CHAPTER V

DISCUSSION

The mean values of heart rate. respiratory rate and rectal body temperature of buffaloes in normal ambient temperature are similar to the values of previous studies (Chaiyabutr et al., 1983a; Chikamune, 1986). During acute heat exposure , the pattern of changes in cardiorespiratory frequency as well as the rectal body temperature are similar to those reported in animals after being exposed to solar radiation (Chaiyabutr et al., 1983a). However, in the present study, the animals were exposed to heat in climatic chamber. The sensitivity to thermal stimulation did not pronounce enough in comparison to animals exposed to sunlight. An increase in heat load in animals exposed to the sun can be attributed to extraheat from radiation and reflection from the ground to the body as well as the conformation of buffalo which can absorb large amount of solar radiation.

Since the buffaloes have a large compact body conformation, black melanin-pigmented skin, thickness of skin and low density of sweat gland (Hafez et al., 1955a, b) when compare with cattle, these would cause to poor heat dissipating mechanism for evaporative heat loss. Therefore, the animal would show sign of panting and high respiratory frequency. The result was similar to the previous report in buffalo and was higher than native and temperate cattles (Shafie, 1985).

A tendency of an increase in rectal body temperature of buffaloes in control group was consistent to the concomittant increase in diurnal ambient temperature. However, the rectal temperature of buffaloes exposed to heat showed a marked increase at the first hour of the experimental period. Therefore, rises in body temperature was positively correlated with the dry bulb ambient temperature ($P < 0.01$). This indicates that buffaloes have a rapid response of body temperature to environmental heat which was greater than that reported in cattle (Shafie, 1985).

The study on glucose metabolism indicates that the value of glucose pool size in buffaloes was greater whereas the U-^{14}C glucose turnover rate was less than that reported in cattle (Kronfeld & Raggi, 1964). Glucose pool size per body surface area was also greater than sheep (Sano et al, 1979). However, the glucose turnover rate was in the range that reported in sheep (Sano et al.. 1979) and goat (Chaiyabutr et al., 1983c). It has been shown that the glucose pool size as well as glucose turnover rate of both reversible and irreversible tracers increased in buffaloes exposed to heat for 3 h. These suggested an increase in bodily metabolism which was supported by a reduction of plasma inorganic phosphate concentration. The decrease of P_{Pi} may reflect an increase in metabolic rate and ATP production (Exton, 1972) which has been demonstrated previously in heat exposed steer (Terui, Ishino, Matsuda, Shoje, Ambo & Tsuda, 1979). The increase in endogenous glucose pool size would be due to the high rate of glycogenolysis from the liver, muscle and/or gluconeogenesis from other nutrient substrates. An increase in plasma glucose concentration has also been observed in severe heat stressed calves (Bianca & Findlay, 1962) but not in cattle (Weldy. McDowell.Van Soest.& Bond. 1964) and steer (Terui et al.1979)exposed to chronic high environmental temperature.Moreover,the controversial results about glucose metabolism was reported Sano and his co-worker (1979) which had a tendency of decrease in the glucose turnover rate of sheep exposed to heat at 30^{o} C for 4 and 10 days. It has been suggested that chronic heat exposure inhibit metabolic process by depression of Thyroid function. This can be defined in heat acclimated hamster by reduction of glucose 6-phosphatase activity (Chayoth & Cassuto, 1971, 1972) and decrease rate of gluconeogenesis (Chayoth, 1976) which can be reversed by T_3 supplementation (Cassuto, Chayoth & Zor, 1974). However, the change in thyroid activity might not be expected in acute heat stressed buffalo since the time course of change in thyroid activity during exposed to heat takes at least 60 h. in large ruminant (Yousef & Johnson, 1965). It has also been reported for no alteration of T_3 concentration in buffalo exposed to solar radiation for 10 days (Loypetjra, Chaiyabutr, Chanpongsang, Pichaicharnarong, Katti & Johnson, 1987). Thus, an increase in both 3-^{3}H glucose and U-^{14}C glucose turnover rate may actually due to the direct effect of heat on metabolic rate or an activation of sympathetic adrenergic activity since an increase of the level of plasma and urinary catecholamine concentration during animal exposed to heat has been reported in either pigs (Barrand et al., 1981) or cattle (Yousef, 1979). Catcholamines produces an increase in metabolic rate refer to calorigenic effect by increasing the oxygen uptake of muscle (Eaton, 1964), heart (Fisher & Williamson, 1961), white adipose tissue (Hagen & Ball, 1961) and brown adipose tissue (Joel, 1966). Administration of catecholamines has been shown to increase in glucose production rate markedly in dog (Altszuler et al., 1967; Gray et al., 1980) and man (Rizza et al., 1979) during the first hour period. The direct actions of adrenaline and noradrenaline have been demonstrated in vitro by increasing the concentration of 3'5' C-AMP in many tissues (Bueding, Butcher, Hawkins, Timm & Sutherland, 1966; Butcher, 1966; Sutherland & Robinson, 1966) which causes an increase in activity of glycogen phosphorylase and a decrease in glycogen synthetase (Haugaard & Hess, 1965). These effects will induce glycogenolysis in either skeletal muscle or liver (Svedmyr, 1965; Exton & Park, 1966). Furthermore, adrenaline has also been found to accelerate gluconeogenesis from lactate (Campbell & Rastogi, 1966). In the present study, there was a positive correlation between plasma glucose concentration and U-^{14}C glucose turnover rate which may indicate that the hyperglycemic response to acute heat stress may attribute to the effect on either glycogenolysis or gluconeogenesis.

since the present result showed a significant reduction of glucose carbon recycling which would suggest that a constant level of tricarbon units originally derived from glucose is not reincorporated into glucose during acute heat exposure. It might attribute that the process of gluconeogenesis using intermediate originally derived from glucose was alleviated. The mechanism by which the decrease in gluconeogenesis might be due to the reduction of portal blood flow during hyperventilation (Berry & Schever, 1967), the state of liver anoxia (Exton, 1972) or the reduction of renal gluconeogenesis which has been demonstrated in chronic heat exposed hamster (Inbar, Chayoth & Cassuto, 1975) and during the state of alkalosis (Goodman, Fuisz & Cahill, 1966). However, no available data was obtained in ruminant during heat exposure.

In the present study, the total plasma protein, globulin and albumin concentration in control period were in the range that reported previously (El-Sherif & Fahmy, 1981) but lower than the values obtained from the swamp buffalo in Australia (Canfield, Best, Fairburn, Purdie & Gilham, 1984). After buffaloes exposed to heat for one hour and thereafter, there was an increase in total plasma protein concentration ($P < 0.05$). An increase in total protein concentration was corresponded with an increase in plasma albumin but not globulin resulting in a tendency of rises in A/G ratio. Thus, change in albumin concentration had a large role in determining total protein behavior (Senay & Christensen, 1968). An elevation of plasma protein concentration was demonstrated recently in buffaloes not only exposed to solar radiation (Chaiyabutr et al., 1983a) but also in the control climatic chamber (Chaiyabutr et al, 1987). Chaiyabutr and his coworkers also described that an increase in plasma protein concentration has been shown to coincide with an increase in plasma volume. This change could lead to an increase in colloidal osmotic pressure and augmented water passage from the extravascular tissue space to intravascular compartment. In heat stressed man, Senay (1970) demonstrated that protein concentration increased considerably more than did the hematocrit ratio indicating that protein is being delivered into the vascular volume. Heat has a direct effect on dilatation of cutaneous capillaries which would be accompanied by an increase in the capillary filtration coefficient ascribed to an opening up of precapillary sphincter (Kjellmer, 1965) causing the fluid passing into the interstitial spaces followed by an increase in the rate of delivery of protein by way of lymph flow (Mc Carrell, 1940). However, the controversial result of a parallel increase in packed cell volume and plasma protein concentration has been reported in man (Harrison, 1974). In the present study, no detectable changes of both plasma volume and packed cell volume were observed which might conceivable due to the time course of heat exposure until plasma volume measurement was shorter compared with the previous report by Chaiyabutr et al. (1987). The mechanism of increase in plasma protein concentration would be due to the activation of endogenous nitrogen catabolism (Blincoe and Brody, 1951) or due to the muscle protein breakdown. However, in the present study, neither the changes of plasma urea concentration nor the urinary total nitrogen excretion was observed. Urea and non urea nitrogen excretion did not change during heat exposure. Thus, the high protein catabolism could not attribute to an increase in plasma protein concentration. The negative correlation ($P < 0.05$) between the total plasma protein concentration and total urinary nitrogen excretion has been observed in buffalo during control period which suggested that kidney may play a role in regulation the homeostasis of protein in ruminant. This relationship was not observed during animal exposed to heat which was due to high rate of muscle protein breakdown since plasma creatinine concentration increased indicating skeletal muscle cell degeneration (Terui et al, 1979). The pattern of relationship was similar to the correlation between plasma creatinine concentration and urinary non urea nitrogen excretion. Moreover, triacylglycerol which contain glyceral, a gluconeogenic substrate,decreased markedly during animal exposed to heat. Whether the reduction of plasma triacylglycerol was used as intermediate product for energy utilization or for glucose synthesis which should be further investigated.

Renal function study reviewed that there was no alteration of renal blood flow with a slight increase in GFR during animal exposed to heat. The change of GFR did not expect to be due to change of systemic hemodynamic because there was not any correlation between GFR and HR during animal exposed to heat. The urine flow rate exhibited a tendency to increase at the first hour of heat exposure and declined thereafter which was not similar to the previous study in buffalo exposed to solar radiation in which an increase in renal plasma flow without the variation in urine flow rate was apparent (Chaiyabutr et al., 1983b). Guerrini, Koster & Bertchinger (1980) reported that an increase in urine output was apparent in sheep during chronic exposed to both hot dry and hot humid environment. The fructuation of urine flow rate in the present study was neither due to an increase in water intake which was ascribed in sheep (Sano et al.,1979) nor the change of renal vascular resistance since ERPF did not alter. The variation may depend on renal tubular activity and relied on electrolyte excretion since the positive correlation between urine flow rate and FE_K was observed during both control and heat exposure period ($P < 0.01$).

Plasma urea concentration was in the range reported by Chaiyabutr et al. (1983a) which was relatively high indicating higher rate of muscle protein catabolism in buffalo (Norton, Moran & Nolan, 1979). No specific change of plasma urea concentration was observed which was similar to the previous report in buffalo (Chaiyabutr et al., 1983a). However, the seasonal increase in plasma urea nitrogen have been reported in hill sheep in U.K. (Sykes, 1979) and Pakistan (Nawaz & Shah, 1984) during summer which may depend on the nutritional status as well as the state of dehydration of animal. There was a positive correlation between urine flow rate and renal urea clearance during control period ($P < 0.01$) which indicated that the filtered urea reabsorbed increased as the urine flow decreased. The similar results were observed in sheep (Schmidt-Nielson et al.,1958; Cocimano & Leng, 1967) but not in calves (Nath et al.,1979) and either sheep or deer fed the low nitrogen diet (Maloiy and Scott, 1969). The calculated urea reabsorption exhibited a slight increase and correlated with water reabsorption. Therefore, it was suggested that kidney may play some roles to conserve both urea and water for heat adaptation.

In the present results, the normal values of the fractional excretion of Na^+ was lower while FE_K was higher than that reported in cattle by Neiger & Hagemoser (1985). The variation would probably depend on the level of electrolyte in the diet (Caple, Doake

& Ellis, 1982). There was the same pattern of changes in urinary excretion of K^+, Cl^-, Ca^{2+} and P_i which was consistent to the change in urine flow rate. These would be suggested that the change of urine flow rate depended on the effect of heat on renal tubular activity of these ions. The decrease of FE_{Ca} in heat exposure period might be falsely lowered since calcium can bind to albumin and not filtered by the glomerulus (Neiger & Hagemoser, 1985). However, the urinary Ca^{2+} excretion is little important compared with the faecal Ca^{2+} excretion (Kaneko, 1980). Futhermore,in the present experiment,plasma Ca^{2+} concentration had a tendency to decrease. These result were similar to the previous report in steer (Terui et al, 1979), man (Peter & Van Slyke, 1946) and calves (Bianca & Findlay, 1962) exposed to severe heat. The false measurement of FE_{Pi} in ruminant animal can be observed since phosphate will form crystal in alkaline urine and settle at the floor of urinary bladder (Neiger & Hagemoser, 1985). However, in this study, the urine samples were collected from completely voided samples so that this explanation could be ruled out.

Since there was no correlation between plasma glucose concentration and fractional electrolyte excretions, therefore the systemic changes of substrates for energy supply did not actually affect the renal tubular activity. The possible roles of the alterations of this renal behavior particularly the fractional excretion of potassium might be partly due to many reasons. Firstly, because of an increase in respiratory rate during animal exposed to heat which induces respiratory alkalosis (Hales & Webster, 1967). Thus, kidney will be responsible to compensate by conservation of hydrogen ion with a reciprocal secretion of potassium ion (Johnson & Selkurt, 1966). Secondly, it may be due to an increase in aldosterone secretion during heat exposure resulting in an increase in the excretion of potassium but decrease in sodium excretion. A tendency of increase in aldosterone concentration has been reported previously in heat exposed buffaloes (Youngsukying, 1986). Thirdly, an increase in metabolic rate may enhance Na/K ATPase activity which possibly attributed to changes of electrolyte excretion.

In conclusion, the experiment has been shown that heat exposure affected both glucose metabolism and renal functional behavior. Changes in renal behavior during heat exposure showed no relation to changes in systemic glucose metabolism. Heat load may affect kidney functions either directly on renal metabolism eg. Na/K ATPase activity or indirectly by mediated from changes in acid base balance and hormonal level.