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A review: heat stress in cow and buffaloes in India

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Abstract
India is a tropical climatic country in which heat stress is an important disadvantageous factor that reduces the production performance of cattle and buffalo and conduces to significant decrease in milk yields in dairy cows and buffalo and some metabolically disorders. The objective of this review is to known the heat stress metabolism, its causing factors and its preventative methods for increase the production performance through manage mental and nutritional procedures.

Keywords: Tropical, Heat, Temperature, Conduction, Convection, Radiation, Evaporation, Panting, Sweating, Moisture

Introduction
Climatic conditions of India are such that the hot and humid season is relatively long, there is intense radiant energy for an extended period, and there is generally the presence of high relative humidity. Thus, heat stress is chronic in nature especially for animal, there is often little relief from the heat during the evening hours, and intense bursts of combined heat and humidity further depress performance of animal. Lactating dairy cattle and buffaloes create a large quantity of metabolic heat and accumulate additional heat from radiant energy (West, 2003) [20]. Heat production and accumulation, coupled with compromised cooling capability because of environmental conditions, causes heat strain in the cattle and buffaloes to increase to the point that body temperature rises, intake declines and ultimately the cow's productivity declines.
Heat stress is caused by a combination of climatic factors like air temperature, humidity, solar radiation, wind velocity etc. A common time for experience adverse effects of high temperatures is during transport (Fiore *et al*, 2009) [6]. Transport is a multi affected stressor that can create or exacerbate existing heat loads. Handling of animal, increases body temperature. Animal are adversely affected any time the ambient temperature is more than their thermoneutral zone, which ranges about 25°C. Because that heat stress conduces to some disadvantageous affect on livestock, many researchers work about heat stress in animal.

Thermoneutral zone
The Thermoneutral Zone *(*TNZ) is defined as. "the range of ambient temperature within which metabolic rate is at a minimum, and within which temperature regulation is achieved by non evaporative physical processes alone" (Bligh & Johnson, 1973) [3]. The lower critical ambient temperature range point and the upper critical ambient temperature point indicate the limits of the TNZ. The ambient temperature below, which the rate of heat production of a resting homeotherm increases to maintain thermal balance, is the lower critical temperature (LCT). The upper critical temperature (UCT) may be defined as the ambient temperature when the: (a) metabolic rate increases; (b) evaporative heat loss increases; or (c) tissue thermal insulation is minimal (Silanikove, 2000) [14]. Below and above these temperature limits heat production is increased. The width of the thermoneutral zone will vary depending on age, species and breed, level of nutrition, previous state of temperature acclimation or acclimatization, level of productivity, housing conditions, insulation, and behavior etc (Yousef, 1985b) [22]. In order to more clearly define the TNZ (Silanikove, 2000) [14] suggested that the subdivision of the TNZ into a zone of thermal well-being is most suitable to describe the relation between an animal and its environment. Figure 1, illustrate this concept.

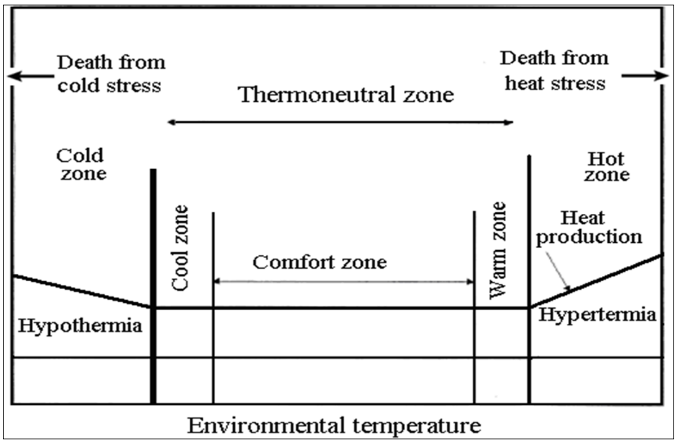

Fig 1: Schematic figure of thermoneutral zone and comfort zone

Heat Input

Animals gain heat from three sources: chemical, mechanical and thermal. Chemical and mechanical heat transfer relates to metabolic processes and represents the body's main heat sources. The influence of the thermal environment on an animal is primarily exerted through energy exchanges involving convection, conduction, radiation and evaporation (Smith, 1996) [15].

Metabolism

In the living organism metabolism is principle source of energy and the energy produced is the sum of the physical and chemical processes associated with anabolism and catabolism (Blood & Studdert. 1993) [4]. Cells use carbohydrates, fats and proteins from food to generate adenosine triphosphate (ATP), which is the body's main energy source (Ruckebusch *et al*., 1991) [12]. Of the energy in foods, 35% becomes heat during ATP formation (Guyton & Hall. 1996) [7]. Still more energy becomes heat as it is transferred from ATP to the functional systems of the cells, so not more than 27% of all the energy from food is finally used by the functional systems (Guyton & Hall. 1996) [7]. Metabolism, or heat production, ranges from a basal level (chemical sources of metabolism), to a level that may be twenty times higher (mechanical sources of metabolism) during work, such as reproduction, muscular work, production and thermoregulation (Smith, 1996) [15]. An increase in body temperature also increases the metabolic rate (Cunningham, 2002) [5].

Conduction

Heat transfer by conduction process is due to the physical contact of the animal with a surface, air or liquid. The rate of heat flow is dependent on the area of contact and the thermal conductivities of the material involved, the distance of the object over which heat needs to flow, and the temperature gradient between animal and conductive surface (Sparke *et al.*, 2001) [16]. For heat gain to occur via conduction the animal's skin or mucosal linings must be in contact with a hotter object. Animals when standing are mainly in contact with the air (except hooves which represent 2% of body surface area and are in contact with the ground), therefore most heat transfer takes place with air, and since air has a poor thermal conductivity. Therefore, conductive heat transfer plays a small role in the total heat transfer from animal in the environment. If either air-temperature or the temperature of the ground on which animal is lying is higher than the skin temperature then the animal will gain heat by conduction adding to the metabolic heat load (Robertshaw, 1985) [11].

Radiations

All solid objects in proximity of an animal emit electromagnetic radiation in the infrared range. Warm objects emit more energy of shorter wavelength per unit time than do cool objects. Net heat transfer in animal is from warm to cool objects, therefore if the surroundings are warms than the temperature of the body, a greater quantity of heat is radiated to the body than is radiated from the body and thus body gain heat (Guyton & Hall. 1996) [7].

Williams *et al.,* (1960) analyzed thats solar radiation had a direct effect on body temperature when air temperatures were close to the range of thermoneutrality (below 90 ^{0}F). At higher air temperatures (above 90 ^{0}F) solar radiation had little effect on the changes in the body temperatures. Respiration rates the most consistent physiological response studied have been affected more by solar radiation than by other weather influences. Large differences in respiration rate due to genetic variations have been observed.

Heat Loss

Convection

Heat loss by convective processes takes place in animals. Heat must conduct to the air from the skin by the air currents (Guyton & Hall, 1996) [7]. As the temperature of the air rises, the density decreases and the air move upwards and away from the animal, which is referred as free convection (Robertshaw, 1985) [11]. Forced convection involving a cold air or water moving over the skin surface is more effective than natural convection mainly due to the thermal gradient, which is maintained by the constant renewal of the cooled air or water that blankets the surface of the skin (Cunningham. 2002) [5].

Radiation and Conduction

Heat loss by conduction and radiation occurs and net heat transfer is from warm to cool objects so if the temperature of the body is greater than the temperature of its surroundings, a higher quantity of heat is lost by conduction and radiation from the body than is radiated to the body (Guyton & Hall, 1996) [7].

Evaporation

The process of water evaporation causes heat loss and when water evaporates from the body surface, 2.43 joules of heat is lost for each gram of water (Guyton & Hall, 1996) [7]. Evaporative heat loss occurs through the diffusion of water from skin and by loss of water vapour from the respiratory tract. Rates of evaporative heat loss from surfaces are dependent on air temperature and humidity and the movement of the air.

Heat stress

The normal core body temperature range given for adult cattle living in temperate climates is between 36.7 and 39.1°C' (Cunningham, 2002) [5]. At this temperature, cellular and biochemical activities operate most effectively. Lower and higher temperatures affect metabolism. Increase in metabolic activity, increase heat production that further causing increased metabolic activity. Uncontrolled metabolisms and directly heat exposure result in to *"run-away hyperthermia'* leading to death (Sparke *et al.*, 2001) [16]. With body core temperatures above 42°C there is a risk of this phenomenon developing (Sparke *et al.*, 2001) [16].

Some behavioural signs such as seek shade, going in water, refuse to lie down, inability to move, increased respiration rate, heart rate and laboured breathing, or panting, excessive salivation, sweating. Decrease dry matter intake and feed intake, milk production, and milk quality or absent rumination (chewing of cud) and slower feed passage rate through digestive tract also change in body hormones level, body hormones level. Poor reproductive performance, lower calves birth weight and increase the maintenance energy requirements.

Methods of Heat Stress Prevention

Reducing and prevention of heat stress in cattle and buffalo requires a multi-disciplinary approach. It involves breeding of cattle for improved heat tolerance and improved nutrition for the animals, and improved structural design and environmental control for their housing (Armstrong, 1993) [1]. Breeding of cow for improved heat tolerance is a long term process and is not practical way in most dairy farms in short period of time. Therefore we must focus on short term ways of reducing the heat stress. Prevention of increase in body temperature in hot environments can be approached in three ways (Shibata, 1996) [13].

Environmental Control and Management Practices

Shade, fans, mist and fan systems, and night grazing, are presented as effective methods of modifying the environments of dairy cattle for prevention of heart stress in hot climate. Depend of the different climate, several different methods can apply. In every method, we must cool cow and buffaloes finally decline their body temperature. For better management categorize to climate that includes very humid, mild humid, low humid and very dry climates. Physical modification of the every environment is based on two concepts: Protecting the cow and buffaloes from heat stress, and enhancing evaporative heat loss by the animal. Use of cooling system is a very effective procedure for reducing of heat stress affects on cow and buffaloes. The major objective of every cooling system is to reduce the air temperature, to keep the animal's body temperature as close as possible to the normal. In very humid climates, cow and buffaloes enable to excrete body temperature with sweating. Humidity in this climate, block the sweating mechanism of cow and buffaloes we must cool animals with another methods that don't depend to sweating mechanism. To cool cows in a very humid climate, large water droplet is required to wet the skin of the cow and buffaloes. In hot and humid subtropical regions, evaporative cooling is enable act alone and requires the use of forced ventilation. Sprinklers can installed on the roof or at every various place of animal's house. Spray and fan systems can use for decline heat stress affects in humid areas. Natural air movements, or the use of fans, will also increase the evaporation rate. Fans are the most common type of cooling device used in many countries. Fans can increase the air movement and air movement increases the rate of heat loss from a cow's body surface, as long as the air temperature is lower than the cow's skin temperature. In climates with a low relative humidity, fog or mist systems (fine spray) usage provides evaporative cooling. These systems cool the air around the dairy cattle. In very dry climates dairy cattle can sweat and this sweating cause that most of body heat excreted. Therefore usage of shades is a proper recommendation for dry climates.

Simple shade is the basic method in summer of protecting animals from direct solar radiation during the day. Shades reduced solar radiation negative effects. Animal housed in dry lot or pasture situations should be provided with solid shade. Shade will reduce the amount of radiant heat load the cattle would face that is especially true with dark hided cattle. Natural shading (trees) is effective, but most often shades are constructed from metals that are conductor of heat and especially if their surface be dark, it can be stressor. This is because those dark materials can absorb the sunshine. This subject is worse for dark metals, because they fist absorb sunshine and then conduce to dairy cows body surface.

Natural wind in open housed cows can increase the heat loss from body, but air temperature must be lower than body temperature. If the air temperature is higher than the cow's skin temperature, the skin will gain heat from the surrounding air. At air temperatures above 39 ^{0}C moving air becomes a source of heat stress for dairy cattle.

Late evening grazing

Because that heat stress usually observed under sunlight, therefore one of effective methods for decline the affects of sunlight is evening or night grazing in summer. Air temperature and the level of solar radiation begin to fall after about 3 pm. After 6 pm, usually in all regions, the sunlight is very low and is not stress full for cows. When you cannot send cows in evening or night to pasture, cows should always be ensured of sufficient shade and fresh water.

Delaying the afternoon milking

In hot climates or in summer, in large dairy farms, usually most of lactating cows, waiting a lot of time for milking and at this period of time, they experience the heat stress. One of effective methods for prevention the heat stress is create a delay in afternoon milking for 1-2 hours.

Free Water Availability

Providing access to water during heat stress period is critical and it is a common method for heat stress eliminates in every climate and don't depend to humidity levels. Lactating cattle water requirements is more than dry cows. In normal condition, every dairy cow needs 4-5 kg water for each kg of milk produced. Therefore high producing dairy cows need more water than low producing dairy cows and this high producing dairy cows will be more disposable against detrimental effects of heat stress. It is concluded that dairy cows water needs increase 1.2 to 2.0 times when cows are under heat stress. Water temperature is important factor and if water temperature is high or moderate, dairy cattle needs to more water for eliminating the heat from body. Cool waters are more suitable for prevention of heat stress. Water should be fresh, clean and potable. Availability of clean and cool water to cows leaving the milking parlor is beneficial for increasing water intake during times of heat stress. Access to a 2.5-metres water trough when cows are leaving the milking centre is adequate for milking parlors with 25 stalls or less per side. Ideally, water should be available at every crossover between feeding and resting areas.

Nutritional management

Nutrition is one of the most important factors that affect on heat stress. Changes in ration formulation and feeding programs can help reduce the negative effects of heat stress on the dairy cow. Changes in the ration should be made slowly and prior to the onset of hot weather. Heat stress causes a decline in dry matter intake, the cow's energy and protein requirements in hot environments increase. Therefore, it is important to increase the energy and by-pass protein contents of diets in order to maintain the performance of dairy cows in a hot environment. First we must increase the DMI for compensate the DMI decreased in hot climate. Then we must use of high energy diets, through the use of available grains or fat supplements. One special characteristics of fat is that their heat increment is very lower than another natural feeds. Use of fatty feeds, or the calcium salts of fatty acids, as way of improving the energy supply for dairy cows in summer, is effective method for eliminate the negative affects of heat stress on energy intake of dairy cows (Terada, 1996) [18]. Cows that fed such diets, have a lower body temperature, panting and produce more milk. Among several protein supplements, fish meal is a good source of bypass protein. This protein supplement led to lower body heat production and is very useful for cows in hot climate (Terada, 1996) [18].

In hot climate and heat stress period, cows appetite depressed and every procedure that cause to elevate animal appetite, can help to decline heat stress negative effects. Use of some additional feeds or supplements such as molasses or citrus pulp, cause to increased animal appetite elevation. Molasses are very good select in hot climate, because in hot and dry climate, cows sweating cause that large quantities of body electrolytes such as potassium (Mallonee *et al*, 1985) [10], excrete through sweat and because that molasses are rich source of potassium, use of molasses can replace the excreted potassium and this cause to an elimination in acid-base imbalance.

One of the nutritional procedures for prevention of heat stress is increased feeding frequencies. In most dairy herds in the world, 3 times of feeding are common methods for herds feeding. But if we increased frequencies of feeding from 3 times at day to 4 times at day, lower heat production in body produced and this lower heat product of body conduce to lower heat stress. Another important factors that conduce to more heat production in body, must be attention.

One of the most important affecting factors in incidence of heat stress is levels of low quality fiber in the ration. High levels of hays in ration, conduce to more heat increment and finally more negative effects of heat stress. Use of lower hays levels cause to lower heat increment and conduce to lower heat stress and a very important prevention method. Another recommendation is use of high-quality forages to reduce heat produced in digesting and assimilating feed. If high quality forages availability be low, use of fibrolytic enzyme can increase forages fiber digestibility (Atrian and Shahryar, 2012) [2].

Maintain optimum temperature

Dairy cows have decreased mortality when their environmental temperature is between 14 and 24°C (Stull *et al*, 2008). According Hahn, In lactating Holstein cows, the comfortable temperature is within the range 4-24°C (Hahn 1981)

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