

*Review Article***Effect of Heat Stress on Production and Reproduction Potential of Dairy Animals *Vis-À-Vis* Buffaloes****P. B. Purohit^{1*}, J. P. Gupta¹, J. D. Chaudhari¹, T. M. Bhatt¹, M. M. Pawar², A. K. Srivastava³ and M. P. Patel⁴**

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Abstract

Production and fertility of animals are greatly influenced by management of environment or climate. Buffaloes, due to morphological, anatomical and behavioural characteristics express the signs of great distress when exposed to work in hot weather. Thermo neutral zone is range of temperature and other climate parameter within which healthy animal can maintain its normal body temperature with minimal change in metabolic activity. There are many environmental factors which influence effective surface temperature, air temperature, relative humidity, air movement and radiation from the sun or other sources. The effect of heat stress is aggravated when it is accompanied by high ambient humidity. Temperature humidity index is a simple index, which indicates the degree of heat stress on dairy animals which incorporates the effect of climate parameters like, temperature and relative humidity. Heat stress is negatively correlated with production and fertility parameter. Harmful effect of the heat stress is observed by decline in the milk production, change in composition of the milk, change in growth rate etc. Increase in THI simultaneously increases age at first calving, service period, dry period, calving interval, incidence of silent heat and decreases conception rate, pregnancy rate, lactation length in females. Male reproductive performances are also influenced by temperature. Increase in temperature, decreases sexual desire, ejaculate volume, live sperm concentration, viability, motility, conception rate and fertility rate. Environmental modification is a short-term strategy but can be applied very efficiently for mitigation of heat stress on animals. Long term strategy may include the requirement of genetic tolerant animals by selection of animals in heat stressed conditions and through introgression of heat adaptation genes from local adaptive breed in to non-adaptive or less tolerant herd.

Key words: Fertility, Genetic Evaluation, Heat Stress, Mitigation, Production, THI

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Introduction

India is agriculture-based country and about 70% people are depending on it for their livelihood (DAHDF, 2010). The agriculture and allied sectors contribute about 15.87 per cent of gross domestic production (GDP) of the country which is much higher than world's average (6.4%) in 2018-19 (MSPI, 2018-2019). India is leading milk producer in the world having production of 176.3 million tonnes with per capita availability of 375 gm/day in 2017-18 (NDDDB, 2019). But it is expected that in near future with increase in population, the demand of animal products will increase simultaneously and thereby, security for food and water will be one of the biggest challenges. Over the same period, world will experience shift in local climate which ultimately has impact on local and global agriculture as well as allied sectors. To achieve ceiling milk production, there should be optimum balance between productivity and fertility. Productivity and fertility are influenced by various factors such as genetic, nutritional, hormonal, physiopathology, management of environment or climate. Most of the fertility traits in dairy animals show a very low heritability, and this indicates that most of the variations in these traits are determined by non-genetic factors or environmental effects. The major environmental factors affecting livestock system include air temperature, relative humidity, solar radiation, atmospheric pressure and wind speed. All these environmental factors are pooled to produce heat stress on animals, which is defined as the state at which the animal body physiological mechanisms activate to maintain the body's thermal balance, when exposed to elevated temperature.

Climate change is one of the major threats for survival of various species, ecosystems and sustainability of livestock production systems across the world, especially in tropical and temperate countries. Intergovernmental Panel on Climate Change (IPCC-2014) reported that temperature of the earth is increasing by 0.2 °C per decade and also predicted that the global average surface temperature would be increased by 1.4-5.8 °C by year, 2100. It was also indicated that developing countries tend to be more vulnerable to extreme climatic events as they largely depend on climate sensitive sectors like agriculture and allied sectors. Livestock in tropical country like India experience extreme weather conditions where temperature may reach up to 48°C in summer and decline to as low as -20°C in winter. Buffaloes are more susceptible to heat stress because of their anatomical and physiological characteristics.

Domestication and Adaptation of Buffaloes

All the buffaloes are domesticated from their wild progenitor *Bubalus arnee* (Clutton-Brock, 1999), which is still found within the forest of Assam. *Bubalis arnee* is originated from the genus *Bubalis* from group

Bubalina of Sub-family Bovidae. Two extant types of domestic water buffalo (*Bubalus bubalis*) are recognized based on morphological and behavioural criteria – the riverine and the swamp buffalo. The riverine buffalo is relatively heavier, high producer and highly adaptable to a large range of environmental conditions where temperature rises above 46°C and fall below 4°C than swamp buffalo. Almost all the best milch breeds of buffaloes are river type and found in tropical climatic condition.

Adaptability of Buffalo

Buffaloes are magnificently suited to the hot and humid climate and mucky territory (Marai and Habeeb, 2010). Due to morphological, anatomical and behavioural characteristics they express the signs of great distress when exposed to work in hot weather. Morphologically, the calves having soft hair on their coat at the time of birth and during early calf-hood it becomes sparser and almost devoid as the animal grows. The amount of hair that coat retains varying considerably, depending on the breed, season, housing practices and its exposure to water and mud. Anatomically, buffalo skin is covered with a thick epidermis and the basal cells which contain many melanin particles which give black surface to skin (Shafie, 1985). The melanin particle helps to prevent penetration of the ultraviolet rays through the dermis to inner tissue. Excessive exposure of animal tissue to solar radiation (UV rays) may be detrimental and many-a-times it results in skin tumours. Buffaloes have well developed sebaceous glands than in cattle (Shafie and El-Khair, 1970) which secrete sebum. The greasy sebum, along with the thick hornified top layer of skin, prevents water and the solutes in it from being absorbed into the skin. Moreover, the sebum layer melts during hot weather and becomes glossier to reflect heat rays, thus relieving the animal from the excessive external heat load.

Although, buffaloes are perfectly suited to their environment, even then they suffer a lot in summer, since they exhibit signs of great distress when exposed to direct solar radiation. Greater sensitivity of buffaloes to hot conditions could be due to dark body colour and sparser hairs. It can also absorb more heat and have lesser density of sweat glands which causes inefficient heat dissipation. Thicker epidermis leads to reduction in the capacity of cutaneous evaporation (Sastry, 1983).

Heat Stress

Stress is a reflex reaction of animal in harsh environment and cause unfavourable consequences ranging from discomfort to death. 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) (Buffington *et al.*, 1981). The TNZ explains relationship between animal and environment related to surface temperature and it can be defined as range of temperature and other climate parameter within which healthy animal can maintain its normal body temperature with minimal change in metabolic activity (Dash *et al.*, 2016).

There are mainly four environmental factors which are influencing effective surface temperature; air temperature, relative humidity, air movement and radiation from the sun or other sources. Heat stress exists when air temperature exceeds above the TNZ of an animal, particularly when humidity is high with temperature. The temperature humidity index is one of the best indicators of the degree of stress, which is based on temperature and relative humidity and having significant negative correlation with average milk yield. Dairy buffaloes respond to heat stress in several ways, which include reduced feed intake, increased water intake, changed metabolic rate and maintenance requirements, increased evaporative water loss, respiration rate, rectal temperature etc. This leads to decrease in production and reproduction performance in them. High performing animals are especially more prone to heat stress. Ravagnolo *et al.* (2000) reported that when THI exceed 72, the milk yield declined @ 0.2 kg per unit increase in it.

Elevated body temperature is largely due to a reduction in the temperature gradient between skin surface and the environment. In cattle, heat stress is cyclic in nature, generally, at the peak by mid-afternoon and cool in the evening and early morning hours. During the day, cows in an unshaded environment have higher rectal temperatures and respiratory rates than shaded cows, but at night both measures were lower for unshaded cows (Blackshaw *et al.*, 1994). Exposure of buffaloes to the hot conditions evokes a series of drastic changes in the biological functions such as depression in feed intake, efficiency and utilization, disturbances in metabolism of water, protein, energy and mineral balances, enzymatic reactions, hormonal secretions and blood metabolites. Such changes result in impairment of reproduction and production performances. The effect of heat stress is aggravated when heat stress is accompanied by high ambient humidity (Marai *et al.*, 2009, Marai and Habeeb, 2010).

Global Warming and its Impact on Fertility and Animal Production

Global warming refers to the increase in the earth's average temperature because of the accumulation of greenhouse gases in the atmosphere. Since early 20th century, earth's mean surface temperature has raised by about 0.7°C (1.4°F) out of which about two third of it is raised after 1980. Global warming has multiple effects on ecosystem, agriculture, animal and human health, soil, water resources etc. across the world. Assessment of the potential direct impact of climate change on the reproduction of buffaloes indicate that there is increasing trend in incidences of silent oestrus, the decline in reproductive activity and conception of buffaloes due to increase in air temperature during summer (Singh *et al.*, 1989; Das and Khan, 2010; Upadhyay *et al.*, 2012). The negative impact of global warming on total milk production in India is estimated as loss of about 3.2 million tons of milk by 2020 and more than 15 million tons by 2050 (Das *et al.*, 2016).

Heat Stress Model

Heat stress models are the models formulated by various parameter of the climate after giving different weightage to different parameters. Heat stress models are widely used to know the degree of heat stress due to combination of different parameter.

Various Heat Stress Models for Formulation of Optimum Temperature Humidity and Heat Load Index

Hahn *et al.* (2003) demonstrated that the main natural physical environmental factors affecting livestock system are air temperature, relative humidity, wind speed, solar radiation, precipitation, atmospheric pressure, ultraviolet light and dust. This leads to the establishment of thermal indices which can better reflect the thermal stress of the animal. The majority of studies on heat stress in livestock have focused mainly on temperature and relative humidity because data on the amount of thermal radiation received by the animal, wind speed, and rainfall are not publicly available but temperature and humidity records can be obtained from a meteorological station located nearby.

Temperature Humidity Index (THI)

It is a simple index, which indicates the degree of heat stress on dairy animals which incorporates the effect of climate parameters like, temperature and relative humidity. These indices have been developed as a weather safety index to control and decrease the heat stress-related losses (Wiersma, 1990).

THI is widely used in hot areas worldwide as practical indicator to quantify degree of heat stress on cattle caused by environmental condition as it incorporates effect of both surface temperature and humidity in index. It is one of the best predictors of body temperature in heat-stressed cows than other measurements of environmental conditions (Bonmanova *et al.*, 2007). It has been extensively used for estimation of degree of heat stress in dairy cattle and exhibited that various model of THI were predictive of milk yield in dairy animals, globally. THI indices are often classified to indicate degree of heat stress and the ranges of THI used to define each class are arbitrary (Habeeb, 2018 a&b). In addition to THI various other indices have been developed. One such index is, Heat load index which measure heat stress level in feedlot cattle by incorporating other climatic parameters like RH, WS, black-globe temperature (BGT) etc. (Gaughan *et al.*, 2008).

Various methods have been developed over period of time to formulate the THI, which is applied to measure the level of heat stress on animals (Table1). In general, the THI is a common measure of heat stress for humankind by combining the dry bulb and wet bulb temperature (Thom, 1959). Later on, calculation formulae of THI were extended by including either RH or dew point temperature or both (National Research Council, 1971; Yousef, 1985). There are number of models for formulating THI index. Bonmanova *et al.* (2007) compared different THI models and concluded that there is variation in use of THIs according to

the weather condition. The THI which give more weightage on the humidity work best under humid climates, whereas the indices with more weightage on ambient temperature work more appropriate for region of semiarid climates. When an animal is exposed to harsh climate condition having THI above threshold level, it increases the core body temperature and if the duration of exposure is longer then it leads to greater heat stress in animal. If there are high temperature and humidity in the environment above thermo-neutral zone (TNZ), then it is very difficult for the animal to dissipate heat and the animal undergoes heat stress. There was considerable variation in the result obtained from the different THI models because of the fact that the THI models equation differs, mainly, in the way of estimating humidity. Berman *et al.* (2016) observed that THI equations differ with coefficients associated with temperature humidity estimation which reflect as conversion factors between units and different weights to air humidity as a stress factor.

Table 1: Different heat stress models for formulating temperature humidity indices

| Heat stress models | Formulae | References |
|--------------------|---|-------------------------------|
| THI1 | $3.43+1.058 \times T_{db}-0.293 \times RH+0.0164 \times T_{db} \times RH+35.7$ | (Berman <i>et al.</i> , 2016) |
| THI2 | $(0.8 \times T_{db}) + [(RH/100) \times (T_{db}-14.4)] + 46.4$ | (Mader <i>et al.</i> , 2006) |
| THI3 | $T_{db}+(0.36 \times T_{dp}) + 41.2$ | (Yousef, 1985) |
| THI4 | $(T_{db}+T_{wb}) \times 0.72+40.6$ | (NRC, 1971) |
| THI5 | $(1.8 \times T_{db}+32) - (0.55-0.0055 \times RH \times (1.8 \times T_{db}-26)$ | (NRC, 1971) |
| THI6 | $(0.55 \times T_{db}+0.2 \times T_{dp}) \times 1.8+32+17.5$ | (NRC, 1971) |
| THI7 | $(0.35 \times T_{db}+0.65 \times T_{wb}) \times 1.8+32$ | (Bianca, 1962) |
| THI8 | $(0.15 \times T_{db} + 0.85 \times T_{wb}) \times 1.8 + 32$ | (Bianca, 1962) |
| THI9 | $[0.4 \times (T_{db}+T_{wb})] \times 1.8+32+15$ | (Thom, 1959) |

T_{dp} =Dry bulb temperature, T_{wb} =Wet bulb temperature, RH =Relative humidity, THI =Temperature humidity index

Heat Stress Zone (HSZ)

In general, the TNZ is bounded by two boundaries of temperature as lower critical temperature and upper critical temperature. The upper critical temperature has been defined in dairy cows as 25-26°C (Berman *et al.*, 1985). When the surface temperature of environment surpassed the upper critical temperature, the harmful effect of the heat stress is observed by decline in the milk production, change in composition of the milk, inferior reproduction performance, change in growth rate etc. in cattle and buffalo. Numbers of authors have developed different zone under which animals are comfortable or susceptible to heat stress based on the THI values (Table 2).

Table 2: Classification of heat stress zones based on THI values in cattle

| S. No. | Range of THI | Heat Stress Zone | Author |
|--------|---------------|-------------------------|--------------------------------|
| 1 | 56.71 - 73.21 | NHSZ | Dash <i>et al.</i> 2016 |
| | 75.39 - 81.60 | HSZ | |
| | 80.27 - 81.60 | CHSZ | |
| 2 | <72 | Comfortable | Armstrong, 1994 |
| | 72-75 | mild stress | |
| | 79-88 | moderate stress | |
| | 89-98 | several stress | |
| | >98 | dead cow | |
| 3 | ≤74 | Normal | Livestock weather safety index |
| | 74-79 | Alert | |
| | 79-84 | Danger | |
| | ≥84 | Emergency | |
| 4 | ≤70 | Comfortable | McDowell <i>et al.</i> , 1976 |
| | 71-78 | Stressful | |
| | >78 | Extreme distress | |
| 5 | <72 | No stress | Moran, 2005 |
| | 72-78 | Mild stress | |
| | 78-89 | Severe stress | |
| | 89-98 | Very severe stress | |
| | >98 | Dead cows | |
| 6 | 70-74 | Uncomfortable | Thom, 1959 |
| | 75-79 | Very uncomfortable | |
| | >80 | Seriously uncomfortable | |
| 7 | <70 | no stress situation | Costa <i>et al.</i> , 2015 |
| | 70-72 | state of alert | |
| | 72-78 | critical state | |
| | 78-83 | dangerous state | |
| | >82 | state of emergency | |

NHSZ = Non-heat stress zone, CHSZ = Critical heat stress zone, HSZ = Heat stress zone, THI = Temperature humidity index

Impact of Heat Stress on Female Fertility Traits

Heat stress had hostile relation with the economically important traits. It induces behavioural and metabolic changes leads to adverse effect on important traits. As increase in THI or heat stress levels, traits like age at first calving, service period, dry period, calving interval, incidence of silent heat *etc.* gradually increased while there is attrition in traits like pregnancy rate, conception rate, milk yield, lactation length, protein and fat percentage in milk *etc.*

Age at First Calving (AFC)

AFC is an important economic trait because it is having direct influence on initiation of the productive stage in animal resulting in to giving more number of births, increase in overall lactation yield and decrease in generation interval. AFC is significantly affected by season of calving in buffaloes as reported in many of the studies. AFC was higher in animals which calved during hotter months (January-June) than in cooler months (July-December) (Prajapati *et al.*, 2018; Parmar *et al.*, 2019; Sathwara *et al.*, 2018). El-Sheikh and Mohamed (1965) found that the AFC is shorter in the buffaloes which are born in October, November and December than in those born in any other months, but the differences were not significant.

Silent Heat

Buffaloes are known to be shy breeder and heat symptoms in them are highly affected by the climatic conditions. The percentage of silent heat was found to be 85 and 56 for hot and mild seasons, respectively (Barkawi, 1981). It was also observed that the incidence of silent heat was higher in buffaloes which were calved in hot seasons (35.7 %) compare to mild season (27.3%) (Badr, 1993). Estradiol level is significantly lower during hot climate conditions compared to other months while progesterone level have significant reverse trend in Egyptian buffaloes (Shafie *et al.*, 1982). Decrease estradiol level on the day of oestrus in hot season leads to decreased intensity of oestrus resulting in to silent estrus in Indian buffaloes (Upadhyay *et al.*, 2009). High incidence of quiet ovulation and high percentage of sustained anoestrus in hot month calvers, are most probably due to the effect of hot conditions which cause decrease in pituitary gland responsiveness to GnRH and consequently depress the ovarian activity (El-Foulya *et al.*, 1976; Aboul-Ela *et al.*, 1983).

Service Period

Higher ambient temperature and relative humidity in hot season results into physiological disorder by affecting the digestive system, acid-base balance, blood hormones which leads to longer service period in cattle (Dash *et al.*, 2016). The service period is significantly affected by season of calving in Indian conditions. Significant effect of season of calving on the first service period reported in Mehsana buffaloes (Prajapati, 2017; Sathwara, 2018 and Bhatt, 2019). Further, silent heat is the foremost reason for increasing service period in the hot and humid climate resulting in to poor reproduction ability (Singh and Barwal, 2012).

Dash *et al.* (2013) in their study observed that the average service period of Murrah buffaloes was prolonged (180 days) in May, having THI value of 80.27 and shortest (119 days) in March, having THI value of 67.80. The service period will increase as there will be increase in THI value above 75. Oseni *et al.* (2004) reported that high THI in summer depressed fertility by observing longest service period in March/ April and shortest service period in September. Kaewlamun *et al.* (2011) reported that lowest THI was observed in December

as 72 and highest in April as 80 in Thailand. They further noted that the cows which calved in February had the longest service period as 299 ± 11 days while cows calved in October and November had a significantly shorter mean service as 133 ± 7 days.

Conception Rates

Conception rate is calculated by dividing the number of pregnant cows by the total number of inseminations. The seasonal effect on reproductive behavior is commonly seen in buffaloes. Sexual activity is increased with decrease in the day length and temperature (Zicarelli, 2010), resulting in highest breeding frequency in winter and lowest in summer. The non-return rate (NRR) is one of the important measures for the reorganization of the reproductive ability of the animals. After insemination, if the animal is not returning for further insemination in same lactation then it should be assumed that success in conception. Average number of inseminations required for the fertilization of ova is called as conception rates. Conception rate (CR) is important economic trait because if average conception rate is reduced then it increases the service period and calving interval.

Abayawansa *et al.* (2011) found that the postpartum oestrus exhibition is high in September followed by October and it was low in April and May because of the high ambient temperature. Dash *et al.* (2016) studied the effect of average monthly THI on average monthly conception rate over the period of 20 years and reported significant effect of heat stress on conception rate. They further noted that the highest (78%) average conception rate was recorded in the month of October and lowest (59%) in the month of August. Conception rate decreased with increase in the THI value above 75 in buffaloes.

High ambient temperature in summer season above the TNZ of animal drastically reduced in CR and increases the embryonic loss in cattle. In Florida CR declining up to 10-15% during insemination in hot months due to heat stress (Gwazdauskas *et al.*, 1973; Badinga *et al.*, 1985). Gwazdauskas *et al.* (1975) showed that rising ambient temperature from 12.5 to 35°C was accompanied by decline of CR in cattle from 40 to 31%. An increase in rectal temperature by 1°C at 12 h post insemination was found to be associated with a decrease of CR in cattle (45 vs 61%) (Ulberg and Burfening, 1967). Sarkar *et al.* (2005) reported significant effect of season of calving on the conception rate in Indian buffaloes. Rawat *et al.* (2014) reported that maximum conception rate was achieved at THI within 67 to 72 and THI beyond this range adversely affect the conception rate. THI values above 70 on days prior to breeding cause significantly linear decline in CR and they also reported that when THI value increase from 70 to 84 conception rate decline from 55 to 10 percent. Nabenishi *et al.* (2011) observed that conception rate during the hot period (July to September) was significantly lower than cooler period (October to June). They subsequently found that when the mean THI was more than 80 on a day before the date of service, conception rate declined significantly in a range between 11.6 to 40.5 %.

Pregnancy Rate

Pregnancy rate is defined as the percentage of cows eligible to become pregnant that actually do become pregnant in a given period of time. Daughter pregnancy rate (%) calculated by the formula (VanRaden *et al.*, 2004)

$$\text{DPR} = 21 / (\text{First Service Period} - \text{Voluntary Waiting Period} + 11)$$

In the tropical areas of Amazon basin in Brazil it is suggested that, as THI increase above 75, it has negative effect on the reproduction efficiency in buffaloes (Vale, 2007). Drost and Thatcher (1987) reported that, the temperature of uterus is higher than the blood so, during heat stress there is reduction in the blood flow to the uterus to allow uterine temperature to rise. Decrease level of estrogen in heat stress consequently leads to suppression of the growth and maturation of the follicle; in addition to that it depresses or postpones the "ovulatory spurt" of LH. The correlation between the THI and pregnancy rate has also been reported in buffaloes (Table 3).

Table 3: Effect of heat stress on pregnancy rate

| Decline in PR | THI value | References | Breed |
|---------------|-------------------------------------|-------------------------------|-----------------------------------|
| 41 to 25 % | ≥ 75 | Dash <i>et al.</i> , 2015 | Murrah |
| 34.1 to 15.7% | From 69 -74 | El-Wishy, 2013 | Holstein cow |
| 32.6 to 20.5% | THI above TNZ | Khan <i>et al.</i> , 2013 | Cross bred cattle |
| 2.06% | Each unit increase in THI above TNZ | Amundson <i>et al.</i> (2006) | <i>Bos Taurus</i> cross bred cows |

PR = Pregnancy Rate, THI = Temperature humidity index, TNZ = Thermo-neutral zone

Lactation Length

Lactation milk yield is greatly influenced by the time period for which animal give milk after calving. Thiruvankadan *et al.* (2014) reported that in Murrah buffaloes summer season recorded significantly shorter lactation length when compared with winter season. Lactation length was affected by season of birth in Egyptian buffaloes (Marai *et al.*, 2009). In many studies shortest lactation length have been reported in the summer season in comparison to winter and spring season (Mohamed, 2000).

Dry Period

In Mehsana buffaloes first dry period were reported to be significantly longer in summer months (Prajapati, 2017). Similarly, Thiruvankadan *et al.* (2014) reported significantly longer dry period during summer season in Murrah buffaloes. Same trend has also been reported by Mohamed (2000) in Egyptian buffaloes.

Calving Interval

Calving interval is combination of both gestation period and service period or lactation length and dry period. In Mehsana buffaloes, it has been reported to have longer calving interval in summer months than in winter months (Prajapati *et al.*, 2018 and Sathwara *et al.*, 2018).

Milk Yield

Due to heat stress, the normal physiology of cattle is affected which results in decline in production of milk. High producing cows become negative in energy balance as a result of the catabolic processes which are associated with metabolic heat production over and above that already induced by high nutrient intake. Decline in milk yield as a direct result of high environmental temperatures had been reported widely (Table 4).

Table 4: Effect of heat stress on milk production

| Increase | Milk decrease | References | Breed |
|---------------------------------------|------------------|--------------------------------|-----------------------|
| Each value THI | 0.020 to 0.29 kg | Behera <i>et al.</i> , 2018 | Murrah |
| Temperature | | | |
| From 20-30°C | 9% | Marai and Habeeb, 2010 | Egyptian buffalo |
| Average temperature above 21°C | | | |
| 1.6°C | 4.50% | Marai and Habeeb, 2010 | Egyptian Buffalo |
| 3.2°C | 6.80% | | |
| 8.8°C | 14% | | |
| THI above 69 | | | |
| Each value THI | 0.41 kg | Bourauoui <i>et al.</i> , 2002 | Friesian-Holstein cow |
| Each value THI | 0.41 kg | Spiers <i>et al.</i> , 2004 | Holstein cow |
| THI above 72 | | | |
| Each value THI | 0.2 kg | Hill & Wall, 2015 | Friesian-Holstein cow |
| Each value THI | 0.2 to 0.32 kg | Ravagnolo <i>et al.</i> , 2000 | Friesian-Holstein cow |

THI = Temperature humidity index

On the other side, the decline in the daily temperature by 7°C below normal resulted in an increase in daily milk yield by 6.5% in dairy cattle (Petkov, 1971). The milk yield was significantly different between the heat stress zone and non-heat stress zone ($p < 0.01$) and indicating that the milk yield of dairy cow in region with different microclimates can be significantly affected when THI reaches heat stress level (Gantner *et al.*, 2011). For every 1°C temperature above 21-27°C, production decline of approximately 36% was recorded in dairy cattle (Rhoads *et al.*, 2009 and Das *et al.*, 2016). Cowley *et al.* (2015) estimated a reduction in milk yield, milk protein and casein concentration due to heat stress and also found negative relationship between milk yield and rectal temperature. In an experiment on Holstein cows to assess the decrease in milk yields due to heat stress in tropical conditions, a yield loss of 0.23 kg per day was observed

for unit rise of THI above 66 (Santana *et al.*, 2016). Upadhyay *et al.* (2009) reported that the annual total milk loss due to thermal stress at the all India level was 1.8 million tons or approximately 2% of the total milk production of the country amounting whopping Rs. 2661.62 crores per year.

Milk Composition

Heat stress also influences the milk composition, mainly in high yielding breeds (Ganter *et al.*, 2011; Das *et al.*, 2016). Internal metabolic heat production during lactation can reduce the resistance of cattle to high ambient temperature, resulting in altered milk composition and reduction in milk yield (Chebel *et al.*, 2004; GhaviHossein-Zadeh *et al.*, 2013). When temperature rises above the TNZ, milk composition changes (GhaviHossein-Zadeh *et al.*, 2013). Heat stress reduced milk protein, milk fat, solids-not-fat (SNF) in dairy cows (Kadzere *et al.*, 2002). Further, heat stress reduces milk fat, protein and short-chain fatty acids while increases long chain fatty acids in the milk (Bandaranayaka and Holmes, 1976). In other study, decreased milk protein and fat values were recorded during summer by Bouraoui *et al.* (2002).

Elevated temperature and humidity can reduce the ability of cattle to dissipate excess heat and cause physiological changes which leads to reduce milk protein and fat (Novak *et al.*, 2007). Gorniak *et al.* (2014) reported decline in milk fat and protein when THI rises above 60. Averages of phosphorus and magnesium values were found to be less in summer (Marai and Habeeb, 2010). Citric acid and calcium contents also decline during early lactation while potassium reduced in all stages of lactation in high temperature (Kamal *et al.*, 1962).

Impact of Heat Stress on Male Reproductive Performance

Bull is known as half of the herd, so it is equally important to identify such bulls that can efficiently negate the effect of heat stress. The temperature of bull testes must require 2-6°C cooler than the normal body temperature to produce viable and fertile sperms which indicates that the temperature is an important aspect for the bull fertility. As the testicular temperature increases there is dwindle in the quality of the spermatozoa or it may lead to infertility problems in the bulls.

The noteworthy seasonal difference in semen characteristics were reported by many authors. Ahirwar *et al.* (2018) reported that the thermal stress increases scrotal temperature and reduces semen quality in buffalo bull. Balic *et al.* (2012) studied seasonal influence on 19 *Bos Taurus* (Simmental) bulls and found that in summer heat stress declined semen quality parameters. They also reported that younger bulls are more sensitive to elevated air temperatures during the summer seasons. Mishra *et al.* (2013) observed that the membrane integrity status of fresh spermatozoa in four different breeds of bulls (crossbred, Red Sindhi, Hariana and Jersey) were affected significantly with increases in air temperature from 10-18°C to more than 35°C. Rahman *et al.* (2014) reported that HS spermatozoa showed a highly reduced fertilization rate in comparison to non-HS or normal control spermatozoa (53.7% vs. 70.2% or 81.5%, respectively). Bhakat

et al. (2014) observed optimum 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. Sexual desire is negatively affected by high environment temperature. Such phenomenon, altogether with adverse effects on ejaculate volume, live sperm concentration, viability and motility (Gamecik *et al.*, 1979), reduces conception and fertility rates of the male, *i.e.* reduce the male's fitness. The reaction time was reported to be generally shorter in summer season than during the other seasons. The shortest time (9.4 ± 0.6 minutes) was recorded during summer and longest (15.9 ± 1.5 minutes) in autumn. Values of 10.5 ± 0.7 and 14.7 ± 1.1 minutes were recorded in spring and winter, respectively (El-Saidy, 1988).

Strategies to Combat Heat Stress

Heat stress has negative influences on production and fertility traits of animals that lead to huge economic loss in livestock. Poor nutrition, poor environment and poor management had negative impact on economically important traits (Fair, 2009; Walsh *et al.*, 2011). Basically, three mitigation strategies are commonly being applied for ameliorating the negative influence of heat stress in animals which is being described as, environment modification, nutritional interventions and development of genetically heat tolerant dairy breeds.

These strategies may either be used individually or in combination to achieve better results by providing optimum productive environment to farm animals. Strategies that are cost effective and involve indigenous knowledge have the better success rate in adopting those strategies by the farmers.

Environment Modification

It is the most general approach to combat heat stress and usually attracts more attention as there is augment in the effect of global warming across the globe. Primary means of altering environment is classified in to two broad categories (1) provision of shade and (2) evaporative cooling techniques (Dash *et al.*, 2016). Environment modifications are very critical to get optimal production and reproduction performance in cattle particularly, in arid and semiarid region (Brantly, 2013). Shading reduces the heat stress by reducing direct effect of solar radiation on animal. It is of two types natural or artificial, Trees are natural shade for animal and it captures radiation by evaporation of humidity in leaves. Some researcher also pointed out that painting of upper part of shade and proper construction will help to decrease the heat stress. Evaporative cooling system, spray and fans, use of sprinklers etc. helps to get optimum production and breeding efficiency in animals (Sejian *et al.*, 2012).

Nutritional Modification

Optimum nutrition level to livestock is crucial to get maximum production from the animals in the changing climatic condition. It's important to provide balanced ration to the animals to get optimum breeding efficiency, as energy balance is closely related with their fertility (Sejian *et al.*, 2015). When the animals are under heat stress, there is decrease in dry matter and feed intake due to negative energy balance in the body of heat stressed buffaloes. Due to increase in body temperature and inefficient heat dissipation process, energy requirement for maintenance is found to be increased. Therefore, the measures should be adapted to increase the nutrient density include feeding of high-quality forage, concentrates and use of supplemental fats in the diet of animals. The feed additives are also very useful for stabilizing rumen environment from dietary modifications and also to improve the energy utilization. Feeding of good quality low degradable protein has shown to improve milk production in heat stressed cow.

Feeding supplemental niacin is also helpful in reducing the effect of heat stress in cattle (Dash *et al.*, 2016). Supplementation with antioxidant during the heat stress period is another way to improve fertility through a decrease of oxidative stress in buffaloes (Megahed *et al.*, 2008). Supplementation of inorganic chromium in the feed of buffalo calves reared under high ambient temperature improved heat tolerance and the animal immune status without affecting nutrient intake and growth performance (Krishnan *et al.*, 2017). Inclusion of ascorbic acid in feed ameliorates, heat stress induced problems like poor immunity, feed intake weight gain, oxidative stress, body temperature, fertility and semen quality (Abdin and Khatoon, 2013). HS causes oxidative damage which could be minimized through supplementation of vitamins C, E, A *etc.* and mineral such as zinc (McDowell, 1989). Further, yeast supplementation also was found to reduce the negative effect of heat stress on dairy cows (Amaral-Phillips, 2016)

Development of Genetically Heat Tolerance Dairy Breeds

Differences in thermal tolerance exist between livestock species. Long term strategies have to be evolved for adaption to climate change. Such variation will provide clue or tool to select thermo-tolerant animals using genetic tools. Selection for higher milk yield in cattle has led to increased metabolic heat production and this causes more susceptibility of animal toward heat stress. The productivity and heat tolerance are antagonistic so, the identification and selection of heat tolerant dairy animals is useful to maintain both high productivity and survivability when exposed to heat stress condition. Therefore, the inclusion of THI covariate effects in the selection index should be targeted for genetic evaluation of dairy cattle especially in hot climate (Bernabucci *et al.*, 2014).

Improvement in animal adaptation to climate stress can be obtained in two ways such as, through selection of animals in heat stressed conditions and through introgressions of heat adaptation genes from local breed in to commercial herd (Renaudeau *et al.*, 2012). Heat tolerance is regulated by many genes in the animal

body, there were many studies conducted to know the mechanisms behind the animal's response to heat. These studies can be classified in to, association studies of polymorphism at specific genes and genome-wide association analysis, genome comparison between adapted and non-adapted breeds/species to harsh environment and, differential expression analyses of genes associated with heat stress. As per national livestock policy 2013, cross breeding of non-descript and low yielding cattle with high yielding exotic breeds suitable for respective agro climatic conditions which reveals to improve the production and reproduction potential of cattle in relation to particular environment.

The genes responsible for traits like coat colour and hair length confer heat shock resistance in cells (Hansen and Arechiga, 1999). Cattle with shorter hair, hair diameter and lighter coat colour are most adapted to hot environment than those with longer hair coats and darker colours (Bernabucci *et al.*, 2010). Hair coat characteristics like hair coat thickness and hair weight per unit surface are important determinant of non-evaporative heat loss from the body. The slick hair gene has been identified for increased thermal resistance due to its association with increased sweating rate and a lower metabolic rate in animals (Dikman *et al.*, 2008). The slick hair gene responsible for slick coat improves heat tolerance capacity when introduced into temperate climate cattle breeds (Berman, 2011). Introgression of the slick hair gene (present in Senepol cattle and some lines of highly productive Holstein cattle) has been shown to produce animals with lower body temperature and small declines in production under hot conditions (Dikmen *et al.*, 2014; Ortiz-Colon *et al.*, 2018).

There are many heat shock genes related to thermos-tolerance which was identified and being used as marker in marker assisted selection as well as in genome-wide selection to developed thermos-tolerant bull that can be used in breeding program. The heat shock proteins and DnaJs proteins are two families that are associated with heat stress regulation and they are important for protein translation, folding, unfolding, translocation and degradation (Qiu *et al.*, 2006). Major families of heat shock proteins are, Hsp100, Hsp90, Hsp70, Hsp60, Hsp40 and the small Hsps (so-called Hsps of sizes below 30kDa). HSPs have critical role in cell recovery and in cyto-protection as well as guarding cells from subsequent insults. If the stress persists, these gene expression changes leads to altered physiological state referred to as "acclimation" a process under control of endocrine system. The HSP70 family genes were found to have higher expression in summer in Sahiwal and Tharparkar cattle and buffaloes in India (Kumar *et al.*, 2015). This will increase their thermos-tolerance and adaptive capacity to dry/hot and humid environment. The HSP90, iNOS (Nitric oxide synthase), eNOS, TLR 2/4 (Toll like receptor) and IL (Interleukins) 2/6 could play important role in thermo tolerance in Tharparkar cattle (Bharati *et al.*, 2017^{a&b}; Dangi *et al.*, 2017). HSP70 has also important role in chronic heat stress in Tharparkar cattle (Bharati *et al.*, 2017^c).

There are some other genes viz., ATP1A1 which have been identified to be involved in conferring thermal resistance and adaptation to thermal stress in cattle (Liu *et al.*, 2010; Basiricò *et al.*, 2011). The ATP1A1 gene is also known as Na⁺/K⁺ -ATPase subunit alpha-1. This gene is well recognized for heat shock response because it has association with oxidative stress in cattle (Liu *et al.*, 2010). ATP1A1 gene is responsible for establishing the electrochemical gradient of Na⁺ and K⁺ across the plasma membrane, which is essential in the maintenance of body fluid and cellular homeostasis. The ATP1A1 gene, ATPB2 gene and osteopontin were found to have significant association with thermos-tolerance in buffaloes (Jayakumar, 2014). Prolactin releasing hormone (PPRH) and superoxide dismutase 1 (SOD1) gene had significant role in the heat tolerance in Chinese cattle (Zeng *et al.*, 2018). Liu *et al.* (2019) have reported that in Chinese water buffaloes, plasma heat shock protein (HSP70 and HSP90) and cortisol (COR) levels were higher in heat tolerant buffaloes than in non-heat tolerant buffaloes.

Association of polymorphisms in HSP90AB1 gene with heat tolerance has also been reported in Thai native cattle (Charoensook *et al.*, 2012), Sahiwal and Frieswal cattle (Deb *et al.*, 2014). On the same line, HSF1 gene (Li *et al.*, 2011_a), HSP70A1A gene (Li *et al.*, 2011_b) and HSBP1 (Wang *et al.*, 2013) in Chinese Holstein cattle have also found to have association with heat tolerance. There are many non HSPs genes also which revealed to undergo changes in expression of response against heat stress. These SNPs could be used as markers in marker assisted selection to developed thermo-tolerant animal in early ages. Further, thermos-tolerant bull can be used for breeding to produce thermal adaptive offspring. Identification of major genes associated with thermo-tolerance helps in selecting animal through marker assisted selection and this will help in producing better progeny which can give better production and reproduction performance in the period when THI is higher.

Conclusion

Production and reproduction in cattle and buffaloes are highly affected by the environmental condition. High ambient temperature and relative humidity leads to heat stress in animals. THI is the best indicator for determining the degree of heat stress on animals which amalgamate both the measures of temperature and humidity. Metabolic rates in animals are highly affected by the increased temperature and humidity which leads to change in normal physiology resulting in decline in performance. Decline in the performance traits results in to huge economic loss in dairy farming which may affect GDP of country as well as global economy. Looking in to the global hue and cry about climate change; to minimize the effect of heat stress for long term, there is urgent requirement of improving the animals genetically against heat stress. There is need to adopt breeding strategy which simultaneously select for high productivity as well as heat tolerance. Breeding strategy may involve the adoption of genetic evaluation of animals with suitable THI models. Many of the genes have been identified to be associated with the heat tolerance or susceptibility, concerted

effort is needed to introgress such genes in the susceptible population. Marker assisted selection can be done with polymorphism reported in the associated genes. Global climate change is one of the burning problems, with increase in the world population day by day, it need more animal product to satisfy their wants. To satisfy human needs in the future there is need to increase the animals which are having high productivity in the harsh climatic conditions. For getting maximum production it is required to select animal which are having heat-tolerance gene. Selection of animal which are best performer in harsh climate condition especially in condition where THI is high is most critical and important criteria. In the wake of climate change, application of better breeding strategies and selection of appropriate animals will be helpful in fulfilling human requirements.

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