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Climate change: Impact on dairy animals vis-à-vis adaptation strategies followed by dairy farmers

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Abstract
This paper presents critical review on impacts of climate variability and their change on dairy animals and major adaptation strategies followed by the dairy farmers to mitigate the effects of climate change. Dairy sector is highly sensitive to climate variability and change and at the same time acting as a contributor to the phenomenon. Climate change imposes the great risk and challenges to the growth and development of Indian dairy sector. The climate change would adversely affect the performance of dairy animals, causing heat stress and reducing the area under which the dairy animal cane economically reared, if the temperature will rise between 2.3 to 4.8 °C with increased precipitation resulting from climate variability. The impact of climate variability can be clearly seen as heat stress and cold stress in dairy animal which can affect the reproductive and productive traits of dairy animals. The heat stress is depicted by Temperature Humidity Index (THI) value, when mean THI values are found to be between 35 and 72, the milk production in dairy cows is not affected by heat stress. The impact of climate variability can be reduced by adapting effective strategies like by changes in micro-environment of animals, making changes in the feeding patterns etc. Dairy farming plays a major role in sustaining the rural livelihoods, and acts as a buffer to sustain their lives especially when crop failure occurs. Thus it is important to save dairy animals from the vagaries of climate variability and change.

Keywords: climate change, dairy farming, livestock, heat stress and adaptation strategies

Introduction
One of the greatest challenges being faced by dairy farmers and livestock around the world is heat stress which is associated with the impact of climate variability and change and it strongly affects the animal bioenergetics along with adverse effects on the performance and wellbeing of livestock too. Heat stress to cattle is brought on by solar radiation, high air temperatures and high relative humidity. This is further aggravated by heat production from the animal's own body. In the course of climate change, it is assumed that also in regions traditionally characterized by less extreme climate conditions, dairy animals would be faced with temperatures beyond their comfort zone (IPCC 2007) [6]. The estimated negative impact of global warming on the climate of India is large (Nordhaus 1998) [13]. Data of ambient temperature for the period 1901-2005 indicates that annual mean temperature for the India as a whole has increased by 0.51 °C. The annual mean temperature has been consistently above the normal (normal based on period, 1961-1990) since 1993. This warming is mainly due to rise in maximum temperature across the country. From 1990, the increase in minimum temperature is slightly higher than that of maximum temperature. Spatial pattern of trends in the mean annual temperature shows significant increasing trend over most parts of the country except over parts of Rajasthan, Gujarat and Bihar, where the significant decreasing trends was observed. Season-wise, maximum rise in mean temperature was observed during the post-monsoon (0.7 °C) season followed by winter (0.67 °C) season, pre-monsoon (0.50 °C) season and monsoon (0.30 °C) season. Since 1991, during the winter season, rise in minimum temperature is appreciably higher than that of maximum temperature over the Northern plains of India may be due to pollution leading to frequent occurrences of fog. All India pattern of rainfall during monsoon months does not showed any significant trend. Drought and cyclone frequency are increasing in India (IMD Pune).

Contribution of livestock to climate change
The animal production system is vulnerable to climate change. The Animal Husbandry and agriculture sector is a large producer of greenhouse gas (GHG) emissions. Livestock sector contributes about 18 percent of the global GHG emissions. The GHG includes carbon dioxide, methane and nitrous oxide which accounts for 9 percent, 37 percent and 65 percent of the total GHG emissions, respectively. Methane emission occurs from enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules

for absorption into the bloodstream. Nitrous oxide emission occurs from animal wastes. In India more than 90 percent of the total methane emission from enteric fermentation is being contributed by the large ruminants (cattle and buffalo) and rest from small ruminants and others (Swamy and Bhattacharya, 2006) [17]. The major contributors to methane emission were Indigenous, Crossbred Cattle, Buffalo and sheep & goat accounting 40, 8, 40, and 10 percent respectively. The other livestock consisting of equines (horses, ponies, mules and donkeys), pigs, yak, mithun and camels contributed only 2 percent (0.15Tg) of total emission from livestock sector.

Impact of climate change on dairy animals

Impact of heat stress on production traits in cattle: The intensive selection of dairy animals for high milk production makes them more susceptible to heat stress because of both both reason i.e. higher metabolic heat production and high environmental temperature. There is antagonistic relationship between THI and milk production as the THI and milk production in dairy cattle are negatively correlated with r = -0.76. The decline in milk production was estimated as 21 percent with increase in THI from 68 to 78. With per unit increase in THI above 69 there is decrease in milk yield by 0.41 kg per cow per day (Bouraoui *et al*., 2002) [1]. The milk production in dairy cows is not affected by heat stress when mean THI values are found to be in between 35 and 72 (Du Preez *et al*., 1990) [3]. When THI values are above 76, there is sharp decrease in milk production. Besides the changes in milk yield, heat stress also causes changes in milk composition, milk somatic cell counts (SCC) and mastitis frequencies (Du Preez *et al*., 1990) [3]. Milk yield of Holstein dairy cows was reported to be declined by 0.2 kg per unit increase in THI when THI exceeded 72 (Ravagnolo *et al*., 2000). Therefore THI level 72 is very critical to produce heat stress in cattle which affects the productive performances.

Impact of heat stress on reproduction traits in cattle: High temperature in summer months combined with a high level of humidity has negative influence on reproductive performance in cows and buffaloes. Heat stress is of the factors associated with reduced fertility of dairy cows in summer through poor expression of oestrus. The negative effects of heat stress on conception rate of Holstein cows seem to appear when THI ≥75 on 3 days prior to artificial insemination and the effects of heat stress are more evident in the form of declining conception rate from 30.6 percent to 23 percent when THI was above 80 (Garcia Ispierto *et al*., 2007) [5]. The average pregnancy rate of Murrah buffaloes was found declining from 0.41 to 0.25 with onset of THI ≥75 and therefore the threshold THI for pregnancy rate in buffaloes was determined as 75 above which the detrimental effects of heat stress on fertility were observed in buffaloes. The low reproductive activities have also been observed in animals during summer.

Assessment of heat stress

Assessment of heat stress can be done by measuring meteorological variables of environment and then evaluating their effect on animals by using appropriate heat stress index. Various indexes have been developed which take into account such factors as ambient temperature, relative humidity, solar radiation and evaporation rate. These are known as THI (Temperature Humidity Index). Measuring heat stress can help the farmers for maintaining cows at optimal temperature and prevent from negative results of heat stress.

THI can be assessed by different equations and most commonly used are the following:

$$THI = Tdb + 36\ Tdp + 41.5\ THI = 0.72\ (Tdb + Twb) + 40.6$$

Where Tdb is the dry bulb, Twb- the wet bulb and Tdp- the dew-point temperature (in ^{0}C) value of THI is 70 or more than 70, cows and buffaloes are supposed to be under little discomfort. If the THI is 70-75, the animals are uncomfortable. They show depressed feed intake and milk production. At 78 or more THI value, cattle show a measurable degree of discomfort. As this THI increases, the level of discomfort also increases. This range is applicable to all livestock species.

Impacts of thermal stress on milk production: Reduction in milk production is one of the major economic impacts of climatic stress in dairy cattle. Decreased synthesis of hepatic glucose and lower Non Esterified Fatty Acid (NEFA) level in blood during thermal stress causes reduced glucose supply to the mammary glands resulting in lower level of lactose synthesis which in turn ensues low milk yield. Reduction in milk yield is further affected by decrease in feed consumption by the animals to compensate high environmental temperature. Reduced milk production due to thermal stress is attributable only partly to decrease in feed intake. Approximately 35 percent reduction in the milk production is mainly due to decreased feed intake while remaining 65 percent is attributable to direct effect of thermal stress. Other factors resulting reduced milk production during thermal stress are decreased nutrient absorption, effect in rumen function and hormonal status and increased maintenance requirement resulting in reduced net energy supply for production.

Table 1: Milk production decline (%) in relation to THI

THI value	69	70	72	73	74	76	77	78	79	80	81	82	83
Percent decline in milk	0	9	11	8	19	27	28	25	23	34	22	31	30

Milk yield of crossbred cows in India (e.g., Karan Fries, Karan Swiss and other Holstein and Jersey crosses) are negatively correlated with Temperature Humidity Index (Table 1). The influence of climatic conditions on milk production has also been observed on local cows which are more adapted to the tropical climate of India. The magnitude of the reduction in milk yield under hot conditions depends on the environmental conditions under which animals are kept, composition and quality of the diet provided, access to fresh water and shade, genotype (adaptability and milk yield potential) and Management of animals.

Cold stress: Like all mammals, cows are warm blooded and need to maintain a constant core body temperature. Normal rectal temperature for a cow is around 38 °C (101°F). Below the lower limit of the thermo-neutral zone, in the "lower critical temperature," the animal experiences cold stress. To combat cold stress, the animal must increase its metabolic rate to supply more body heat. This increases dietary requirements, particularly for energy. The effects of cold stress on metabolic and physiological adaptations are as following:

- Increased dry matter intake and increased rumination
- Increased gastrointestinal tract motility
- Increased rate of passage of feed and liquid in the rumen and digestive tract

- Increased basal metabolic rate and maintenance energy requirements
- Increased body oxygen consumption and cardiac output
- Increased adrenalin, cortisol and growth hormone levels
- Increased lipolysis, glyconeogenesis, glycogenolysis
- Increased hepatic glycose output
- Decreased rumen volume and dry matter digestibility
- Decreased insulin response to a glucose infusion
- Decreased temperature of skin, ears, legs

There are a number of factors that alter the effects of cold temperatures on animals: wind, hair depth, hair coat conditions etc. It is important to emphasize the value of a clean, dry hair coat and clean, dry environment with minimal wind for animals exposed to low temperatures.

Adaptation strategies

Adaptation to Climate variability and change particularly in livestock is possible and different approaches may be followed. Some of these approaches may be used without much investments however others require economic and policy support for adaptation of resource poor farmers.

Micro-environment modification

Heat stress alleviation to an extent is possible by environmental modifications and provision of animal shelter or shade decreases direct solar radiation exposure. Either an increase in convection with fans or to decrease air temperature by evaporative cooling or to directly cool the cow through use of sprinklers and soakers are some of the strategies that may be followed (Knapp and Grummer, 1991) [9].

Animal shelters: The environmental modifications to reduce the thermal stress of livestock that may be used under tropical conditions are proper shade or shelter that reduces the incoming solar radiation as much as 30 percent for the livestock and thus reduces thermal loads (Wiersma *et al*., 1984) [20]. Adequate shade or protection from direct solar radiation should be provided where livestock are kept. A tree shade is an ideal choice under most tropical and subtropical climatic conditions. The three main locations where tree shade can be used are a) holding pens, b) confined feeding areas and c) resting areas. In holding pen or areas shade against direct solar radiation can be provided by either trees like banayan, neem, peepal or shelters made of straw and other locally available materials like bamboo. In absence of trees or shelters cloth or gunny bags shades with the help of Bamboos or tied with hooks using ropes or cables may be provided to livestock for protection from solar radiations. These shades should be removed during comfortable weather (Feb-March and Sept-November) and re-installed during summer and extreme winter.

Ventilation in shelters: During the hot weather conditions hot air gets trapped inside the animal shed therefore it becomes essential to increase the air flow inside the shed. Air movement should be free in all the section of an animal shed. Two approaches may be used to increase air flow in a shed. First one is by the structural modification of the shed that permits use of normal air wind velocity and flow of air in a building, however second option is to install the fan. Most animal sheds with proper orientation may increase ventilation by making use of natural ventilation. One of the latest designs used regarding this is tunnel ventilation system. In this system large volume of air moves in a linear or "tunnel" fashion through the shed. Fan at the one end of the shed operate to draw fresh air at high speed in large inlets located on the opposite end. It has been suggested that the air movement at high speed may help in decreasing THI and improve animal comfort.

Heat alleviation by water cooling or Sprinkle System: In addition to shade and ventilation, water is also used to reduce the thermal stress on livestock. Sprinklers system can be used for increasing evaporative cooling. The main purpose of sprinkler system is to maximize the amount of heat removed from the animal through evaporative cooling at a reduced water cost. In addition, the ambient air temperature is lowered in the area immediately surrounding the animal, increasing the heat gradient and increasing the effectiveness of non-evaporative cooling mechanisms. Four major categories of sprinkles system are in common use now a day: a) sprinklers, b) drippers, c) misters, and d) foggers. Sprinklers are the most commonly used and recommended type of emitter. Sprinklers spray water as large droplets into some predetermined pattern. Drippers will drip water at a relatively slow rate as individual droplets. The individual droplets will drip from the emitter and tend to all land in the same general, small location. Since drippers do not really create a wetted pattern, they are not used much for dairy applications.

Misters spray water as relatively fine droplets into some predetermined pattern. The flow rate tends to be fixed, but the patterns available can be circular or rectangular. Misters are not recommended because misters generate relative small droplets. The small water droplets tend to collect on the hair coat surface and not soak through to the skin. Foggers spray water into a very fine mist or aerosol. This mist or aerosol will evaporate into the air and decrease the temperature of the air.

Ceiling fans: In holding areas and free stall shelters the fans should be installed longitudinally, spaced not more than 10 times their blade diameter. They should be located vertically and just high enough so that they are out of reach of the cattle and do not interfere with alley scraping or bedding operations.

Cooling ponds: Animals in pond loses heat primarily by conduction, since the animal surface is in contact with water but during 5-10 minutes and immediately after leaving the pond (during 5-10 minutes), a small amount of heat is also lost by evaporative cooling.

Animal feeding and nutritional modification

When animals are exposed to heat stress, the biological functions are affected which include depression in feed intake and utilization, disturbances in the metabolism of protein, energy and mineral balances, enzymatic reactions, hormonal secretions and blood metabolites (Marai *et al*., 2009) [10], resulting in the impairment of production and reproduction performances. The dry matter intake is (DMI) reduced under heat stress conditions, as a result the negative nitrogen balance may occur (West, 1999) [19]. When the dairy animals are in heat stress condition, it was also found that dry matter digestibility and protein/energy ratio were decreased (Moss, 1993) [12]. During the period of heat stress in summer dietary feed intake of livestock is decreased and impacts livestock production. Therefore, some simple feeding and nutritional strategies can be implemented to reduce the negative effects of heat stress on livestock production. The composition of the diet is believed to be important in alleviating heat stress. The first nutritional approach to decrease the effect of heat stress is to decrease dietary fiber intake to the levels where the rumen can function properly. Although increasing the level of grain feed is widely practiced in summer, any drop in fiber levels should be approached cautiously. For high producing animals fat content of 6-7 percent of diet dry matter is recommended. Cattle suffering from heat stress often have a negative nitrogen (N) balance, because of reduced feed intake. Both the quantity and quality of protein in the diet need to be considered when feed is being provided for heat-stressed livestock and particularly dairy cows or buffaloes. Increasing the level of crude protein may increase energy requirements and cause problems of environmental pollution. Excess dietary protein is converted into urea and excreted. The level of crude protein (CP) in the diet should not exceed 18 percent during heat stress and the level of rumen degradable protein should not exceed 61 percent of CP or 100 grams of N/day (Higginbotham *et al*., 1989; Huber *et al*., 1994) [8, 7].

Minerals and their supplementation: Heat stressed livestock decrease their voluntary feed intake during hot weather, thus their mineral intake is also less than optimal that becomes an additional limiting factor in hot humid environments. The increased pulmonary activity and perspiration also cause an excessive loss of water, thereby reduce mineral levels. Minerals, sodium (Na) and potassium (K) are important in the maintenance of water balance, ion balance and the acid-base status of heat-stressed cows. Livestock utilize potassium (K^+) as their primary osmotic regulator of water secretion from their sweat glands. As a consequence, K^+ requirements are increased (1.4 to 1.6% of DM) during the summer, and therefore this should be adjusted for in the diet of animals. In addition, dietary levels of sodium (Na^+) and magnesium (Mg^+) should be increased during summer, as they compete with potassium (K^+) for intestinal absorption. Addition of minerals and electrolytes during summer could also improve milk yield. Studies indicates that the lactating cows fed complete mixed diets supplementation of K (Mallonee *et al*., 1985) [11] and K and Na (Schneider *et al*., 1984) [18] above recommendations (NRC, 1978) [14] during heat stress resulted in 3 to 11% increases in milk yield. In hot weather, the level of milk fat is usually lower, therefore supplementation with buffers such as sodium bicarbonate ($NaHCO_3$) and magnesium oxide (MgO) is recommended during summer. Adding sodium bicarbonate to the diet may help in maintaining the pH of the rumen.

Animal feed additives: Along with the major dietary nutrients feed additives can also be used to alleviate the heat stress. The feed additives generally increase the heat dissipation and thereby decrease the internal body temperature. Studies indicate that the fungal culture in diet decreased body temperatures and respiration rates in hot weather (Huber *et al*., 1994) [7]. Niacin (nicotinic acid) can also be used as beneficial supplement because it induces peripheral vasodilation for transferring body heat to the periphery (Di Constanza *et al*., 1997) [4]. Studies on feeding of encapsulated niacin have been observed to increase sweating rates and lower core body temperatures with additional benefit of increase in fat- and energy-corrected milk (Zimbelman *et al*., 2007) [22]. Feeding of antioxidant (Vit-A & E, selenium, Zinc etc) may help in reducing the heat stress and serve as a good strategy to prevent mastitis, optimize feed intake and reduce the negative impact heat stress. Antioxidants enriched yeast also help in reducing the impact of heat stress on the oxidative balance and improve milk quality and cows health. In addition to this feeding of microbial or "probiotic" products deals with either A. oryzae or S. cervisiae may help in reducing the impact of heat stress (Huber *et al*. 1994., Yoon and Stern 1996) [7, 21].

Feeding Time: Heat production from feed intake peaks from 4 to 6 hours of post feeding in animals. The heat production in animals fed in the morning will peak during the middle of the day when environmental temperatures are also high. Therefore, it has been suggested that feeding animals later in the day or cool parts prevents the coincidal occurrence of peak metabolic and environmental heat load (Reinhardt and Brandt, 1994; Brosh *et al*., 1998) [16, 2]. In order to improve the dry matter intake during summer and to reduce heat stress the frequency of feeding should be increased and small quantities of the ration should be given during the day. Often feeding fresh feed improves dry matter intake and more frequent feeding keeps feed fresh and encourages the animals to eat more.

Water: Providing enough access to water during summer is critical in livestock management. During heat stress water requirement is increased by 1.2 to 2 times. Production is severely reduced when water is limited as feed intake, and milk yield is related to water turnover. Consumption of the water is the quickest and simple method to reduce the core body temperature via reticulo-rumen and cooling effects of panting and sweating. Therefore, adequate supply of cool, fresh, and clean water is essential to minimize the effects of heat stress in lactating cows and buffaloes.

Feeding during summer: A proper emphasis should be given to the feeding of animals during summer to maintain the milk production. Generally there is a chronic shortage of green fodders in months of May-June and the animals are fed dry materials, like straws and stalks (Kadbi) of Bajra, sorghum and maize. In order to obtain maximum milk yields a concentrate mixture containing 16 percent DCP and 70 percent TDN along with palatable, digestible and laxative fodders should be provided to the animals. Multicut fodders like guinea grass, napier, bajra hybrid can be maintained for milk production throughout summer. Mixing of cowpeas to the above fodders benefit additionally to overcome the deficiency of protein. Feeding schedule should be shifted to early morning or late evening during summer.

Management of effects of cold stress

- Environmental temperature should be recorded and increase feeding during cold weather. There is additional grain feeding require during periods when the effective temperature falls below the lower critical level for cows in the last trimester.
- Protect animals from the cold wind by providing adequate dry bedding and curtains etc.
- Cows should have ample water available at all times. Frozen troughs and excessively cold water seriously limit water intake.
- Dry teats when the dairy animal leaves the milking parlor are important. Dip the teats for about 30 seconds and then blot dry using a paper towel.

Conclusion

The Indian livestock sector, one of the most important parts of agrarian economy is vulnerable to climate change. The increase in temperature due to climate change is likely to have negative impacts on milk production, growth, reproduction and animal diseases. In order to improve the livestock production system in the present and future climate change scenarios, there is need to develop various adaptation strategies. Adaptation strategies like micro-environment modification, animal feeding and nutritional modification, livestock breed improvement, genotype modification and improvement in animal health service should be adopted. This sector has great potential for employment generation and substantially contributes towards food and nutritional security and alleviation of poverty. The severity of heat stress issues would become more of a problem in the future as global warming progresses and genetic selection for milk yield continues. Evaporative cooling systems improve the environment for lactating dairy cows and buffaloes in arid climates by reducing air temperature. The fan cum mist cooling system is very effective during the hot-dry climate when temperature may rise as high as 46 ^{0}C but, the effectiveness of evaporative systems in climates with high relative humidity is limited. The blasting of air by high speed fan through animal shed causes a significant decrease in relative humidity which in turn enhance rate of heat dissipation from animal to environment leading to maintenance of awnings. Though crossbreeds have the high genetic potential of milk production, but the productivity declines due to environmental stress (low quality feed and fodder and high susceptibility to diseases). With improved care and management milk production can be increased in indigenous cattle.

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