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Impact of Heat Stress on the Physiological Responses of Buffaloes

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Abstract

Thermal stress is a concern for all livestock production systems and its effects have been studied because of the negative impact on production, health and even mortality. Exposure to high ambient temperature is the major constraint on buffalo productivity in hot climatic areas due to the fact that it reduces feed intake and its utilization, disturbance in water metabolism, protein, energy, mineral balance, enzymatic reactions, hormonal secretions and blood metabolites. Such changes result in impairment of productive and reproductive performance of animals, particularly buffaloes. Most of the livestock species experience stress of varying degrees but are able to cope with these environmental stressors through behavioral measures such as sweating, panting, drinking water, shivering or by regulating their metabolic rates. Buffaloes are the most affected species due to their anatomical features and hence it is very important to understand the different physiological responses to thermal stress which can be considered as elementary markers of thermal stress. Therefore, this review focuses on the changes in physiological responses like respiratory rate, pulse rate and rectal temperature during thermal stress. These responses can also be easily monitored by the farmer and accordingly necessary precautionary and mitigation strategies could be adopted to prevent further adverse effects and even reverse the negative effects there by maintaining the optimum productivity and prevent any economic loss.

Keywords: Thermal stress, buffaloes, production, reproduction, physiological responses

1. Introduction

Climate is one of the major constraints that hinder the efficiency of livestock production, especially in sub-tropical and tropical areas (Li et al., 2021). Thermal stress is a major problem causing great economic losses to the dairy farmers. The word, "stress" is very common butreflects vast effective results (Suguna., 2020). Thermal stress reduces feed intake, milk yield and composition, growth rate and reproductive function in livestock (Kumar et al., 2018). The Buffalo population in India is 108.7 million which contributes around 21.23% to total livestock population in India (Basic Animal Husbandry Statistics, 2019). Buffaloes are homeotherms, but at the same time, they are less tolerant to extremes of heat and cold conditions than various breeds of cattle (Aggarwal and Singh, 2010). They are insufficiently heat tolerant and the milk yield, growth and fertility are reduced during periods of high ambient temperature (AT) (Burgos et al., 2007). Buffaloes display amalgamation of thermoregulatory responses to overcome the changes occurring in micro and macro climatic conditions (Mishra., 2021). These thermoregulatory responses are behavioral, physiological, neuro-endocrine and molecular responses acting synergistically to counteract the deleterious effects of heat stress. During extreme hot humid conditions, the thermoregulatory capability of buffalo to dissipate heat by sweating is compromised and thermal stress occurs (Kumar et al., 2018). An increase in body temperature of around 1ºC may result in detectable, deleterious effects on metabolism, tissue integrity and a significant depression in production (Kadzere et al., 2002). Buffalo, an animal of hot and humid climate has a unique wallowing behavior that supports heat dissipation due to an increase in the blood volume and flow to the skin surface in hot conditions (Koga et al., 1999). Body temperature is a good measure of heat tolerance in animals. It represents the resultant of all heat gain and heat loss processes of the body (Ganaie et al., 2013). High AT and high RH are the primary factors that cause heat stress in dairy animals. Temperature humidity index (THI) range is used to indicate degree of heat stress i.e., mild, moderate, and severe (Umar et al., 2021). Rectal temperature (RT) is considered as a good index of body temperature even though there is considerable variation in different parts of the body core at different times of the day (Srikandakumar et al.,2003). Increased respiratory rate (RR) is the first reaction when animals are exposed to environmental temperature above the thermoneutral zone (TNZ). The physiological response to heat stress results in the reduction of heat production (Seif et al., 1979), which in turn cause a reduction in feed intake (Seif et al., 1979 and Lough et al., 1990), milk yield (Johnson, 1965; Lough et al., 1990 and Elvinger et al., 1992), and thyroid hormone secretion (Al-Haidary et al., 2012).

In order to maintain homeothermy during heat stress, respiratory rate increases to dissipate excessive heat as other physical heat loss mechanisms such as conduction, convection and radiation becomes inadequate (Hahn et al., 1997). The major stressor affecting RR is ambient temperature, which has much more influence on RR than humidity and increased RR is the first reaction of stress when animals are exposed to environmental temperature above the TNZ (Seath and Miller, 1946). Alteration in pulse rate is also one of the major indicators of stress. Badreldin and Ghany (1954) reported that buffaloes had a lower level of PR than cattle and exhibited noticeably more stress in summer. A rise of 1ºC or less in RT is enough to reduce performance in most livestock species (McDowell et al., 1976), which makes body temperature a sensitive indicator of physiological response to heat stress. The RT is an indicator of thermal balance and may be effective in quantifying the harshness of the thermal environment (Silanikove, 2000). Heat production in buffaloes is markedly influenced by diurnal changes in temperature (Koga et al., 1999).

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2. Materials and Methods

The rectal temperature (RT) has to be recorded with a digital clinical thermometer. The thermometer has to be inserted 3 inches in the rectum for about 2 minutes to ensure that the rectal mucosa is in contact with the bulb of thermometer. Respiration rate (RR) of the animals has to be recorded by flank method. One outward movement was counted as one respiration and the respiration rate was expressed as breaths per minute (bpm). Pulse rate (PR) has to be counted by observing pulsation of middle coccygeal artery at the base of tail and the results expressed as pulse rate per minute.

3. Results and Discussion

Respiratory rate

Wankar et al. (2014) observed that the RR increased in the adult buffaloes when exposed to varying temperatures in a controlled chamber. Younas et al., (2020) reported significantly increased respiratory in a study on NiliRavi buffaloes. Li et al. (2021) reported increased respiratory rate in summer when THI >80. Silanikove (2000) reported that measuring RR appears to be the most accessible and easiest approach for evaluating the degree of heat stress in farm animals (low: 40–60 bpm; medium high: 60–80; high: 80–120; and severe stress: above 150 bpm). All these findings imply that animals tried more to maintain their core body temperature through evaporative cooling during the hot dry season. The RR is the most sensitive index which reflects more response to the environmental conditions than the other physiological responses and is the first indicator of stress in animals (Fayza, 2008). McDowell (1972) stated that increased RR is the first outward indication that an animal is responding to increased thermal load. At higher temperature, the peripheral warm receptors in the skin become activated and send neural signals to the warm receptors located in the anterior hypothalamus in order to trigger the respiratory activity to increase the rate of heat loss from the body (Hafez, 1968). Wankar et al. (2014) opined that the increased RR in buffaloes was probably adopted to increase the evaporative cooling. Yousef (1985) stated that RR maybe a more appropriate indicator of heat stress than internal temperature, as RR increased more rapidly during heat exposure than other responses such as RT, skin temperature and changes in feed intake. RR increased as stressors caused an animal to maintain homeothermy by dissipating excess heat when other physical heat loss mechanisms (i.e., conduction, convection and radiation) become inadequate (Hahn et al., 1997). During heat stress, respiration is directed towards evaporation of moistures from the respiratory tract. This increase in RR associated with heat exposure involves an increase in ventilation of the dead space (Yousef, 1985). The rise in RR showed the attempt of the animals to increase pulmonary evaporative heat loss to attain thermal equilibrium.

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Pulse Rate (PR)

Alteration in pulse rate is also one of the major indicators of stress. Blackshaw and Blackshaw (1994) reported significantly increased HR and RR but insignificant rise in RT during heat stress in cattle.Younas et al. (2020) reported significantly increased pulse rate in a study on Niliravi buffaloes.The elevated heart rate (HR) and pulse rate (PR) during stress may be due to two reasons; one is the increased muscular activity controlling the rate of respiration, along with elevated RR and the second reason is the reduction in resistance of peripheral vascular beds and arteriovenous anastomoses. Arterial blood pressure decreases under mild heat stress as a consequence of the decrease in total peripheral resistance (Rubsamen& Hales, 1985) and this stimulates HR. Increase in pulsation rate increases blood flow from the core to the surface as a result of which more heat is lost by sensible and insensible means (Marai et al., 2007). The increase in cardiac output and cutaneous blood flow by heat stress, due to blood redistribution from deep splanchnic to more peripheral body regions, has been found in goat (Silanikove, 2000).The cardiovascular and respiratory adjustments to combat the increasing stress indicate the significance of physiological adaptations which are the first line of defense to prevent drastic metabolic alterations and maintain thermoregulation (Wankar et al., 2014).

Rectal Temperature (RT)

Das et al. (1997) recorded a riseinRTfrom38.70±0.21to40.00±0.10°C during the 24 h diurnal change and RR rise from 11.25±0.38 to 48.66±1.26 bpm in Murrah buffaloes during solar exposure in summer when the minimum and maximum AT were27.1and44.1°Crespectively. The heat stressed buffaloes in the study of Khongdee et al. (2011) exhibited a higher mean RT than that of non-heat stressed buffaloes reported in previous studies ((37.9°C (Bunyavejchewin et al., 1985) and 38.5°C (Chaiyabutr, 1993)). The RT increased from 38.5 to 39.7 °C when swamp buffalo and cows (340–375 kg, 4–7 years old) were subjected to acute heat exposure (41 °C; without wallow) for 5 hours (Chaiyabutr,1993). Younas et al., (2020) reported siginifcantly increased rectal temperature in a study on Niliravi buffaloes.

4. Conclusion

It can be therefore concluded that recording of physiological responses is of paramount importance; since their alterations are of physiological significance particularly with respect to effect of thermal stress on the animals. Since these parameters are easy to estimate, the farmers can use them as markers of heat stress at field level. Accordingly, necessary precautionary measures to alter the microclimatic and macroclimatic climatic conditions can be taken to prevent adverse effects of thermal stress on production and reproduction of animals.

Conflict of Interest

The authors declare that no conflict of interest exists.

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