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Heat Stress in Dairy Animals - Its Impact and Remedies

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Abstract: Sustainability in livestock production system is largely affected by climate change. An imbalance between metabolic heat production inside the animal body and its dissipation to the surroundings results to heat stress (HS) under high air temperature and humid climates. The foremost reaction of animals under thermal weather is increases in respiration rate, rectal temperature and heart rate. It directly affect feed intake thereby, reduces growth rate, milk yield, reproductive performance, and even death in extreme cases. Dairy breeds are typically more sensitive to heat stress than meat breeds, and higher producing animals are, furthermore, susceptible since they generate more metabolic heat. HS suppresses the immune and endocrine system thereby enhances susceptibility of an animal to various diseases. Hence, sustainable dairy farming remains a vast challenge in these changing climatic conditions globally.

Introduction

Stress is a reflex reaction of animals in harsh environments and causes unfavorable consequences ranges from discomfort to death. Climate change is one of the major threats for survival of various species, ecosystems and the sustainability of livestock production systems across the world, especially in tropical and temperate countries. Intergovernmental Panel on Climate Change reported that temperature of the earth has been increased by 0.2°C per decade and also predicted that the global average surface temperature would be increased to 1.4-5.8°C by 2100. It was also indicated that mainly developing countries tend to be more vulnerable to extreme climatic events as they largely depend on climate sensitive sectors like agriculture and forestry (IPCC, 2007). Recently, Silanikove and Koluman (2015) also forecasted the severity of heat stress issue as an increasing problem in near future because of global warming progression.The thermoneutral zone (TNZ) of dairy animals ranges from 16°C to 25°C, within which they maintained a physiological body temperature of 38.4-39.1°C. However, air temperatures above 20-25°C in temperate climate and 25-37°C in a tropical climate like in India, it enhance heat gain beyond that lost from the body and induces HS (Vale, 2007). As a results body surface temperature, respiration rate (RR), heart rate and rectal temperature (RT) increases which in turn affects feed intake, production and reproductive efficiency of animals. RT >39.0°C and RR >60/min indicated cows were undergoing HS sufficient to affect milk yield and fertility. However, the animal being homeotherms can resist to HS up to some extents depending on species, breed and productivity (Kadokawa *et al.*, 2012).

Among dairy animals, goats were the most adapted species to imposed HS in terms of production, reproduction and also to disease resistance. Studies stipulated that the native breeds survive and perform better as compared to exotic breeds and their crosses under tropical environmental conditions may be due to inability of the exotic genes to express/adapt under tropical conditions. Further, the sensitivity of dairy cattle to HS increases with increase in milk production, which might be due increase in metabolic heat output with increase production levels in dairy animals (Silanikove and Koluman, 2015; Kumar *et al.*, 2014).

Effects of Heat Stress on Health of Dairy Animals

Heat Stress effects health of dairy animals by imposing direct or indirect affects in normal physiology, metabolism, hormonal and immunity system.

Effect of Heat Stress on feed intake and rumen physiology

Increase in environmental temperature has a direct negative effect on appetite center of the hypothalamus to decreases feed intake. Feed intake begins to decline at air temperatures of 25-26°C in lactating cows and reduces more rapidly above 30°C in temperate climatic condition and at 40°C it may decline by as much as 40%, 22-35% in dairy goats or 8-10% in buffalo heifers (Hooda and Singh, 2010). Reducing feed intake is a way to decrease heat production in warm environments as the heat increment of feeding is an important source of heat production in ruminants (Soriani *et al.*,2013). As results, animals experience a stage of negative energy balance (NEB), consequently body weight and body condition score goes down. Increase environmental temperature alters the basic physiological mechanisms of rumen which negatively affects the ruminants with increased risk of metabolic disorders and health problems. Nonaka *et al.* (2008) reported animal under HS has reduced acetate production whereas propionate and butyrate production increased as rumen function altered. As a response animal consumed less roughages, changes rumen microbial population and pH from 5.82 to 6.03, decreasing rumen motility and rumination. Subsequently, affects health by lowering saliva production, variation in digestion patterns and decrease dry matter intake (DMI). Moreover, HS also results into hypofunction of the thyroid gland and effects on metabolism patterns of the animal to reduce metabolic heat production (Helal *et al.*, 2010).

Effect of Heat Stress on Acid-base balance

Animal under HS has increased RR and sweating which results increased body fluid loss that lift up maintenance requirements to control dehydration and blood homeostasis. As RR increases, expiration of CO2 via the lungs increases. This results to respiratory alkalosis, as blood carbonic acid concentration decreases. Therefore, animal needs to compensate for higher blood pH by excreting bicarbonate in the urine to maintain the carbonic acid: bicarbonate ratio. Compensation results in urinary bicarbonate loss in an attempt to balance the ratio of carbonic acid to bicarbonate in the blood. Chronic hyperthermia also causes severe or prolonged inappetence which further aggravates the increased supply of total carbonic acid in the rumen and decrease ruminal pH thereby, resulting into subclinical and acute rumen acidosis (Kadzere *et al.*, 2002).

Effect of Heat Stress on Immune system

The immune system is the major body defense systems to protect and cope against environmental stressors. Primary indicators of immunity response include white blood cells (WBCs), red blood cells (RBCs), hemoglobin (Hb), packed cell volume (PCV), glucose and protein concentration in blood get altered on thermal stress. High ambient temperatures result in significant alterations in hematological, biochemical and endocrine parameters. Initially, high temperatures cause significant dehydration, and there would be significant increase in erythrocyte, leukocytes and hemoglobin concentration relative to plasma which results in high erythrocyte, leukocyte and hemoglobin concentration. In contrast, under prolonged exposure to heat, the values of hematological and biochemical (total protein, cholesterol and triglycerides) parameters decrease due to lack of precursors for synthesis which is associated with depressed feed intake and deviation of energy for thermoregulation. Similarly, during the initial phase of heat stress, there is more of lipid peroxidation leading to oxidative stress. In order to combat oxidative stress, the antioxidant enzymes such as catalase, dismutase and glutathione peroxidase increases. If the existing stressor is for short period the antioxidant enzymes takes care of oxidative stress but under prolonged heat stress the antioxidant system fails leading to heat stress. The increase in THI resulted in increased incidence of mastitis in cows (Murrah buffaloes were less affected. Further incidence was more in Sahiwal and Tharparkar cows than the crossbred Karan Swiss and Karan Fries cows. Higher incidence of mastitis in dairy cows could be due to high temperatures facilitating survival and multiplication of pathogens carrier fly population associated with hot-humid conditions. Excess heat load in extreme cases not only compromises animal welfare but also results into death of the animals (Jingar *et al.*, 2014; Vitali *et al.*, 2009)

Effect of Heat Stress on production and Reproductive performance

Effect of Heat Stress on Milk production and composition

HS adversely affects milk production and its composition in dairy animals, especially animals of high genetic merit. Berman (2005) estimated that effective environmental heat loads above 35°C activate the stress response systems in lactating dairy cows. In response dairy cows reduce feed intake which is directly associated with NEB, which largely responsible for the decline in milk synthesis (Wheelock *et al.*, 2010). Moreover, maintenance requirements of energy also increased by 30% in HS dairy animal. Therefore, energy intake would not be enough to cover the daily requirements for milk production. HS during the dry period (i.e., last 2 months of gestation) reduced mammary cell proliferation and so, decreases milk yield in the following lactation. Hot and humid environment not only affects milk yield but also effects milk quality. i.e., milk fat, solids-not-fat (SNF) and milk protein (Tao and Dahl *et al.*, 2013).

Effect of Heat Stress on Reproductive performance

High air temperature and humidity affects cellular functions by direct alteration and impairment of various tissues or organs of the reproductive system in both the sexes of the animal.

Effects on female reproductive performance

HS reduces the length and intensity of estrus besides increases incidence of anestrous and silent heat in farm animals. It increases ACTH and cortisol secretion, and blocks estradiol-induced sexual behavior. Low estradiol level on the day of estrus during summer period may be the likely factor for poor expression of heat in Indian buffaloes (Hein and Allrich, 1992). When female goats exposed to 36.8°C and 70% relative humidity for 48 h follicular growth to ovulation suppresses, accompanied by decreased LH receptor level and follicular estradiol synthesis activity. A period of high-temperature results to increase secretion of endometrial PGF-2α, thereby threatening pregnancy maintenance leads to infertility (Bilby *et al.*, 2008).

Effects on male reproductive performance

Bull is recognizing as more than half of the herd and hence, bull's fertility is equally or more important for fertilization of oocyte to produce a good, viable and genetically potential conceptus. It is well known that bull testes must be 2-6°C cooler than core body temperature for fertile sperm to be produced. Therefore, increased testicular temperature results from thermal stress could changes in seminal and biochemical parameters leads to infertility problems in bulls. Optimal semen qualities during winter, poor during summer and intermediate during rainy season and conclude that hot-dry or summer season adversely affect the various bio-physical characteristics of semen in Karan Fries bulls. Hence, HS significantly lowers conception as well as fertility rates per insemination of male and subsequently reduces male's fitness (Bhakat *et al.*, 2014).

Effect of Heat Stress on Endocrinal changes

The endocrine system acts as second line of defense to combat adverse temperatures. During the initial phase of heat stress the plasma glucose levels tends to decrease due to reduced feed intake and expenditure of energy for excess respiratory function. While on the other hand a low blood glucose levels are lethal to the body. Here the endocrine system plays a crucial role in maintenance of plasma glucose levels by gluconeogenesis which is primarily mediated by nor epinephrine initially and later by prolonged secretions of cortisol from adrenal gland. In order to reduce metabolic heat production, the secretions of growth hormone (GH), Insulin like growth hormone (IGF-1) and thyroid hormone (T3&T4) concentration reduces. The secretions of GnRH, follicle stimulating hormone, luteinizing hormone (LH) also reduces as production gets compromised. In addition, prolactin helps in maintenance of extracellular fluid volume and thus supports heat dissipation. Overall endocrine system is mainly involved in control of metabolism i.e homeorhesis (Atrian and Shahryar, 2012).

Management of dairy animals during heat stress

Conclusion

Extended periods of high air temperature coupled with high relative humidity compromise the ability of dairy animal to dissipate excess body heat which affects feed intake, milk production, and reproductive efficiency and ultimately reducing profitability for dairy farmers. However, by minimizing body temperature, greater feed intake could be encouraged. Moreover, the gross efficiency with which dietary nutrients are used by the cow for performance could also be improved. The loss of electrolytes via skin secretions has to be minimized by improvement of housing and cooling of the animals. Standardization of mineral supplement to control acid-base balance should be considered in animal under different level of thermal stress. Increase pregnancy rate of HS cows could be achieved by improving various managemental conditions. Identification of genes associated with thermotolerance and using these genes as markers in the breeding program or marker assisted selection should be applied to identify animals adapted to thermal stress considering genotype-environment interactions (G × E) in addition to higher productivity.

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