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Effect of environmental stressors on productive and reproductive performances of dairy cow and buffaloes

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Abstract
The dairy sector is more vulnerable to global warming and climate change. Environmental Stressors affect the economic sustainability of the farmers and farm directly by reducing the productive and reproductive performance of dairy animals. Dairy animals under stress conditions exhibit lower DMI and milk yield. Reduction in the synthesis of milk and susceptibility of dairy cows more to illness is the result of stress, which can affect further directly and/or indirectly metabolic and physiological acclimation. Stress does not only affect productive performance but also directly affect reproductive performance like reducing duration and intensity of estrus, altered follicular development, impaired embryonic development and growth of cattle through disordering of metabolism. Low reproductive efficiency in dairy cows and buffaloes inflict heavy economic losses all over the world. Nutritional and management (i.e. cooling systems) strategies used to minimize the negative impact of environmental stress on dairy cow and buffaloes. In this review an attempt has been made to bring forth the effect of heat stress and to discuss their impact on dairy cows and buffaloes.

Keywords: Climate, stress, heat stress, cold stress, temperature-humidity-index

Introduction
Stress is the biological response elicited when an individual perceives a threat (“stressor”) to its homeostasis. Stress responses involve endocrine, paracrine and neural these stress responses negatively affect the productive and reproductive efficiency of dairy cattle and buffaloes [21]. There is much type of stressors like climatic, physical, noise, transportation and deprivation or restriction of food. Stressors can also be psychological, such as isolation from calf after weaning, social isolation or mixing with unfamiliar animals, restraint and handling. Stressors can also be classified based on genetic and physical origin as endogenous and or exogenous, if they originated from the social and physical environment. These stressors are responsible for behavioral, metabolic and physiological changes in animals [8]. Many stressors directly affect the physiology of dairy animals mainly climatic stressors like heat and cold stress.
Stress is one of the environmental factors that affect handling and decreases the production and reproduction of livestock, it is considered that the main factor which should be controlled in units Animal Production, since it is closely related to pathogens and infectious agents and affect the health of animals [17]. Stress responsible for the decreasing economy of the farm directly by reducing productive and reproductive performance.

Neuroendocrinology of stress
Various stressors trigger the central nervous system (CNS) which is responsible for the stress induction and transmission of stress signal by the pathway, which including the thalamus, hypothalamus and cortex. These pathways become activated when animal suffer to any type of stress and it gives rise to a stress response by the sympathetic-adrenal-medullary (SAM) axis and hypothalamus-pituitary-adrenocortical (HPA) axis [22].
The HPA axis mediates both acute and chronic responses. In the acute stress response, changes in the environment activate receptors in the body. Which triggers the SAM axis to turn on the production of two catecholamines, norepinephrine in the peripheral sympathetic nerves and epinephrine in the adrenal medulla? These hormones trigger a fight-or-flight response in which the heart rate and respiration rate increase, blood pressure rises and activity in the

gastrointestinal tract decreases. The HPA axis induces the hypothalamus to secrete corticotropin-releasing hormone (CRH) and vassopresin (VP) [23] which in turn induces the pituitary gland to release adrenocorticotropic hormone (ACTH). ACTH causes the adrenal cortex to secrete glucocorticoids, mainly cortisol [9]. When the hypothalamus and anterior pituitary detect high cortisol concentrations, they exert negative feedback via VP, CRH and ACTH to inhibit further cortisol release by the adrenal cortex; thereby ending the stress response [5] Cortisol and other glucocorticoids in cattle regulate the balance between anabolism and catabolism and under conditions of heat stress. When a stressor activates the HPA axis and triggers the secretion of CRH, ACTH and glucocorticoids in response to stress, there is a negative feedback effect of progesterone on luteinizing hormone (LH) increasing the first. Due to elevated cortisol levels there is gradually depression, there are changes in the release of LH. The level of prostaglandin F2 alpha (PGF2 ∞) and ACTH increase. All this adversely affects reproductive function in mammals [6].

Environmental Stressors

Solar radiation, wind speed, air temperature and humidity are all factors that are concerned with heat stress [10]. Climate can be a chronic stressor for dairy cattle because they usually stand outside during most of the year. Cold, heat, humidity, rain, ice and wind act as stressors affecting the endocrine system and the reproductive system. Heat stress is perhaps the best studied of all climatic stressors. Heat and cold stress exert different effects, although they are interrelated through climate and the effects of each depend on seasonality, latitude and intensity.

Heat stress

Environmental stress is aggravated due to global warming accompanied by periods of extreme weather. If there are high temperature and humidity in the environment, then it is very difficult for the animal to dissipate heat and the animal undergoes heat stress [10]. Heat stress is the state at which mechanisms get activated to maintain an animal's body thermal balance when exposed to uncomfortable elevated temperatures. Heat stress is defined as any combination of environmental parameters producing conditions that are higher than the temperature range of the animal's thermo neutral zone (TNZ) or Heat stress is caused when the body temperature of an animal is beyond its normal range which creates a problem in heat dissipation and finally reduces physiological as well as behavioral responses [3]. Temperature stress imparts physical and economical losses to livestock production in temperate, subtropical and tropical regions of the world. Heat stress as a level on the temperature-humidity index (THI) that persistently lies above the thermo-neutral zone and that adversely affects the animal's performance. THI > 72 negatively affects dairy cattle performance.

Although changes in rectal temperature are the ultimate indicator of heat stress in cattle, such data are not always available. Therefore, heat stress is frequently defined as occurring whenever the temperature humidity index (THI) exceeds 72 [2]. Ravagnolo *et al*. (2000) reported that THI, based on the maximum temperature and minimum humidity, most effectively accounted for the effect of heat stress on production.

The importance of classifying the THI into different classes involves the determination comfortable zone or heat stress zone where the animals have been exposed to heat stress. The acute exposure to extreme heat load is associated with disturbance to a physiological mechanism to the body like rapid respiration and excessive saliva production along with significant depression in reproductive performances in animals.

Thermo-Neutral Zone (TNZ) and Heat Stress Zone (HSZ)

The TNZ explains the inter-relationship between the animal and the environment and it is defined as the range within which metabolic rate is minimal, and a healthy animal can make physical adaptation to maintain the normal body temperature with minimal change in metabolic activity [14]. The TNZ is surrounded by lower critical temperature and higher critical temperature. The upper critical temperature has been defined in dairy cows as 25-26°C. When the environmental temperature moves away from the upper critical temperature, the detrimental effects of heat stress in terms of reduction of milk production, changes in milk composition and lower reproductive performances are observed in cattle and buffaloes. Various authors developed different zones of whether the animals are comfortable or susceptible to heat stress based on the THI values.

Cold stress

Animal, which is not protected against cold are more susceptible to cold stress or hypothermia and there are two possible conditions for the formation of cold stress which are natural and artificial. Serious illnesses, injuries, everlasting tissue problems as well as deaths are due to difficulty in regulating body temperatures. More energy is required as animals are exposed to cold weather to maintain their body reserves and body temperatures. Increasing the feed intake of cattle is one way to compensate for colder weather [7]. Cold stress in also responsible for the reduced productive and reproductive performance of dairy cattle. However, how much they can consume can be limited by the physical of cattle. Once that physical limit was reached, to compensate for the increased energy requirement cattle need higher quality feeds and supplements.

Effects of the environmental stressors on productive performance

Heat stress lowers feed intake of animal which in turn reduces their productivity in terms of milk yield, body weight [11]. The responses by cow to maintain normal body temperatures are observed in reduced feed intakes, 10 to 25% lower milk production, decreased milk fat percentage, higher maintenance requirements, and overall less efficient milk production [28]. Heat stress can affect various component of milk such as fat, Protein, SNF and lactose. Heat stress increases the somatic cell count indicating reduction in the milk quality. Heat stress through udder temperature may cause mastitis in dairy animals [4]. High temperature and low relative humidity are critical; parameters contributing to heat stress per unit increase in THI beyond 72, 0.2 kg reduction in milk yield was recorded. Dairy cattle show signs of heat stress when THI is higher than 72.The comfort limit depends on the level of production [15]. Animals presenting higher level of production are more sensitive to heat stress. Even though high milk production is connected with high heat production of cattle, the body of a cow can maintain and avoid hypothermia. The heat loss is avoided by animals through production of more hair coats. Due to increased feed intake and decreased heat stress in cattle, rumen volatile fatty acid production increased in cold stress season. The thermo neutral zone (comfort level) of cow is between -2 - 20°C. Depending on other factors such as humidity, housing, ventilation, etc. temperatures above or below the thermo neutral zone may affect dairy animals.

In lactating dairy cows, more than 35°C of body temperature stimulates stress and this reduces milk yield through reduction of feed intake and metabolic problems. Due to reduce in feed intake in dairy animals, drop in milk production up to 50% was resulted. In the summer season, there is lower milk fat and milk protein. However, heat stress has not effect on the content of lactose in milk but significantly reduces milk production, percentage of milk fat and percentage of proteins [30].

Effects of the environmental stressors on reproductive performance

When dairy cattle are subjected to heat stress, reproductive efficiency declines. Heat stress in dairy animals has been shown to alter the duration of estrus [18], Follicular growth and development, luteolytic mechanisms, early embryonic development and fetal growth. Although heat and cold stress alter endocrine profiles and fertility in females.

Effect on estrus cycle and Fertility

Temperature can affect the reproductive process at many stages ranging from pubertal development through conception and embryonic mortality [29]. Low and high environmental temperatures cause delay in the onset of puberty in both males and females. Follicular dynamics of the heat stressed cow is altered when compared to control cows. Although the average size of the first wave dominant follicle was normal before heat stressed but later during heat stress decreased in size sooner, and the second wave dominant follicle emerged earlier [12]. The second wave dominant follicle in heat stressed cattle may then be an aged follicle at ovulation; thereby reducing fertility. Sexual behavior and fertility rate are the main indicators of mammalian female reproduction that are negatively affected by environmental stress [20].

The gonadotropins luteinizing hormone (LH) and follicle-stimulating hormone (FSH) play important roles in ovarian function, including regulation of follicular growth, ovulation, and corpus luteum (CL) development. Reduced LH surge and/or alteration in the sensitivity of follicular cells to LH might, in turn, impair the cascade of events leading to ovulation and formation of a functional CL [16]. Moreover, reduced estradiol concentrations under heat stress in cows close to ovulation may also disrupt the preovulatory LH surge. Unlike LH, FSH secretion increases under heat stress and is associated with a larger number of follicles growing in the ovaries. Low LH surge may cause the development of suboptimal CL secreting low levels of progesterone. Together, altered gonadotropin secretion can depress cow fertility in the summer [26]. Due to heat stress causing a decrease in the cow’s production of luteinizing hormone and estradiol. Heat stress reduces the length and intensity of estrus. Therefore, a cow may be in estrus, but will not express it due to her body’s response to overheating.

The Higher ambient temperature during the summer has been associated with reduced fertility in dairy cattle through its deleterious impact on oocyte maturation and early embryo development

Maximum environmental temperature on the day after insemination was associated negatively with conception rates [11]. The main cause of low fertility in dairy cows during summer is the level of hyperthermia that lactating cow develop daily during summer.

Effect on Oocytes and Embryonic Development: Heat stress has adverse effects on reproductive performances of cattle and buffaloes. There are several possible mechanisms by which heat stress can prevent the growth of oocytes. The foremost is the reduction on the synthesis of preovulatory surge in luteinizing hormone and estradiol. Hence, there is poor follicle maturation and this leads to ovarian inactivity in cattle Heat stress before insemination has been associated with decreased fertility in cattle [1]. During heat stress, the intrauterine environment of the cow is compromised. Hence, there is decrease in blood flow to the uterus and elevated uterine temperature [13]. The exposure of females to heat stress conditions during days 0-3 of pregnancy or days 0-7 of pregnancy reduced embryonic survival. Heat stress has a deleterious effect on the oocyte quality in buffaloes. Follicular growth and atresia during anestrus are attributed to the inadequate secretion of gonadotropins by the hypophysis. There is a decrease in the concentration of oestradiol-17 beta in summer which reduces the intensity of estrus manifestation and results in silent heat in buffaloes. The mean plasma prolactin concentration was significantly higher in summer than winter which may cause acyclicity or infertility in buffaloes [27].

Several studies have indicated that in cattle, embryonic development is highly sensitive to high temperatures, in the top three to 11 days after service; acquiring more heat tolerance as the gestation period progresses [13]. During the first 3 or 7 days of pregnancy decreased embryonic viability and development [19]. Heat stress has a negative impact on quality of ova, which may decrease the viability of young embryos. Two-cell stage embryos are more sensitive to heat stress than those at four- and eight-cell stages. Embryos at later developmental stages (i.e., morula, blastocyst) are more resistant to heat stress. Interestingly, heat shock differentially affects embryonic development in different breeds, with a moderate negative effect in *Bos indicus* (Brahman and Nelore) and a larger negative effect in *Bos Taurus* (Angus, Holstein).

Conclusion

Environmental stressors reduce the productive and reproductive efficiency of dairy cattle through a variety of different mechanisms. The productive performance in particular, milk production, milk components, somatic cell count and mammary gland health are highly sensitive to suddenly changes in environmental temperatures. Heat stress has adverse effects on the reproductive performances of cattle and buffaloes. The THI is the most commonly used index to measure the level of heat stress in animals. The reproductive traits of cattle are susceptible to the negative impacts of heat stress with an increase in THI above 72, while the buffaloes are more prone to heat stress when the THI level surpasses 75. The heat tolerant dairy animals should be selected which can enhance both the reproductive and productive ability and adaptability to the adverse climate.

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