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Impact of Climate Change on Dairy Animal Health, Physiology, and Milk Yield

*Dr. Swarnalata Bara
Assistant Professor, Department of Livestock Production and Management, Kumari Devi Chaubey College of Agriculture and Research Station, Saja, IGKV, Raipur, Bemetara (C.G.)-491993, India
*Corresponding Author's email: swarnalata14366@gmail.com

Climate change is one of the most pressing challenges facing global agriculture, and its effects on dairy farming are profound. Rising temperatures, altered rainfall patterns, extreme weather events, and increased frequency of heatwaves directly influence dairy animal health, physiology, and productivity. Dairy animals, particularly high-producing cows, are highly sensitive to environmental changes due to their metabolic demands, thermoregulatory limitations, and complex physiological processes. Understanding the impacts of climate change on dairy animals is essential for devising management strategies that maintain animal welfare, optimize milk production, and ensure the sustainability of dairy operations.

Heat Stress and Thermoregulation

Heat stress is the most immediate and visible impact of climate change on dairy animals. When ambient temperatures exceed the thermoneutral zone of cattle (generally 5–25°C depending on breed), animals experience heat stress, which affects metabolic efficiency, feed intake, reproduction, and milk production. Physiologically, heat stress triggers increased respiration rate, sweating, and panting as animals attempt to dissipate excess heat. Blood flow is redirected toward the skin, often at the expense of internal organs, reducing nutrient absorption and metabolic efficiency. Chronic heat stress can suppress immune function, increasing susceptibility to diseases such as mastitis, respiratory infections, and metabolic disorders.

Alterations in Feeding Behaviour and Nutrient Utilization

Climate-induced heat stress and altered environmental conditions affect feed intake and digestive efficiency. Dairy animals typically reduce feed intake during hot periods, leading to a negative energy balance. Lower nutrient intake directly impacts milk yield and composition, as energy and protein are diverted toward maintaining basic physiological functions rather than lactation. Additionally, heat stress affects rumen microbial populations, decreasing fiber digestion efficiency and overall nutrient absorption. This imbalance can lead to metabolic disorders such as ketosis, acidosis, or ruminal hypomotility, further impacting animal health and productivity.

Physiological and Endocrine Changes

Climate change induces significant physiological and endocrine responses in dairy animals. Elevated environmental temperatures and heat stress trigger the release of cortisol and other stress hormones, which influence metabolism, immune function, and reproductive efficiency. Thyroid hormones may also be affected, altering basal metabolic rate and energy expenditure. Heat stress can disrupt electrolyte balance, increasing the risk of dehydration and negatively

affecting cardiovascular function. These physiological changes collectively reduce milk yield and can compromise overall animal health, particularly in high-producing dairy cows.

Reproductive Efficiency

Rising temperatures and heatwaves reduce reproductive performance in dairy animals. Heat stress interferes with estrous cycles, reduces conception rates, and increases early embryonic loss. Fertility is further compromised by impaired oocyte quality, reduced sperm viability, and altered hormonal regulation. Delayed or failed pregnancies directly affect milk production and herd replacement rates. Adaptation strategies, such as cooling systems, shade provision, and altered breeding schedules, are critical to mitigate climate-related reproductive losses.

Milk Yield and Composition

Milk production is highly sensitive to environmental stress. Heat stress decreases milk yield by reducing feed intake, altering metabolism, and affecting mammary gland function. In addition to reduced quantity, milk composition may also be affected. Fat, protein, and lactose levels may decline, while somatic cell counts can increase, indicating stress or subclinical mastitis. These changes impact the economic value of milk and dairy products, highlighting the urgent need for management interventions to maintain both yield and quality under changing climatic conditions.

Immune Function and Disease Susceptibility

Climate change can exacerbate the prevalence of diseases in dairy animals. Heat stress suppresses immune function, reducing white blood cell activity and antibody production. This makes animals more vulnerable to infections such as mastitis, bovine respiratory disease, and parasitic infestations. Changes in rainfall and humidity patterns also influence vector populations, increasing the incidence of vector-borne diseases. Maintaining health under such conditions requires proactive vaccination, biosecurity measures, and monitoring of environmental stressors.

Water Requirements and Hydration

Rising temperatures and increased evaporation rates increase the water requirements of dairy animals. Adequate hydration is critical for thermoregulation, milk synthesis, and nutrient absorption. Water scarcity or poor water quality under climate change scenarios can exacerbate heat stress, reduce feed efficiency, and further impair milk production. Ensuring consistent access to clean and sufficient water is essential for sustaining dairy productivity.

Mitigation Strategies and Adaptive Management

To counter the effects of climate change, dairy farmers must adopt adaptive management practices. These include environmental modifications, such as shade provision, fans, misting systems, and proper housing ventilation. Genetic selection for heat-tolerant breeds or crossbreeds is another long-term strategy. Nutritional adjustments, such as increasing dietary energy density, supplementing electrolytes, and providing high-quality forages, can help maintain milk yield and animal health. Strategic breeding schedules, health monitoring, and vaccination programs further enhance resilience to climate-induced stressors

Economic Implications

Climate change-related reductions in milk yield, reproductive efficiency, and animal health directly affect farm profitability. Increased veterinary costs, reduced milk quality, and lower feed efficiency contribute to economic losses. Adoption of smart technologies, precision nutrition, and climate-adapted infrastructure, though initially costly, can offset long-term losses and improve overall productivity and sustainability.

Future Research Directions

Ongoing research is focused on understanding the genetic, physiological, and behavioural traits that confer resilience to heat and climate stress in dairy animals. Development of

climate-resilient breeds, precision feeding strategies, and predictive health models using AI and sensor technologies are emerging areas of interest. Research is also needed on the integration of environmental monitoring with herd management to develop holistic approaches for sustaining productivity under climate change scenarios.

Conclusion

Climate change poses significant challenges to dairy animal health, physiology, and milk production. Heat stress, altered feeding patterns, metabolic disruptions, and disease susceptibility collectively reduce milk yield and animal welfare. Adaptive strategies, including environmental modifications, precision nutrition, genetic selection, and health management, are essential to mitigate these impacts. Integrating smart monitoring systems and climate-adapted practices can help maintain sustainable dairy production, ensuring productivity, profitability, and animal well-being in the face of global climate change.

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