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Invited Review Article

Impact of climate change on livestock production

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Abstract

As climate change is directly related to agriculture, hence, any climate change will ultimately affect food production. It is assumed that in the coming decades there will be marked global warming owing to the fact of increased atmospheric carbon dioxide along with other greenhouse gases leading to obvious hydrological regimen alterations affecting agriculture and animal husbandry. The major problem is related to changes in crop biomass availability and its quantity, which in turn reduces the fodder supply. Another vital impact of climatic change is the heat stress on the animals leading to elevation of body temperature and requiring more energy for maintenance which ultimately hampers the production and reproduction attributes. Mitigating strategies like nutritional modifications, housing management, breed selection, etc. will help to alleviate the prevailing and forecasted hindrances and will finally benefit the animal keepers with more profitability, suitability, and sustainability.

Key words: Animal production, Climate change, Stress

Highlights

- Nutritional management may help to alleviate the negative impact of climate change.
- Housing management will help to reduce the stress of extreme climates.
- The introduction of tolerant trees-tolerant varieties along with the application of ITK will help for sustainable production.
- Contingent planning along with insurance hold an important part of management.

INTRODUCTION

Significant variation in the mean state of climate over decades is defined as climate change. Of late, this climate change is a widely accepted statement, and everybody is concerned about the effects of climate change. Warming of global climate has multidimensional paraphernalia in nature and affects economic and social systems including agro-ecosystem, health, soil, and water resources. The agricultural scenario from an Indian perspective is changing rapidly due to the climatic aberrations and nowadays, it is the most challenging aspect for all the stakeholders of coastal areas of Sundarbans and the northeast region of our country having the vast biodiversity will be affected much more due to this climatic aberration to a great extent which may affect the agro-allied practices of this region (Khan *et al*., 2009).

The financial impact of the agricultural sector is huge on the national economy as this sector contributes 23% of GDP. As climate change is directly related to agriculture, climate change will ultimately affect food production. It is assumed that in the coming decades, there will be marked global warming owing to the fact of increased atmospheric carbon dioxide along with other greenhouse gases leading to obvious hydrological regimen alterations (Mimikou *et al*., 1991, Watson *et al*., 1998). The change in climate will affect agriculture in the manner

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of drastic alterations in farm productivity and profitability, hampering the supply-demand chain. These changes will ultimately increase the ongoing demand for food which will be for the increased population.

The change in climate affects the crop production system including animal husbandry and horticultural crops. The major problem is related to changes in crop biomass availability and its quantity, which in turn reduces the fodder supply. Another vital impact of climatic change is the heat stress (Thornton *et al*., 2009) on the animals leading to the elevation of body temperature and requiring more energy for maintenance. Thermo-neutral zone is defined as the range of ambient zone of environment that is favorable to help and performance of animals (Hahn, 1999; Sirohi and Michaelowa, 2007). The temperature above the upper critical level induces heat stress on animals. Besides, high humidity and radiant energy from sunlight also cause stress to the animals. The THI (temperature humidity index) is the best indicator to evaluate heat stress in animals. THI more than 72 is the point of precipitating heat stress to the animals.

The climatic aberrations have already affected all the continents hampering their biological systems (Rosenzweig *et al*., 2008). The IPCC, in the Fourth Assessment Report (AR4), stated the temperature increment in the range of 1.8-4ºC in 2090-2099 relative to 1980-1999 related to projected greenhouse-gas emissions.

As the ambient temperature rises, the thermal gradient between animals and their environment decreases. This reduces the quantity of heat that the animals can lose to the environment by physical means such as convection and conduction, thus forcing the adoption of survival strategies for dissipation of body heat like behavioral changes, decreased feed intake, increased evaporative losses (i.e., respiratory and sweating), increased water intake, and alterations of body fluid volume and blood flow distribution (Mallonee *et al*., 1985). In heat stress conditions, calves require more blood flow to the cutaneous portion resulting in reduced blood flow to the vital internal organs which ultimately leads to impaired metabolism and lack of energy. Hence, the energy required for the production of milk is reduced. Moreover, climate change, especially in hot and humid climates, may also affect reproduction. Heat stress leads to reduced infertility (King *et al*., 2006), less hatchability, and even the production of weak offspring. Easterling and Apps (2005) pointed out the paucity of appropriate models that narrate climate to animal physiology. As the increment of temperature alters the heat exchange of animals with the environment, hence, intake of food, mortality, production, and reproduction along with all other traits and attributes will be hampered. Another important factor, especially for the coastal Sundarbans region, is an increase in the frequency of cyclones and the ingression of saline water into agricultural land due to the breaching of the embankment. This poses a serious threat to the animal rears of this region, mainly for the scarcity of drinking water for animals, breakage of animal houses, lack of grazing fields, and post-flood/inundation disease outbreak. The impact of climate change has been summarized in a schematic diagram (Fig. 1).

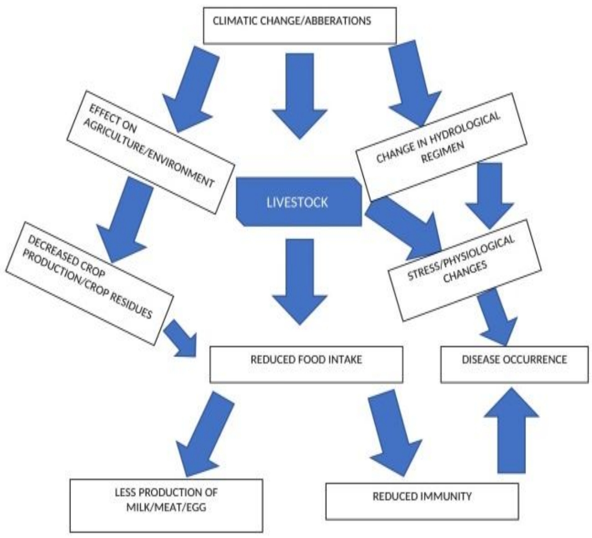

Fig. 1. Diagram showing the impact of climate change

Effect on fodder production and mitigating strategies

The major strategies to be developed for fodder production combating climatic aberrations is to shift from natural precipitation-based production to irrigation-based production, selecting C4 and CAM plants over C3 plants if possible. High temperatures cause prolonging of the potential vegetation period with a shortening of the actual vegetation period; hence fodder of longer duration should be of choice for better yield (Thornton *et al.*, 2009).

Impact of climatic change on animal production

The animal production system has got a significant impact on climatic aberrations due to the increase in average earth temperature. The total effects are discussed in the following subheadings.

Effect on metabolism: As the environmental temperature rises above the ambient temperature (>30ºC), heat production exceeds the sum of heat loss from different ways like radiation, evaporation, conduction, and convection. As a result, feed intake decreases to compensate for heat production. Lowered feed intake leads to less availability of nutrients and protein affecting the productivity of farm animals and poultry birds as well.

Apart from that, an excessively hot and humid climate precipitates/initiates panting and hyperventilation resulting in higher CO_2 emissions leading to respiratory alkalosis. This respiratory alkalosis again settles down acid base imbalances, ultimately hampering the metabolism. The animals having higher basal metabolic rates suffer more from heat stress. Thus, to sustain this climatic change, a genotype having comparatively less growth rate, and less egg and milk production should be of choice to minimize metabolic heat production (Joshua and Sandeep, 2022).

In poultry, the activity of trypsin and chymotrypsin, and amylase is reduced greatly (Hai *et al.*, 2000) due to heat stress which impairs the digestibility of nutrients. In pigs, heat stress affects the thyroid hormone activity and reduces its level, which intern influences the protein turnover in the body (Fernandez *et al.*, 2015).

Effect on the immune system: The changing trends of temperature beyond optimal limits tend to reduce the numbers of WBCs (Heller *et al.*, 1979) as well as cause a decline in antibody production (Zulkifli *et al.*, 2000). As the condition leads to lowered immunity, the chance of invasion by microorganisms is more compared to animals in the thermo-neutral zone.

Effect on animal produce/production: Due to climatic vulnerability, there is impaired metabolism resulting in reduced uptake of nutrients which has a positive correlation with the production of animals. Apart from this, heat stress reduces the defense mechanism of the body vis-à-vis and increases the chance of infection. In this situation, the administration of antibiotics and antimicrobials becomes compulsory, which directly or indirectly reduces the quantity and quality of animal meat/ produce or hampers food safety standards. Altogether this may lead to a loss of consumer confidence.

The effect of heat stress is visualized more in poultry. Beyond 30ºC, poultry birds reduce their feed intake remarkably (Daghir, 2009), and egg production falls rapidly. In broilers, the reduction of feed intake reaches a maximum of up to 50% decreasing the nutrient availability required for optimum growth in broilers. Heat stress invades panting and stimulates to loss of a large amount of CO_2, which is an essential part of Calcium Carbonate in eggshell formation. Thus, thin-shelled eggs, broken eggs, and lighter eggs are the result of heat stress in poultry (Mashaly *et al.*, 2004).

Heat stress in pigs precipitates/causes more cutaneous blood supply to augment the heat dissipation procedure and thus less supply to the mammary gland leading to lowered milk availability for the piglets (Renaudeau *et al.*, 2003). Thus, the growth of piglets and their body weight gain hampers. This type of physiological compromise happens beyond 36°C temperature (Babinszky *et al.*, 2011). Comparative to other species, the pig performs well in the 30-33°C temperature range and displays compensatory growth by overcoming the heat stress in this range. But, more interestingly, it has been observed from recent studies that apart from impaired growth, heat stress also causes altered nutritive value of pork, and hence the quality of the product/produce deteriorates. This happens because of reduced protein deposition in growing pigs (Le Bellego *et al.*, 2002; Kerr *et al.*, 2003), and back fat thickness reduces due to lowered activity of the lipogenic enzyme (Noblet *et al.*, 2001).

Feed refusal is likely to affect the cattle population also with the development of some metabolic disorders, especially ketosis. This condition affects milk production due to impaired blood circulation in the mammary gland during heat stress. In ruminants, milk quality depends on two volatile fatty acids- acetic acid and propionic acid for protein incorporation. During heat stress, lowered feed intake along with high water consumption changes the normal ruminal environment and reduces the production of volatile fatty acids resulting in low milk yield with poor quality.

Effects of thermal stress on the endocrine system: Thermal stress alters the level of different hormones in the body and in turn influences the acclimatization and adoption of animals toward adverse climatic vulnerability (Bernabucci *et al.*, 2010). When there are high rises in temperature, the T_4 level decreases (Collier *et al.*, 1982; McGuire *et al.*, 1991; Nardone *et al.*, 1997).). T_4 is closely associated with gut motility, and hence, as T_4 decreases in stress, the appetite will also decrease (Beede and Collier, 1986). Thermal stress in animals has been found to alter the activity of the thyroid gland resulting in a reduced concentration of thyroxine (T_4) and an increased concentration of tri-iodothyronine (T_3) in plasma. It has been speculated that reduced thyroid activity reduces GI tract motility and rate of ingesta passage. Similarly, the secretion of adrenal hormone aldosterone is decreased due to thermal stress, which causes reduced sodium reabsorption in kidney tubules resulting in electrolyte imbalance. Levels of catecholamines (adrenaline and noradrenaline) and glucocorticoids (hydrocortisone) were found to be sharply increased when Holstein cattle were exposed to high ambient temperature (40 - 43°C) with glucocorticoid levels returning to normal after long heat exposure, but the level of catecholamines remained persistent. Likewise, the level of prolactin hormone was found to be increased during thermal stress. In contrast, the secretion of plasma somatotropin was marginally reduced during thermal stress, which is independent of reduced dry matter intake (Kahl *et al.*, 2015).

Strategies to combat stress effects

- Climate change and resulting stress due to excessive heat are one of the major problems in the poultry industry which account for huge losses (St-Pierre *et al.*, 2003) (Fig. 2). Sudden alterations of climate and changes in ambient temperature led to the loss of control for adaptation of body temperature (Lara and Rostagno, 2013) and a rise of environmental heat above 25°C precipitates heat stress (Donkoh, 1989) which leads to acid-base imbalance and settles respiratory alkalosis and the birds start excreting higher bicarbonate which again couple with Na^+ and K^+ ions. Supplementation of $NaHCO_3$ and KCl helps to reduce heat stress and improves eggshell quality and overall performance in broiler birds (Hurwitz *et al.*, 1973; Smith and Teeter 1987; Benton *et al.*, 1998; Ahmad *et al.*, 2008; Mushtaq *et al.*, 2013). As heat stress increases potassium (K^+), sodium (Na^+) loss, hence supplementation is necessary.
- Reproduction and nutrition are uttered simultaneously as they are intensively correlated (Maurya *et al.*, 2010). Besides

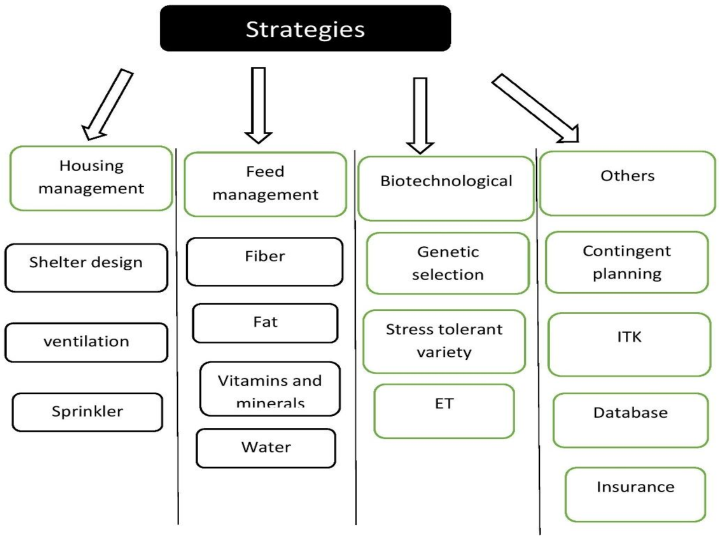

Fig. 2. Strategies to mitigate the climate change

from lack of year-round feed (Salem and Smith, 2008; Kawas *et al*., 2010), heat stress has been proven to have a great impact on postpartum ovarian activity (Zarazaga *et al*., 2004) and improper oestrus signs (Schillo, 1992). Therefore, replacement with specific needs of the ruminants, especially protein, fat, and minerals are of paramount importance (Maraia *et al*., 2008). Sulfur should be incorporated into the ruminant ration for synthesizing protein by ruminal bacteria, the ultimate source of protein to ruminants (Silva *et al*., 2014)

- As milk contains a significant amount of Na and K, hence, restriction in diet may result in a drop in milk yield (Mallonee *et al*., 1982) which may be involved with climatic change affecting fodder quality also (Cunha,1983). In heavy heat stress, loss of Na and K may occur, which ultimately will hamper the thermos-regulatory capacity of the body (Johnson,1970; Jenkinson and Mabon,1973; Mallonee *et al*., 1985) as well as the renal selective regulatory capacity of excretion and conservation. Thus, dietary deficiency of Na and K may lead to a severe loss of milk production. $NaHCO_3$ should be provided at a higher level to increase milk production in heat-stressed dairy animals (Schneider *et al*., 1984).
- Heat stress always leads to a loss of production and reproduction attributes. Even in the stressed conditions, the attributes may be continued in the same magnitude with the modifications of diet like the lower quantity of consumption, change of feeding time, and several feedings. These modifications stand very effective in the poultry sector as the poultry are worst affected by heat stress (Renaudeau, 2012). Frequent feeding with small quantities instead of a full ration at a time should be provided even during the time of cooler part of the day.
- Generally, the digestion of feed produces metabolic heat, which may be referred to as internal heat production. If fat is added to the feed, it may reduce the total required dry matter intake. Fats are not fermented in the rumen and hence, there will be no further metabolic or internal heat production which in turn may help the animal to keep its body comparatively cool. Additional fat in the diet should be incorporated to boost energy through diet as well as to reduce heat production during heat stress (Das *et al*., 2016).
- A low-protein diet should be provided during heat stress as excess protein contributes further heat production.

- The addition of betaine in the diet, especially in pig and poultry ration in heat stress, helps to incorporate methyl as a potential lipotropic effect and thereby reduces heat production.
- A stress-tolerant variety of poultry like naked neck may be selected. The introduction of naked neck gene in the present stock will produce the stock with fewer feathers in the neck area which ultimately results in better heat dissipation from the body (Hester, 2017).
- Strengthening/remodeling of animal houses. Health and production along with welfare are being hampered due to the hot and humid conditions of the environment. Proper housing management can greatly reduce such stress. This stress drastically reduces the overall performance of animals. Along with providing shelter, appropriate heat-absorbing roof materials with proper angle; microenvironment, and aeration; scientific manger and supply of clean and fresh water should be considered (Singh *et al.*, 2020)
- Contingency planning: Real-time contingency planning (RTCP) may be theorized and applied at grass root level in farmers' plots. RTCP application during delayed monsoons, droughts and heat waves may yield improved performances in animals (Rao *et al.*, 2016).
- Use of Indigenous technical knowledge (ITK): The technical knowledge, even though mostly is not validated, still have been proven to be efficacious for a long time. Use of such locally available knowledge may be accepted and employed to reduce the deleterious effects of heat stress. One example of such ITK is maintaining male with the female in practice; providing boiled Maithi (*Trigonella foenum graecum L.*) with wheat bran for three days; offering 0.5-1 kg boiled Bajara (*Pennisetum typhoides L.*) mixed with Gur (Jaggery) for a week, and giving 0.5-1 kg Masurdaal (*Lens esculenta moench*) in the evening time for overcoming summer anestrus in buffalos. There are many more examples that need to be reevaluated in the local microenvironment. (Vijayalakshmy *et al.*, 2018)
- Creation of a database for vulnerable areas: An artificial neuronal network (ANN) may be an option gathered from meteorological weather stations. This model may be considered counting the number and duration of heat stress events based upon which projections may be done (Hempel *et al.*, 2019).
- Emphasizing insurance for animals: Temperature-humidity index insurance planning and its proper application might be proved as correct risk management means that can minimize loss of animal owner due to heat stress and ultimately yield better stable income from farming (Nikoukar and Sasan, 2017).

Conclusion

Climate change is obvious with its effects and impacts on animals. If we minutely observe the reference section of this article, we will be able to perceive that the topic of heat stress and animal production is a long back agenda and concern of the research. Different mitigating strategies to combat the negative influence must be taken at the earliest to reduce its impact vis-à-vis to prevent losses from farming. The proper and judicious application of remedial/precautionary measures may face the farmers with more profitability and with better sustainable farming.

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Author's contribution: SR, PM: Drafted the manuscript; SC, SSK, RM: Have curated the data for the manuscript; SKN: Developed the concept and finally formatted and corrected the manuscript.

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