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Battling the Heat: The Struggles of Livestock Productivity Under Thermal Stress and Innovative Solutions for Management

Man Singh*, D.S. Bidhan, Vishal Sharma, Sandeep Kumar, Narender Singh, D.C. Yadav and Amandeep

Department of Livestock Production Management

Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar (Haryana)-125004

*Corresponding Author: drmansinghluvas@gmail.com

Abstract

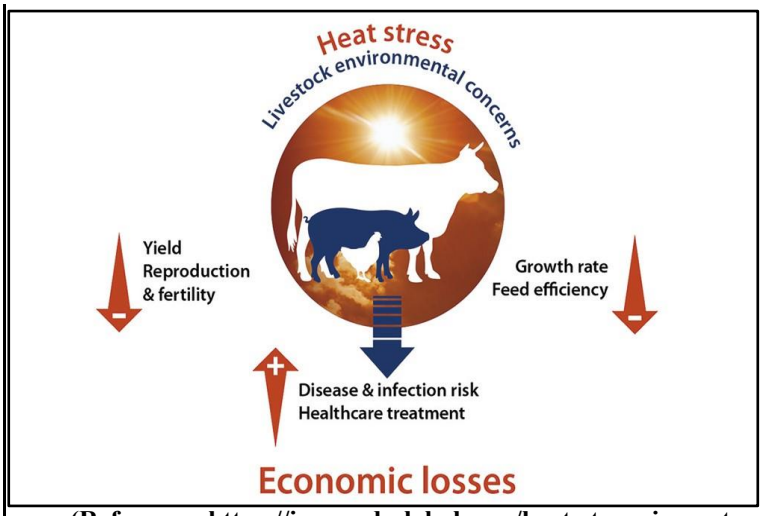
Heat stress, a condition where animals are unable to dissipate excess body heat, poses a significant threat to livestock worldwide. This condition leads to a cascade of negative effects, including reduced feed intake, lower milk and meat production, impaired reproductive performance, and increased susceptibility to diseases. The economic implications for farmers are substantial, as the productivity and health of their animals directly impact their livelihoods. To combat these issues, farmers and researchers are exploring innovative solutions. Traditional methods, such as providing shade and ensuring adequate hydration, remain fundamental. However, advancements in technology are paving the way for more sophisticated approaches. Climate-controlled housing, evaporative cooling systems, and precision farming tools that monitor animal health in real-time are becoming increasingly popular. This exploration delves into the multifaceted struggles of livestock under heat stress and highlights the innovative management techniques that are emerging to address this critical issue. By understanding and implementing these solutions, the agricultural community can better safeguard animal welfare and ensure sustainable productivity in an increasingly warm world.

Introduction

Climate change is expected to disproportionately affect the livelihoods of vulnerable marginal and smallholder populations who maintain only a few animals or small herds and have limited financial resources and low resilience to climate change. Although India's livestock production systems possess a degree of resilience and the capacity to adapt to some anticipated changes associated with global warming, vulnerable livestock and farmers are likely to experience negative impacts. These adverse effects may include reductions in milk production, stunted growth, compromised reproductive health, and an increase in animal diseases which are discussed under following subheads

Milk production

Heat stress during the summer months reduces milk yield in lactating animals, and



(Reference: https://innovad-global.com/heat-stress-impact-animal-health-revenue-and-productivity)

production losses also occur due to its negative effects on puberty, conception, pregnancy, and lactation persistence. Northern India is expected to face greater negative impacts from rising temperatures on milk production in cattle and buffaloes. This decline in milk production is likely to be more pronounced in crossbred cattle compared to buffaloes and indigenous cattle.

Growth

Animal growth rates are influenced by both genetic and environmental factors, with climatic elements and feed availability playing significant roles. High temperatures and heat stress negatively impact energy utilization, making body growth particularly sensitive to temperature fluctuations. A temperature increases above the thermo-neutral zone or a rise in the Temperature-Humidity Index (THI) of 1.0 to 1.2°C with minimal changes in precipitation during March-August, as projected for India, is expected to have a negligible negative impact on the growth rates of adapted livestock like zebu or alter their time to reach puberty. Crossbred animals and buffaloes are likely to be more affected than indigenous livestock due to their lower thermal tolerance and greater sensitivity to high temperatures.

Physiological functions

Rising temperatures increase the physiological responses of livestock species, with cardiopulmonary

functions being most affected. Both the intensity and capacity of these functions are impacted. To dissipate excess heat, livestock increase their pulmonary frequency, and tidal volume adjusts to meet the ventilation requirements for oxygen demand and heat dissipation. Heat stress disrupts thermoregulation pathways, leading to the generation of free radicals, which in turn cause oxidative stress at the cellular and tissue levels.

Reproductive functions

Thermal stress on Indian livestock, particularly cattle, buffaloes, and other vulnerable species, has been reported to decrease milk yield and impair reproductive functions such as estrus expression and conception rates. Buffaloes are especially sensitive to temperature changes, and this sensitivity increases under confined conditions and limited water access, making them more vulnerable to thermal stress. During summer, buffaloes exhibit low reproductive efficiency due to a decline in pregnancy rates caused by silent heat or poor estrus expression, leading to conception losses, prolonged dry periods, and extended inter-calving intervals. A projected temperature rise of 2-5°C by 2100 due to climate change is likely to exacerbate the incidence of silent estrus, shorten estrus duration, and further decline the reproductive efficiency of buffaloes and other vulnerable livestock species.

Disease occurrence

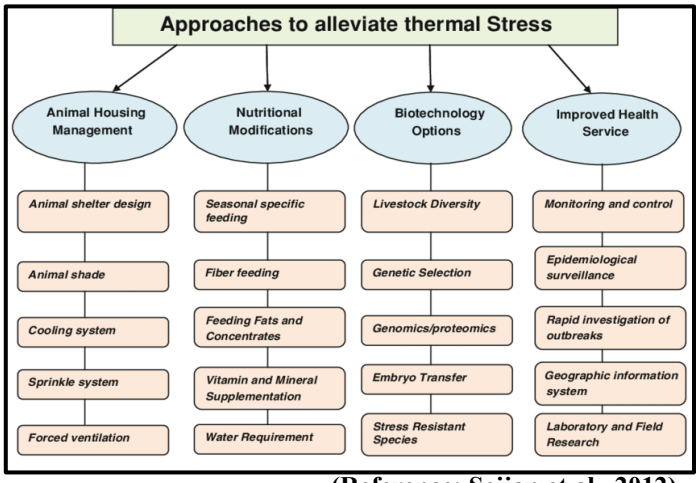
Rising temperatures and climate variability due to climate change are likely to facilitate the breeding of vectors, potentially leading to the emergence of new livestock diseases and the disappearance of existing ones. Prolonged favorable temperature and humidity conditions can promote the emergence of new livestock diseases, impacting the livestock sector and hm babesiosis, may increase in sensitive and non-adapted high-producing crossbred and pure exotic cattle breeds.

Adaptation Practices and technologies to cope climate change

Adaptation to climate 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.

Shelter

To reduce thermal stress in livestock under tropical conditions, proper shade or shelter is essential to cut incoming solar radiation by up to 30%.



(Reference: Sejian et al., 2012)

Providing tree shade is ideal for holding pens, confined feeding areas, and resting zones. Suitable trees include banyan, neem, and peepal. In their absence, shelters made from straw, bamboo, or locally available materials, or shades using cloth or gunny bags, can be used. These shades should be removed during comfortable weather (Feb-March and Sept-Nov) and reinstalled during summer and extreme winter. Orienting shelters north-south allows sun exposure to dry shaded areas in the morning and late afternoon, ensuring effective shade when needed most.

Ventilation

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. To provide the additional cooling sprinkles system may also be incorporated into the system. Other option is the use of high-volume low speed fan to increase air across animals. Along with fan system time-integrated variable control system can also be used. The time-integrated variable ventilation controller tracks air temperature during the day and

when heat stress occurs, keeps ventilation rates elevated and cooling systems operating longer during stress to help animals cool off.

Cooling systems

To reduce thermal stress in livestock, water-based cooling systems such as sprinklers, drippers, misters, and foggers can be utilized to enhance evaporative cooling and lower ambient air temperature around the animals.

- **Sprinklers:** These are the most commonly used and recommended. Sprinklers spray large water droplets in a predetermined pattern, soaking through the animal's hair to wet the skin, where evaporation provides cooling.
- **Drippers:** These emit water slowly as individual droplets in a small area. They are not widely used for dairy applications due to their limited wetted pattern.
- **Misters:** Misters spray fine water droplets in circular or rectangular patterns. However, they are not recommended because the small droplets tend to collect on the hair coat rather than soaking through to the skin, creating an insulating water film instead of cooling.
- **Foggers:** Foggers create a fine mist or aerosol that evaporates into the air, reducing ambient temperature. They are useful where a wet surface is not desirable, often used in conjunction with circulating fans to enhance cooling.

The primary challenge with sprinkler systems is the increased humidity around the animals during hot summer conditions. To counteract this, it is recommended to use fans alongside sprinklers. Fans improve air circulation and reduce humidity, while sprinklers lower the air temperature, providing a combined effect for optimal cooling. This dual approach ensures that the cooling process is efficient, maintaining the animals' comfort and well-being.

Feeding strategies

To alleviate heat stress in livestock, dietary adjustments are crucial. Reducing dietary fiber to levels that support proper rumen function and increasing grain feed during summer can help, but should be done cautiously. Enhancing the energy density of ruminant diets and incorporating dietary fat (6-7% of diet dry matter) provides extra energy with lower heat increment. This is especially beneficial for high-producing animals. Heat-stressed cattle often experience a negative nitrogen balance due to reduced feed intake. Therefore, both the quantity and quality of protein in their diet are important, but increasing crude protein levels should be managed to avoid higher energy requirements and environmental pollution from excess urea excretion. Minerals like sodium and potassium are vital for maintaining water and ion balance and acid-base status. Niacin supplementation can induce peripheral vasodilation, aiding in heat dissipation. Antioxidants such as vitamins A and E, selenium, and zinc can reduce heat stress, prevent mastitis, optimize feed intake, and mitigate the negative impacts of heat stress.

Breeding strategies

To support livestock adaptation to climate change, a focus on developing new breeds, improving reproduction, and enhancing animal health is essential. Indigenous breeds in India are already adapted to harsh agro-climatic conditions but face pressure from increased production demands and land-use changes. Strategies should include:

- Strengthening Local Breeds: Identify and enhance local breeds adapted to climatic stress and feed sources.
- Cross-Breeding: Improve local genetics by cross-breeding with heat and disease-tolerant breeds.
- Conserving Indigenous Breeds: Preserve indigenous breeds in their native regions and similar geo-climatic areas.

Adaptation studies and breeding programs should develop climate-ready breeds for areas likely to be affected by climate change. Altering reproduction protocols, such as using fixed-time artificial insemination (TAI) methods like Ovsynch, can reduce thermal stress impacts on fertility. Advancements in global expression technologies (whole genome arrays, RNA sequencing) allow for selecting genes related to thermotolerance without compromising milk yield. The expression of heat shock protein 70 (HSp70), which is stress-inducible, helps in conferring thermotolerance and adaptability.

Conclusion

Rising temperatures make Indian livestock sector highly susceptible to harmful effects of climate change. It is expected to negatively impact milk production, growth, reproduction, and animal health. To bolster livestock production systems against current and future climate challenges, it is essential to develop adaptation strategies. These strategies include modifying micro-environments, optimizing feeding and nutrition, enhancing livestock breeds, altering

genotypes, and improving animal health services. The sector's potential for job creation, contribution to food and nutritional security, and poverty alleviation is significant.

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