that the plasma level of biogenic amines were used as indicators of thermal stress in cattle. All of the hormones mentioned above are responsible for the changes of metabolism and other blood constituents.

The changes of glucose metabolism were reported in animal during various physiological state for example starvation, pregnancy, lactation and after the administration of some substances such as exogenous glucose, insulin and epinephrine etc. (Spirtos, Stuelke & Halmi, 1957; Altszuler, Steele, Rathgeb & Debodo, 1967; Rizza, Haymond, Cryer & Gerich, 1979; Gray, Lickley & Vranic, 1980; Chaiyabutr, Faulkner

& Peaker, 1982b, 1983c). Sano et al. (1979) reported the changes of glucose metabolism in sheep exposed to an ambient temperature of 30^{o} C (RH 70%) for ten days in climatic chamber. During heat exposure both the pool size and turnover rate of glucose tended to decrease compare with those of 20^{o} C. Although the sheep was refuse to feed,the starvation of this sheep did not decrease glucose turnover rate the same as that by heat. He suggested that the decrease in glucose metabolism was a part of the process of metabolic adaptation by inhibition both glycogenolysis and gluconeogenesis due to the depression of thyroid function. In this experiment,plasma glucose concentration did not change similar to that report in calves exposed to mild heat (Bianca & Findlay, 1962). However, the steep rise in plasma glucose concentration has been demonstrated in buffaloes (Chaiyabutr et al., 1987) and in calves (Bianca & Findlay, 1962) exposed to severe heat for a short period. There is no available data about the changes of glucose metabolism of buffalo under heat stress condition.

It is known that in ruminant urea and non protein nitrogen will be conserved by the process of urea recycling which passes to the rumen and break down to form ammonia. From ammonia it is converted to amino acid for animal utilization especially when body requirement is increase for example starvation, growth, lactation or low protein intake. It has been found that camels on a low protein diet passed less than 0.3 gm urea per 24 hrs in urine but it rose 10 to 12 gm. when feeding with adequate protein (Schmidt-Nielsen, Schmidt-Nielsen, Houpt & Jarnum, 1957). The similar results were obtained in sheep (Schmidt-Nielsen, Osaki, Murdaugh & O'Dell, 1958) and buffalo calves (Nath, Mlhra & Chetal, 1979) on low protein intake without any changes in filtered load of urea. In hot environment, Chaiyabutr et al. (1983a) found that there was a tendency of increase in urea reabsorption in buffalo during exposed to solar radiation. Plasma urea concentration slightly increased while there was not any alteration in glomerular filtration rate. Moreover, the results shown that there were increases in plasma protein and plasma glucose concentration by approximately 6.5% and 73% respectively suggesting the alteration of nutrient supply for metabolism. The experiment of addition of urea together with starch in sheep has shown that there was an increase in protein synthesis (Pierce, 1951). All these evidences indicated the interrelationship between protein and carbohydrate metabolism. Unfortunately, little information was obtained about the changes of lipid metabolism in heat stress condition.

Effect of heat exposure on renal function

Kidney is one of the most important organ responsible for heat adaptation. In ruminant, it take a role of nitrogen recycling, gluconeogenesis and regulation of salt and water excretion. The study of renal function showed that there was the reduction in GFR and E-RPF for a half in five day in Merino ewes deprived of water (Macfarlane, Morris, Howard, McDonald & Budtz-Olsen, 1961). The potassium secretion rate increased whereas urine specific gravity rose also for 3 days. The lower GFR might be due to haemoconcentration which was the same as that reported in sheep during summer (Nawaz & Shah, 1984). In hot environment, there was the higher Na/K ratio of the urine. This renal behavior was supported by Chaiyabutr et al.(1983b) studied in buffalo exposed to solar radiation although there were not any changes in GFR, renal blood flow and Na^+ excretion while K^+ excretion decreased. These phenomena might be some parts of endocrine action. The correlation between plasma aldosterone concentration and urinary sodium excretion has been demonstrated in buffaloes exposed to heat (Youngsukying, 1986). The endocrine and hemodynamic aspects of these ruminant electrolyte control require further analysis both in the short and long term of heat exposure.

The water excretion was the most important factor for heat adaptation. McDonald & Macfarlane (1958) showed that the low GFR and RBF were responsible for water conservation in sheep. Hafez (1968) reported the reduction of urine flow rate in camel and sheep in arid areas. The kidney of camel was expected to be responsed to vasopressin while it had a lower effect in cattle (Macfarlane et al., 1967). In ruminant exposed to hot environments, there was an increase in plasma vasopressin which had the effect by increased in potassium secretion, thus increase in water excretion resulting in diuresis (Hafez. 1968). The information showed the changes of renal function and its role of acclimatization. However, very little information conducted in buffalo which cannot tolerate well in hot environment because of the less efficient of evaporative cooling. So, kidney may play an important role for heat adaptation.