General Article

INFLUENCE OF HEAT STRESS ON BIOCHEMICAL INDEXES IN VARIOUS FARM ANIMALS

Rajendra Bashyal
Agriculture and Forestry University
Rampur, Nepal

Introduction

Stress is the body's reaction to stimuli that disturb homeostasis. Changes in biological functions of the animals due to exposure to heat stress include physiological, hormonal, hematological, and biochemical responses, which make the goats resistant and able to survive in adverse environments (Bernabucci et al. 2010). Among the environmental factors, heat stress is of major concern which lowers livestock productivity in tropical and arid areas and challenges the animal's ability to maintain energy, hormonal and mineral balances. Electrolyte and mineral imbalance during thermal stress result in low performance and reduced fertility in animals.

Determination of heat stress in animals can be determined by physiological and biochemical methods. Physiological methods can be determined by various measuring instruments generally while biochemical methods can be determined by detecting the level of hormone in the blood.

In Stressed animals, cortisol release, increased body heat and pulse rate as well as the influence of many hormones (Roussel et al., 2006).Hormones involved in thermal adaptations include, prolactin, growth hormone, thyroxine, glucocorticoids, mineralocorticoids, catecholamines and antidiuretic hormone. Thermal stressor as a form of environmental heat stress negatively influenced livestock physiological activities especially when an animal is having difficulty in dissipating excess heat load to its environment which subsequently frustrate overall performance e.g. growth, feed intake, lactation, conception, gestation etc.(Sireli. D, Tutkun. M, Tatar. M, 2017)

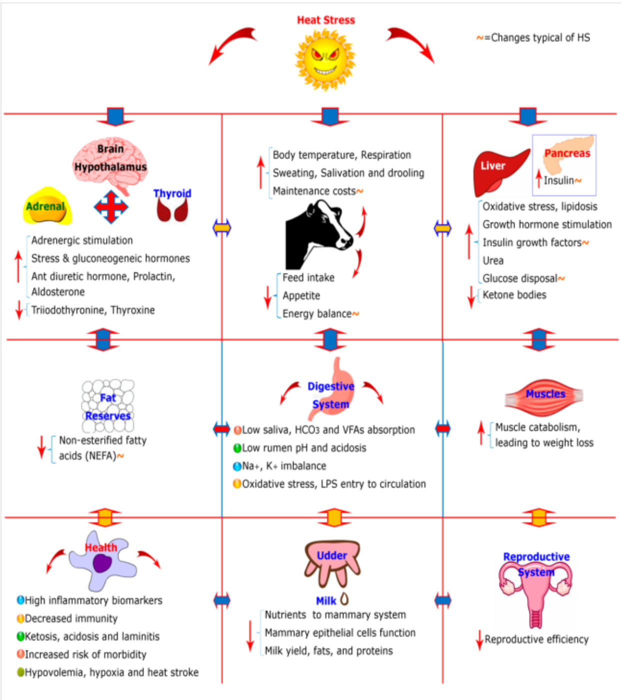

Figure 1. Summary of various heat stress-related physiological and biochemical changes occurring at various systems level in the body of the dairy cows.

Biochemical responses of animals to heat stress

The acid-base balance is a complex physiological process to maintain a stable pH in an animal's body. The body utilizes different mechanisms to combat any change in acid-base balance, i.e. chemical buffering, respiratory adjustment of blood carbonic acid (H2CO3) and excretion of hydrogen ions or bicarbonate (HCO3-) by the kidneys(Houpt, 1989). Metabolic acidosis and alkalosis involving HCO3- as well as respiratory acidosis and alkalosis related to partial pressure of CO2 may occur under heat stress. The vital limits of pH variation for mammals are between 7.35 and 7.45(Houpt, 1989 ; Constable, 1999) and regulated by a complex system of buffers (H2CO3 and HCO3-). Blood pH increased under heat stress in goats (Sivakumar et al., 2010). The increase in pH may be due to reduced H2CO3 (70), total CO2, HCO3- (Hamzaoui et al. , 2013) and base excess in blood and extra-cellular fluid (Sivakumar et al., 2010). The secretion of HCO3- in urine and its reabsorption suggest a large requirement

and turnover of body HCO3- to maintain blood pH during heat stress (Hamzaoui et al. , 2013). Blood biochemical parameters reflect the health (detecting possible diseases) and the metabolic status of an animal (evaluating the body's internal condition, the function of organs (e.g. kidneys and liver), and metabolic processes in the body), which are widely used in clinical situations. heat stress affects biochemical parameters, i.e. alkaline phosphatase, alanine aminotransferase, aspartate transaminase, lactate dehydrogenase, total protein, albumin, globulin, glucose, cholesterol, blood urea nitrogen, non-ester fatty acids, beta-hydroxybutyrate, creatinine, triiodothyroxine, thyroxine, cortisol, prolactin, sodium, potassium, chloride, calcium, magnesium, iron, manganese, copper, zinc and oxidative stress parameters (glutathione peroxidase, glutathione reductase, superoxide dismutase and lipid peroxides).. Heat stress lowered concentration of plasma calcium, magnesium, and sodium and increased the concentration of plasma chloride and phosphorus in cattle (Ronchi et al. 1997).Sanchez et al. (1994) reported that sufficient electrolytes availability in the blood helped to maintain homeostasis in animals during heat stress.

Enzymes:

Metabolic regulators are important in elucidating a picture of modulation in physiological mechanisms during stressed conditions and are best assessed by determining the enzymes governing various metabolic reactions in plasma/serum (Gupta et al., 2013). Enzyme levels reflect the metabolic activities during stress. Heat stress reduces alkaline phosphatase and lactate dehydrogenase activity in goats (Helal et al., 2010).The decrease in these enzymes during heat stress is due to the decrease in thyroid activity during heat stress (Helal et al., 2010). Serum level of aspartate transaminase and alanine aminotransferase is helpful in the diagnosis of the welfare of animals. The serum alanine aminotransferase

value increases during heat stress in goats (Sharma & Nalini, 2011).Serum glutamate oxalo-acetate transaminase (SGOT) and serum glutamate pyruvate transaminase (SGPT), indicators of tissue damage, increased significantly during heat stress in cattle (Sang et al. 2002).

Proteins:

Significant decrease in total protein concentration in goats has been reported during heat stress (Dangi et al., 2012). Total plasma protein, albumin and globulin levels decrease in goats subjected to heat stress (Helal et al., 2010). This may be due to an increase in plasma volume as a result of heat stress, which results in a decrease in plasma protein concentration. In contrast, heat stress increased total protein and albumin in goats (Okoruwa, 2014) and could be due to dehydration which has been reported to occur as a result of increased respiration rate.

A significant increase in the serum protein of sheep exposed to heat stress. The increase in serum protein could be a physiological attempt to maintain extended plasma volume. High environmental temperature caused an increase in total plasma protein in lactating cattle (Podar and Oroian, 2003). In cattle, heat exposure and de-hydration during heat stress resulted in a sharp increase in ADH level, which was associated with a significant de-crease in urine output and a significant increase in plasma protein (El-Nouty*et al.* 1980). Shafie and Badreldin (1962) reported that plasma total protein content decreased by 11.9% in buffaloes and increased by 4.4% in Baladi cattle when exposed to direct solar radiations.

Plasma Albumin

A significant increase in plasma albumin levels was re-ported in cows (El-Masery and Marai, 1991) and buffalo calves (Koubkova*et al.* 2002) during heat stress.

Glucose, cholesterol, blood urea nitrogen, non-ester fatty acids and beta-hydroxybutyrate:

Studies on glucose, cholesterol, blood urea nitrogen, non-ester fatty acids and beta-hydroxybutyrate in response to heat stress are conflicting. Glucose and cholesterol levels show greater differences under heat stress conditions than in the comfort zone. Heat stress conditions decrease glucose and cholesterol levels in goats .The decrease in glucose level could be related to the decrease in availability of nutrients and lower rate of propionate production (Mohamad, 2012), or due to the increase in plasma glucose utilization to provide energy for muscular expenditure required for high muscular activity associated with increased respiration rate (Seijan&Shrivastava, 2010). The decrease in cholesterol level may have a relation with the increase in total body water or the decrease in acetate concentration, which is the primary precursor for the synthesis of cholesterol(Gupta et al., 2013). Heat stress had no effect on glucose and blood urea nitrogen in goats (Hamzaoui et al., 2013). Non-ester fatty acids and betahydroxybutyrate are most indicative of the animal's energy status (Hamzaoui et al., 2013)reported that a reduction in feed intake and body weight under heat stress was not accompanied by body fat mobilization as non-ester fatty acid concentration did not vary between heat-stressed and control goats. Exposure to heat stress resulted in higher beta-hydroxybutyrate concentration in goats (Salama et al., 2014).Thermal stress decreases the energy metabolism (basal metabolic rate) and increases water and electrolyte metabolism.

Hormones:

Hormones (i.e. thyroxine, triiodothyroxine, prolactin, leptin, adiponectin, growth hormone,glucocorticoids,mineralocorticoids,catecholaminesandantidiuretic) are involved in thermal adaptation and could be important indicators for assessment of stress in animals .

Decreased thyroid hormone level during heat stress is an adaptive response and affects the hypothalamic- pituitary-adrenal to decrease thyrotropin releasing hormone (Johnson, 1985), which enables animals to reduce metabolic rate and heat production (West, 1999), and reduces the amount of heat produced by the cells (Barnes et al., 2014) (Barnes et al., 2014) . In goats, (Helal et al., 2010) and(Sivakumar et al., 2010) reported a decrease in plasma concentration of triiodothyroxine and thyroxine levels. Cortisol plays an important role in all types of stress. An increased cortisol level during heat stress was reported in goats (Sivakumar et al., 2010). The prolactin level increased in goats under heat stress (Sivakumar et al., 2010).

Electrolytes:

Heat stress challenges the animal's ability to maintain its mineral balance. The serum concentrations of sodium, potassium and chloride decreased in goats subjected to heat stress due to the fact that heat-stressed animals lost more potassium and chloride in sweat than non- heat stressed animals, and the blood volume expanded where water is transported in the circulatory system for evaporative cooling (Sivakumar et al., 2010).

Oxidative stress parameters:

Heat stress stimulates excessive production of free radicals such as reactive oxygen species (superoxide anion radicals, hydroxyl radical, hydrogen peroxide and singlet oxygen) which are continuously produced in the course of normal aerobic metabolism, and they can damage healthy cells if not eliminated (Rhoads et al., 2013). Normal cells have the capacity to detoxify superoxide radicals using antioxidant enzymes (superoxide dismutase, glutathione peroxidase, glutathione reductase and catalase) and non-enzymatic antioxidants including vitamins (C, A and E), and proteins (albumin, transferrin, glutathione) (Kumar et al., 2011; B.V et al., 2011) reported that oxidative stress increases in goats during summer as superoxide dismutase increases.

References

Barnes, A., Beatty, D., Taylor, E., Stockman, C., Maloney, S., & McCarthy, M. (2004). Physiology of heat stress in cattle and sheep. *Meat and Livestock Australia*, *209*, 1-36.

BV, S. K., Ajeet, K., & Meena, K. (2011). Effect of heat stress in tropical livestock and different strategies for its amelioration. *Journal of stress physiology & biochemistry*, *7*(1).

Constable, P. D. (1999). Clinical assessment of acid-base status: strong ion difference theory. *Veterinary Clinics of North America: Food Animal Practice*, *15*(3), 447-471.

Dangi, S. S., Gupta, M., Maurya, D., Yadav, V. P., Panda, R. P., Singh, G., ... & Mahapatra, R. (2012). Expression profile of HSP genes during different seasons in goats (Capra hircus). *Tropical Animal Health and Production*, *44*(8), 1905-1912.

Gupta, M., Kumar, S., Dangi, S. S., & Jangir, B. L. (2013). Physiological, biochemical and molecular responses to thermal stress in goats. *Int J Livest Res*, *3*(2), 27-38.

Hamzaoui, S. A. A. K., Salama, A. A. K., Albanell, E., Such, X., &Caja, G. (2013). Physiological responses and lactational performances of late-lactation dairy goats under heat stress conditions. *Journal of dairy science*, *96*(10), 6355-6365.

Helal, A., Hashem, A. L. S., Abdel-Fattah, M. S., & El-Shaer, H. M. (2010). Effect of heat stress on coat characteristics and physiological responses of Balady and Damascus goats in Sinai, Egypt. *American-Eurasian Journal of Agricultural and Environmental Science*, *7*(1), 60-69.

Houpt, T. R. (1989). Water, electrolytes, and acid-base balance. *SWENSON, MJ Duke's physiology of domestic animals*, *10*, 486-506.

Johnson, H. D. (1985). Physiological responses and productivity of cattle.

Kumar, M., Jindal, R., & Nayyar, S. (2011). Influence of heat stress on antioxidant status in Beetal goats. *Indian Journal of Small Ruminants (The)*, *17*(2), 178-181.

Minton, J. E. (1994). Function of the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system in models of acute stress in domestic farm animals. *Journal of animal science*, *72*(7), 1891-1898.

Mohamad, S. S. (2012). Effect of level of feeding and season on rectal temperature and blood metabolites in desert rams. *Acad. J. Nut*, *1*, 14-18.

Ocak, S., Darcan, N., Cankaya, S., &Inal, T. C. (2009). Physiological and biochemical responses in German Fawn kids subjected to cooling treatments under Mediterranean climate conditions. *Turkish Journal of Veterinary and Animal Sciences*, *33*(6), 455-461.

Okoruwa, M. I. (2014). Effect of heat stress on thermoregulatory, live bodyweight and physiological responses of dwarf goats in southern Nigeria. *European Scientific Journal*, *10*(27).

Rhoads, R. P., Baumgard, L. H., Suagee, J. K., & Sanders, S. R. (2013). Nutritional interventions to alleviate the negative consequences of heat stress. *Advances in nutrition*, *4*(3), 267-276.

Roussel, S., Hemsworth, P. H., Leruste, H., White, C., Ponter, C. D., Nowak, R., Boissy, A. 2006. Repeated transport and isolation during pregnancy in ewes: Effects on the reactivity to humans and to their offspring after lambing. Appl.Anim. Behav.Sci., vol. 97: 172-189.

Ronchi, B., Bernabucci, U., Lacetera, N. and Nardone, A., 1997. Effects of heat stress on metabolic nutritional status of Holstien cows, Zootecnica-e-Nutizione-Animale, 23, 3-15

Sang Y, Tian S, Li J, Ni J, Han J, Zhao C, Wu P, Ma YB, Zhang J, HuY, Wu Y. 2002. Influences of heat stress on semen quality ofHolstein bull and approach to its mechanism, Chinese journal of Veterinary Science, 22, 407-410

Sanchez, W.K., McGuire, M.A. and Beede, D.K., 1994. Macromineral nutrition by heat stress interactions in dairy cattle: Review and original research, Journal of Dairy Science, 77, 2051-2079

Sireli. D, Tutkun. M, Tatar. M, T. S. (2017). Heat stress in ruminants. *Animal Science Journal*, *LX*, 257–261.

Sivakumar, A. V. N., Singh, G., & Varshney, V. P. (2010). Antioxidants supplementation on acid base balance during heat stress in goats. *Asian-Australasian Journal of Animal Sciences*, *23*(11), 1462-1468.

Sharma, A. K., & Nalini, K. (2011). Effect of extreme hot climate on liver and serum enzymes in Marwari goats. *Indian Journal of Animal Sciences*, *81*(3), 293-295.

Sejian, V., & Srivastava, R. S. (2010). Effects of melatonin on adrenal cortical functions of Indian goats under thermal stress. *Veterinary medicine international*, *2010*.

Salama, A. A. K., Caja, G., Hamzaoui, S., Badaoui, B., Castro-Costa, A., Façanha, D. A. E., &Bozzi, R. (2014). Different levels of response to heat stress in dairy goats. *Small Ruminant Research*, *121*(1), 73-79.

West, J. W. (1999). Nutritional strategies for managing the heat-stressed dairy cow. *Journal of Animal Science*, *77*(suppl_2), 21-35.