Biological Times
Volume No. 3 | Issue No. 6 | Pages 23-24

Impacts and Mitigation of heat stress on dairy animals

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ABSTRACT

Heat stress is one of the greatest challenges regarding productivity in dairy animals. Consistent elevation in global warming is one of its leading causes. Air temperature and high humidity are the climatic or thermal variables that play an integral role in it. Without a doubt, HS compromises feed intake and milk yield because of climatic variables. An increase in respiratory rate, heart rate, and blood flow rate is also noticed during conditions of heat stress leading to changes in the physiological conditions of dairy animals. In addition, modifications in acid-base chemistry and hormones are other factors of altered physiological conditions. Similarly, conception and reproduction efficiency of dairy animals are also affected. High temperature affects cellular functions in reproductive organs in dairy animals. As a result, conception and fertility rates could be lowered. In heat-stressed animals, heat tolerance can be achieved through physical modifications, nutritional management, and genetic selection. This article aims to highlight the effects of heat stress and remedies to overcome it.

Keywords: Heat stress (HS), Dry matter intake (DMI), Milk Yield, Conception, Thermotolerance

1. Introduction:

Heat stress is the environmental condition affecting an animal's homeostasis and health due to excessive heat load. It is an increasing problem in the near future because of consistent elevation in global warming and is a significant challenge in animal husbandry. Behavioral changes in animals are observed during heat stress. Similarly, significant scientific evidence has revealed its influences on the physiological conditions, feed conversion efficiency, and reproduction of dairy animals [1]. It proposes physiological changes by increasing heart rate and respiration rate. Provided, the thermal variables causing heat stress may include temperature, humidity, solar radiation, and wind speed. Keeping in view its impacts as an emerging issue, recommendations for mitigation of heat stress will be provided as physical modification, nutritional management, and genetic selection seem to be vital practices for dealing with HS [2].

2. Thermal variables

The key factors to calculate heat stress are thermal variables which comprise air temperature, humidity, solar radiation, and wind speed. Air temperature and humidity are in fact the elementary parameters of thermal comfort because of the ease of recording them. To calculate heat transfer, dry bulb temperature, wet bulb temperature, dew point temperature, and relative humidity are basic parameters. Commercial devices such as Tinytag Plus 2 loggers from Hasting Data loggers, NWS, AUS are currently being used to measure temperature and humidity [3]. Moreover, wind speed is another factor as the movement of air affects efficiency and evaporation which results in the transfer of heat. The effect of solar radiation can be measured by black globe temperature as it is one of the parameters of the thermal environment. Solar radiation has a primary role in open lots. The assessment of shelter efficiency is generally accomplished by a comparison of solar radiation with shading construction or without shading construction [4].

3. Physiologic effects of heat stress

Physiological adaptations occur due to heat stress or repeated exposure to a hot environment. Physiologic changes occur in the digestive tract, acid-base chemistry, and blood hormones during hot weather conditions which in turn results in reduced nutrient intake. During heat stress reduced feed intake, decreased activity, increased respiratory rate increased heart rate, and increased peripheral blood flow are exhibited by cows. They strive to seek shade and wind as well. Respiration rate (RR) is an early warning signal; however, heart rate measurement has been used for evaluating metabolic energy expenditure in ruminants under heat stress [5]. The temperature-sensitive neurons also play a role in the physiological impact of HS. These neurons are located throughout the animal's body and send information to the hypothalamus for proposing numerous physiological, anatomical, or behavioral changes in a strive to maintain heat balance [6]. In addition, the cows exposed to HS generally have altered acid-base chemistry and alterations in hormones. Increased levels of insulin and decreased levels of thyroid hormones were reported in cows and heifers under heat stress [7]. As there is the elevation of insulin level, glucose uptake by tissues or organs is stimulated, but the CNS and immune system which are obligate users of glucose take high priority of sufficient glucose supply over other tissues. As a result of the hierarchy of glucose utilization, the allocation of glucose to the mammary gland and skeletal muscle decreases [8,9].

4. Effect on DMI and milk yield

Dairy production is compromised by decreasing feed intake and milk yield as a result of heat stress and it may also alter milk composition. Dry matter intake (DMI)of cow and milk yield are mostly affected by climatic variables, not by cow body temperature. Decreased milk yield is regarded as the most basal impact of heat stress on a dairy cow as the most critical variables to heat stress are maximum temperature and minimum relative humidity. A decline of milk yield by 0.2 kg was seen per unit increase in THI (Temperature-humidity index) when THI exceeded 72 [10]. Admittedly, if given sufficient night cooling, cows can tolerate relatively high daytime air temperatures. A cool period of less than 21°C for 3 to 6 h will lower the downswing of milk yield regardless of high ambient temperature during the day [11]. In addition, a cow exposed to heat stress could have a negative energy balance, if feed intake doesn't meet the energy demands of maintenance. Under the conditions of high heat, the decrease in feed intake also worsens the degree of negative energy balance and declines milk production [12]. Besides the impacts of heat stress on DMI and milk yield, it also exerts an influence on reproduction and conception.

5. Effect on reproduction and conception

Heat stress strikes a hit on both the productivity and reproductive efficiency of dairy cattle. The cellular functions are affected by high air temperature and humidity by immediate modification and detriment of various tissues or organs of the reproductive system in both male and female animals.Likewise, the Conception rate (the success rate of artificial insemination) can also be affected. As corresponded with the thermal conditions in winter, the HS in summer can result in a 20–30% decline in conception rate. Moreover, the impact of summer heat stress could even induce adverse consequences during the autumn [13]. In bulls, HS increases the testicular temperature which could induce a change in seminal composition leading to infertility problems. While in females, the length and intensity of the estrus cycle are reduced [14,15]. It raises the ACTH and cortisol secretion [16], and estradiol-induced sexual behavior is blocked [17]. Hence, conception as well as fertility rates are notably lowered. Consequently, some strategies could be concluded to mitigate heat stress.

6. Mitigation of heat stress

Physical modifications of the environment (shading, cooling ponds, sprinklers, evaporative cooling systems), nutritional management, and genetic development are pivotal elements for sustainable dairy production in hot climates.

7. Physical modifications

The first step that should be taken to mediate the stressful effects of heat on cows is protection from direct and indirect solar radiation and it can be done by well-designed shades as 30% to 50% head load from solar radiation could be reduced by well-designed shade [18]. Shading is one of the inexpensive ways to modify an animal’s environment during the hot season. Trees are natural shading materials that provide not only shade but also provide cooling when moisture evaporates from the leaves. Various types of artificial shading are available from metal to synthetic materials such as cloth. Furthermore, sprinklers could enhance evaporation which serves as the chief mode of heat dissipation for animals. The use of fans and cooling ponds for dairy calves also mediate heat stress.

8. Nutritional management

To cite this article: Tariq MT, S Cecil, M Adnan, A Ashraf & MG Nasar. Impacts and Mitigation of heat stress on dairy animals. Biological Times. 2024 June 3(6): 23-24

Nutritional management plays a role in maintaining homeostasis. It also prevents nutrient deficiencies resulting from heat stress. Milk production efficiency and yield in the warm season are enhanced by increasing dietary fat content [19]. High heat causes oxidative damage which could be lowered through supplementation of vitamins C, and E, and also by using zinc [20,21].

9. Genetic selection

Breeds play an important role in genetic influence. Hair color influences the exposure of the cow to heat stress because coat color is associated with the amount of heat absorbed from solar radiation. Cattle having shorter hair with greater diameter and lighter coat color are more accustomed to hot environments than those having longer hair coats and darker colors [22]. Moreover, it would be desirable to select particular genes that control traits related to thermotolerance. As Heat shock genes serve as markers in marker-assisted selection for thermotolerance, they have a critical role in the recovery of cells from stress.

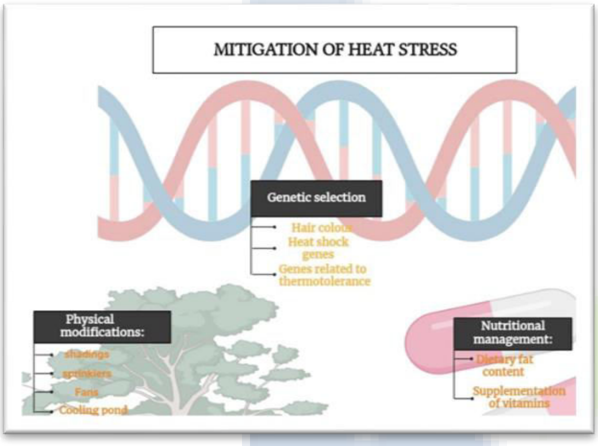

Fig.1: Mitigation of heat stress (retrieved from BioRender)

10. Conclusion

Dealing with heat stress is the primary challenge of dairy farming. The extended time span of high air temperature integrated with high relative humidity compromises the ability of dairy animals to dissolve excess body heat which results in problems related to milk production, feed intake, and conception. These indices reduce profitability for dairy farmers. Heat stress changes the physiological and behavioral conditions of dairy animals resulting in a reduction of feed intake and milk yield ultimately by thermal variables (air temperature, humidity, solar radiation, and wind speed), but it can be improved through supplementation of vitamins and by increasing dietary fat content. Furthermore, physical modifications such as fans, cooling ponds, sprinklers, and shades can reduce heat stress by minimizing the loss of electrolytes via skin. In addition, genetic selection could play a vital role as genes associated with thermotolerance recover the cell from heat stress. Hence, these mentioned strategies could be considered as crucial strategies to mitigate heat stress.

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