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Review Article

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# Ameliorative Strategies to Sustain Livestock Production during Heat Stress

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## Abstract

In the changing climate scenario, heat stress is of major concern among livestock owners as it affects drastically livestock production which otherwise contributes 40% of world agriculture GDP (gross domestic product). Hence there is an urgent need for reviewing the various strategies to counter the heat stress impact on livestock production. THI (temperature humidity index) may not be the ideal index to quantify heat stress impact on livestock as it does not take into account solar radiation and wind velocity. Hence, more appropriate agro-ecological zone specific indices like Dairy Heat Load Index (DHLI) which takes into account all cardinal weather parameters is the need of hour. Development of appropriate heat abatement strategies depends on the type of dairy operation practiced in a particular livestock farm. During heat stress, management strategies such as providing shade, sprinklers, fans, cold water, minimum handling, grazing during early morning and late evening hours might be very beneficial to improve livestock production. Considerable efforts are needed to modify the existing housing condition according to the changing climatic condition to improve the livestock production. Apart from management strategies, nutritional strategies also must be given equal importance which not only will help the animal to survive the stress but also it will ensure optimum energy for production processes. Nutritional interventions such as additional concentrate supplementation, re-formulation of diet that accounts for reduced DMI, fat, minerals, vitamins and antioxidants supplementation are very vital for ensuring optimum production in livestock during heat stress condition. Appropriate health service measures needs to be taken to counter the emergence of sudden disease outbreaks during heat stress condition. Geographic information system (GIS) has to be integrated with disease surveillance program to create the hazardous maps of sudden disease outbreaks and correlating them with climate and other information might be very useful for future predictions. In addition, predictive modeling system can also be used as an effective tool to forecast the probability of a disease outbreak. Advanced technological development need to be integrated with suitable breeding programs using marker assisted selection to develop agro-ecological zone specific thermo-tolerant breeds of livestock. The developed strategies should be user friendly and economically feasible if farmers have to adopt those strategies to improve livestock production in the changing climatic condition.

**Keywords:** Climate change; Cold diet; Livestock; Nutrition; Shelter design, THI

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## Introduction

In the changing climate scenario, heat stress is of major concern among livestock owners in almost all the developed as well as developing countries [1]. Daramola et al. [2] stated that heat stress results from the animal's inability to dissipate sufficient heat to maintain homeothermy. According to Kumar et al. [3] increased ambient temperature may lead to enhanced heat gain as compared to heat loss from the body and may cause heat stress in animals. The main weather parameters that influence the heat stress are temperature, relative humidity, wind velocity and solar radiation while the level of heat stress is dependent on the animal's activity, body condition, coat cover and color, and disposition. Heat stress results in increased body temperature, increased water consumption, decreased feed consumption, reduced weight gain, poor breeding efficiency, lower milk production, increased disease susceptibility, behavioral changes, and ultimately may lead to death. Since the metabolic energy being diverted to ameliorate the stress, the production efficiency of the livestock is drastically reduced and thus leading to huge economic losses to livestock farmers. It has been estimated that heat-related events in the Midwest have cost the cattle industry over $75 million in the past 10 years. Heat stress is the main factor that accounts for the major losses in livestock sector, which contributes about 40% of agriculture GDP in the world and hence there is an urgent need of research attempts in ameliorating the heat stress in livestock. Hence, the main objective of this paper is to review the various strategies to counter the heat stress impact on livestock production. Special emphasis was given to cover measurement of severity of heat stress, shelter designs, nutritional interventions as well as the health services for ameliorating the loss of livestock production in this review.

## Measurement of Severity of Heat Stress

The severity of heat stress can be understood by calculating the Temperature Humidity Index (THI) which is one of the most accepted indexes for assessing the impact of heat stress on livestock production. THI was used as a guide to assess heat stress by combining the effects of temperature and relative humidity (RH) into one single value [4]. The effect of heat stress on livestock is brought about by the cumulative actions of weather parameters like temperature, RH, wind speed and solar radiation. However, THI considers only the effect of temperature and RH, and hence it may not be the ideal index to measure the severity of heat stress in livestock. As a result there were several refinements attempted by various researchers to develop appropriate index incorporating all the weather parameters. Table 1 lists some of the latest equations to measure severity of heat stress which was developed by researchers across the globe.

## Different Approaches to Alleviate Thermal Stress

According to Collier et al. [11] ameliorating heat stress in animals is a multidisciplinary approach involving nutrition, housing, and health. Advances in management strategies have alleviated some of the negative impacts of heat stress on farm animals particularly in dairy cattle [12]. During heat stress, management strategies such as providing shade, sprinklers, cold water, and nutritional supplementation can help to manage the stress condition in livestock. Altering feeding management such as change in feeding time and/or frequency are

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**Table 1:** Different equations to measure severity of heat stress in livestock T-Temperature; RH-Relative Humidity; SR-Solar Radiation; WS-Wind Speed BGT-Black Globe Temperature.

| Equation | Weather Parameters | References |
|---|---|---|
| Livestock weather hazard guide | T, RH | [5] |
| THI = 4.51 + THI-1.992 WS+0.00068SR | T, RH, WS, SR | [6,7] |
| THI = db°C – {(0.31 – 0.31 RH) (db°C – 14.4)} | T, RH | [8] |
| HLI (BG>25)=8.62+(0.38XRH) + (1.55xBGtemp) - (0.5xWind Speed) + ($e^{2.4\ wind\ speed}$)<br>HLI (BG<25) =10.66+ (0.28XRH) + (1.3xBG) - Wind Speed) | BGT, RH, WS | [9] |
| When TA <22.2 then<br>DHLI = {52:8 + (0.06 X RH) + (0.66 X TA) – (0.39 X WS)}<br>When TA >22.2 then<br>DHLI = {1.09 + (0.36 X RH) + (1.42 X TA) + $e^{-WS+2.6}$} | BGT, RH, WS | [10] |

efficient tools to avoid excessive heat load on the animals and can improve their survival rate [13]. Methods to enhance heat exchange between the environment and the animal should be improved so that performance under hot climatic conditions can be enhanced. Differences in heat tolerance exist between species, breeds and within each breed. Thus the effect of heat stress can be reduced by developing suitable breeding program using marker assisted selection. With the advancement of technology, livestock farmers have been able to adapt their amenities to improve the comfort of the animals such as providing shade, increasing airflow and thereby improving evaporative heat loss. Acclimation is yet another resource that naturally happens when animals are born and reared in hot weather. Development of appropriate heat abatement strategies depends on the type of dairy operation practiced in a particular livestock farm. Efforts needs to be made to carry out dairy operations like feeding and milking during cooler parts of the day to prevent handling of animals during heat stress condition. In addition, cooling of holding pen, fly control, attaching high-pressure mist systems to pivots, construction of shade structures and supplying *adlibitum* water may yield better results in relieving heat stress impact on livestock. Also, considerable efforts are needed to implement different nutritional approaches to tackle heat stress impact on livestock. Figure 1 describes the different strategies to counter environmental extremes in livestock.

## Shelter Design for Alleviation of Heat Stress

Shelter management is one of the key techniques for reducing the impact of heat stress in livestock [1]. A good shelter should protect the animals from extreme climatic condition without compromising the animal performance in terms of growth, health and reproduction. Considerable efforts are needed to modify the existing housing condition according to the changing climatic condition to improve the livestock production. However, while doing so emphasis should be given to use the economically viable indigenous materials to modify the sheds so that farmers can adopt those technologies easily [11,13].

### Shade

Use of shade was considered as the most efficient method to minimise the heat load on animals during heat stress [14]. Shade reduces exposure of animals to scorching sun during summer. Shade however does not have influence on weather parameters like RH and ambient air temperature [14]. Construction of shade structures and planting trees around the shed will be highly beneficial to farm animals especially in hot climates [15]. Shades are the most effective method by which the impact of high solar radiation can be reduced and these can be either natural or artificial [1].

### Natural Shade

Tree shades have proved to be more efficient and artificial shade structures need to be constructed only when natural shade is unavailable [1]. They do not effectively block solar radiation but the evaporation of moisture from leaf surfaces cools the surrounding air without interfering with air circulation. The heat load will be very little on animal standing in a natural shade compared to that of shed made up of artificial roofing. Animals consume more feed and water when the feeders and waterers are placed in shade [16]. The ground cover around a shade is a factor of importanceto minimizes the impact of heat stress. The level of thermal radiation above a grass field is less than that of a solid concrete [15]. Grass prevents the soil erosion and saves the trees and with continued management provides a cooler, cleaner, and drier place for animals during periods of hot weather [16].

### Artificial Shade

Solar radiation is the major cause of heat stress which enhances heat gained by the grazing animals' both by direct as well as indirect means. Hence under grazing conditions provision of artificial shading might improve the comfort of animals and thereby the milk production [1]. There are two types of artificial shade: (i) permanent shade structures and (ii) portable shade structures. Major parameters for designing permanent shade structures are: orientation, floor space, height, ventilation, roof construction, feeding and water facilities and waste management system.

The orientation of the shed varies according to different agro climatic zones. The penetration of solar radiation in animal shed may be prevented by placing the longitudinal axis of the shed along east – west direction in the northern hemisphere [13,17,18]. Alignment of the long-axis of the shed in an east-west direction ensures maximum amount of shade to the animals. This type of shed is generally preferred where animals are kept in confined condition. However, in sheds where animals can move freely usually north-south orientation is preferred [16].

Reinforced concrete slab floors at least 4 inches thick, with a

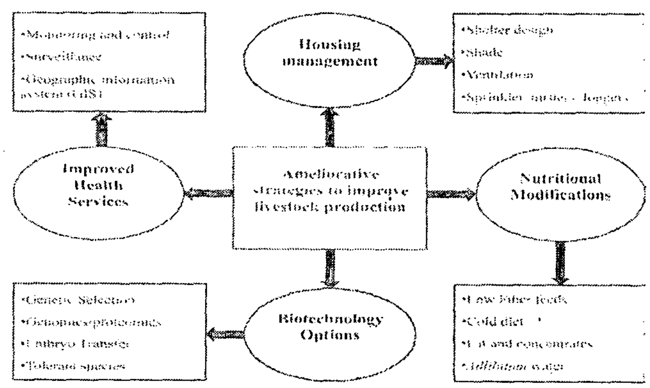


**Figure 1:** Different strategies to counter environmental extremes in livestock.

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smooth finish, and grooved for good footing are recommended in animal sheds. Space requirements inside the shed are doubled especially in hot and humid climates to provide additional open area for improved air movement in order to avoid stress to the animals [16]. He further emphasized that the natural air movement under a shade structure was affected by its height, width, slope of the roof, and the presence of, or size of, the ridge opening. Several researchers have reported that animal sheds should have a minimum of 3 m height to allow sufficient air flow to provide comfort to the animals [14]. For hot climates, the side walls should be equipped with adjustable curtain to ensurecross flow ventilation to provide comfort to the animals [19].

## Cooling Methods

Along with providing the shade, use of water as a cooling agent was found to be an efficient method for reducing effect of heat stress on animals particularly under dry hot and lower humidity climates. Evaporative cooling in animals can be accomplished either by direct evaporation from the skin surface of the animal or by indirect evaporation by cooling the microenvironment of the animals with cooling pads and fans in an enclosed shed [12]. According to Ugurlu and Uzal [18], water and air flow becomes the agents by which the microenvironment is cooled and evaporative cooling by the animals is augmented. Naas et al. [20] suggested that the installation of cooling devices such as fans along with fogging inside the free stall decreases the dry bulb maximum average temperatures which led to a significant improvement in the average milk yield for (4.2 kg/cow/day). Shearer et al. [16] stated that the mechanical ventilation with air speed higher than 0.5 m/s near the animals further reduces the negative effects of heat stress.

Kalyan et al. [13] suggested that the side wall should not be fully enclosed to allow air movement through the shed and should be provided with openings or short side walls of about 1 meter height so as to ensure sufficient air flow. Sejian et al. [1] and Bryant et al. [21] reported that the double wall approach can be used, where the extra wall layers are constructed at the end of the shed and the outer layer was placed 10 cm away from the inside wall, with vertical openings at both ends. In this the bottom opening allowed the cold air to enter, while the upper opening allowed hot air to exit simultaneously. The 10 cm of gap between the two walls provides a thermal barrier or insulation in order to prevent conductive thermal energy from entering the animal shed.

### Direct methods

Several direct methods of cooling are available like misting, fogging and sprinkling systems [1]. Sprinkling does not attempt to cool air as it does in the case of fogging and misting but instead uses large water droplet size to wet the hair coat of the animal directly. However, sprinkling increases the efficacy of non-evaporative cooling mechanism by reducing the ambient air temperature in the vicinity of the animals [14]. Once sprinklers are used to wet the animals, fans are used to force air over the body causing evaporative cooling to take place on the skin and hair coat [22]. High pressure irrigation-type sprinklers are an economical way of wetting the animals, especially when coupled with fans, to increase air movement [1,17,23]. However, cooling in combination with sprinklers and fans are often considered to be highly expensive [17,24]. Several studies have founded that upper body sprinkling together with forced-air ventilation as an effective means to reduce body temperature, increase feed intake and there by the milk yield. Further, Brouk et al. [25] suggested continuous air flow and wetting the animals at 5 minutes interval to be the most practical method of cooling the dairy animals to ensure increased milk production.

### Indirect method

Indirect method of cooling targets cooling the micro-environment rather than directly cooling the animals. The advantage over direct method is that it may not create high humidity problem as that would occur if animals are directly wetted [11]. An economically practicable method to cool the micro-environment is the evaporative cooling pad and fan system which uses the energy from air to evaporate water. Further, these methods have also been observed to be efficient in reducing the ambient air temperature in humid climates too [12,13].

## Nutritional Intervention to Counter Heat Stress

Shelter management strategies alone cannot counter the heat stress impact on livestock production as these strategies may only help to create a congenial environment for the animals to survive and reproduce. If one attempts improving livestock production during heat stress condition, emphasis should be given to develop suitable nutritional strategies to ensure balanced nutrient intake for maintaining both thermoregulation and production [3]. Efficient nutritional strategies such as additional concentrate supplementation, re-formulation of diet that accounts for reduced DMI, fat, minerals, vitamins and antioxidants supplementation are very vital for ensuring optimum production in livestock during heat stress condition [26,27]. Alterations in feed formulations have been useful in reducing heat production, with the adequate supply of essential nutrients for production - especially a good balance of amino acids [13]. In addition, supplementations such as dietary chromium picolinate, betaine as well as altering the rate of starch fermentation have found to be beneficial to counter heat stress impact on livestock [12]. Antioxidant supplementation is one of the primary means of reducing the heat stress impact on livestock as their oxidative balance are generally disturbed during this stress condition. According to Mac Arthur [28] the effect of heat stress can be counterbalanced by improving the antioxidant system of an animal through nutritional supplementation. The supplementation of antioxidants, both enzymatic and non-enzymatic, provide necessary defense against oxidative stress and prevent the accumulation of oxidatively damaged molecules in the body, which may occur as a result of heat stress [3]. According to Sorenet al. [27] addition of electrolytes in the diet was found to be more beneficial to combat heat stress in animals to improve the milk yield, maintain the acid base balance and to lower their body temperature. Supplementation of sodium and potassium in the form of bicarbonate/carbonate also benefited the animals in better regulation of acid-base balance in the blood [29]. Further, Kumar et al. [30] observed that the incorporation of Vitamin C along with electrolyte in the diet was found to be very effective to counter heat stress in buffaloes. Several Studies have shown that the addition of vitamins C, E, A and zinc are very effective in ameliorating the adverse effect of heat stress in the ruminant livestock [27]. Sathya et al. [31] also observed that Vit-E supplementation apart from alleviating the heat stress impact on dairy animals it also improves the antioxidant status and reduces the occurrence of mastitis, merit is, and retention of placenta.

Soren et al. [27] reported that nutritionist's often consider increasing the energy or protein density of the ration during the heat stress period for livestock. According to Sejian et al. [1], animals should be fed with cold diet during the heat stress condition. Cold diet generates a high proportion of net nutrients for energy synthesis

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and reduces the basal metabolic heat generated during fermentation and metabolism. Alterations in diet are needed during hot climatic conditions to maintain nutrient intake, increase dietary nutrient density, and ultimately to re-establish homeostasis [32]. The best nutritional intervention to minimize the negative effects of heat stress on feed intake is to add fat to the diet as fat produces less heat than carbohydrates or protein [27,32]. Beatty [33] reported that the addition of fat to the diet of lactating cattle, during the hot weather was found to be beneficial in reducing the heat production as compared to other feed stuffs. Fat feeding apart from lowering heat production also helps to improve the dietary energy density which produces less metabolic heat. However, the proportion of fat supplementation should not cross the permissible level as overfeeding might lead to metabolic disorders [32,33].

Fiber digestion may significantly increase the metabolic heat production in dairy cows [1]. Kumar et al. [3] reported that beef heifers fed with pelleted diets containing 75% concentrate (low fiber) had lower heat production compared with those fed pellets containing 75% alfalfa (high fiber) proving that high fiber diets do have a greater heat increment than diets low in fiber.Holt et al. [34] also reported similar findings that low fibre and high grain diets lowers the metabolic heat production reducing the additional heat load on the animals. Further, nocturnal feeding and feeding during early morning and late evening hours may improve the feed intake apart from preventing the metabolic heat production coinciding with peak atmospheric temperature during afternoon [35].

## Improving Health Services

Maintaining animal health is an important aspect if one attempts to sustain livestock production during heat stress condition. Efforts are need to be taken to maintain normal animal health during stressful condition. Developing public awareness and other health education programmes to tackle different diseases that arise as a result of heat stress are the primary requirement to tackle health issues [1]. Further, surveillance and disease investigation capacities need to be strengthened. In addition, the development and harmonization of appropriate cross-border disease surveillance have also to be carried out if one attempts providing health care to animals. Modification of public health programmes based on veterinary and medical curriculum and assessing the socio-economic impacts of zoonotic diseases are very crucial for the success of health awareness program. Also proper networking among epidemiological and laboratory units under public health and animal health sectors should be established. Most importantly development of prevention and control strategies like use of vaccines for livestock diseases and pilot projects, incorporating them in the existing control programmes for specific disease are highly essential. Further, proper coordination has to be established among the medical and veterinary institutions, NGOs, international professional associations to ensure success for the health awareness program. Finally, formulation of appropriate environmental, energy and economic policies are the need of hour to control emerging infectious diseases in livestock as a result of heat stress.

### Application of GIS and modeling in prediction of climate change associated livestock diseases

GIS can relate as well as disparate information, on the basis of common geography, revealing hidden patterns, relationships, and trends that are not readily apparent in spreadsheets or statistical packages, often creating new information from existing data resources. This information is very important as a management tool and creates valuable information needed for better decision making [36]. GIS helps in understanding and explaining disease dynamics and spreading patterns. It also helps in increasing the speed of response in case of an emergency at the initial phase of a particular disease [36]. GIS can also be used in way such that we can both monitor the level of stress and how our climate is changing and how it affects the spread of diseases [1]. It generates new information from already existing data and resources, which are very useful for decision making and can lead to better management of disease control programmes and emergency situations [36]. The periods of heavy rainfall as well as high minimum temperature can be identified using a spatial analyst and thereby illustrating it using GIS. This system also enables us to know which pathogens will flourish, under a particular condition [1]. Application of GIS in livestock sector [36] includes: (1) Links between disease occurrence and related explanatory data; (2) Evolution of disease outbreaks (dynamic maps); (3) Response to a disease emergency situation and (4) Correlation of disease trends with climatic and other information that could be used for predictions. Global early warning and response system (GLEWS) is a typical GIS system extensively adopted by Food and Agricultural Organization (FAO), Office International des Epizooties (OIE) and World Health Organization (WHO) which assists in prediction, prevention and control of animal disease threats, including zoonoses through allocation of information, epidemiological analysis and joint field missions to evaluate and control the outbreak, whenever needed [37,38]. In addition, predictive modeling system can also be used as an effective tool to forecast the probability of a disease outbreak. Models have potential to predict the probability of global climate change on ecological system and emerging hazards [1]. Some of the most common examples of livestock related diseases which are predicted using modeling system are: Bluetongue, Japanese encephalitis, Yellow fever, African trypanosomias is, Rift Valley fever and West Nile virus [39,40].

## Biotechnology Options

Advancement in breeding technologies can be effectively used to develop a livestock breed with high thermo-tolerance. Breeds that cope up well to environmental stress conditions without compromising its productive capabilities have to be identified and subjected for breeding programs to evolve a suitable breed for different agro-ecological zones. Genetic improvement is an evolutionary action; evolution should be defined as an incessant process of adaptation of the populations of organisms to the ever-changing geological, biological and climatic conditions [41]. Because of the infinite number of combinations of environmental factors, organisms must have a great variety of genotypes that can deal with a range of climatic, nutritional, or other parameters. Any population must be genetically heterogeneous - i.e., with a great genetic diversity - in order to survive under the challenge of the changing environment. Therefore, any population in a specific environment composed of majority of well-adapted individuals suited for different conditions. This should be the base for the livestock genetic development [41]. Embryo transfer technology may also be used in which, *in vitro* produced embryos not exposed to high ambient temperature or embryos derived from donors of high thermo tolerance may be used. With this technology, encouraging results have been obtained as a means to reduce adverse effect of heat stress on fertility [42]. Kimothi and Ghosh [43] reported that genetic variation exists among animals for cooling ability, which further suggests that more heat tolerant animals can be selected genetically after cross breeding. However, extensive crossbreeding studies have shown little heterosis for heat tolerance [1]. Collier et al. [11], further added that genomic and proteomic studies play a vital role in understanding the mechanisms of thermoregulation and delineation of genes conferring superior thermo-tolerant capability in different livestock species.

## Conclusion

In the changing climate scenario, heat stress seems to be the crucial environmental variable which decreases livestock production and fertility across the globe. Heat stress has long been known to affect animals comfort, health, growth and reproduction, which ultimately has great impacts on animal well-being and farmer's profitability. Modifications in the behavioral, psychological and biochemical thermoregulatory mechanisms are not sufficient to cope up with the heat stress. Hence implementing approaches like shelter management, nutritional strategies as well as improved health services can have significant impact in ameliorating the heat stress effect on livestock sector. Further, suitable indices incorporating all cardinal weather parameters have to be identified to quantify the impact of heat stress on livestock production. This might pave way for developing agro-ecological zone specific amelioration strategies to counter heat stress in livestock farms.

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