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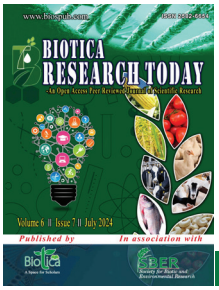

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Growing Resilience against Climate Change: Highlights from the Dairy Sector of India

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Abstract

The dairy industry is an important part of the agricultural sector, contributing significantly to the economy, promoting nutritional health and providing income for small and marginal farmers. India is currently leading in milk production, surpassing all other countries globally. The majority of these abundant supplies are derived from bovines including cattle and buffaloes. Nevertheless, productivity remains a pressing concern for researchers, farmers and the government. Although, the news about climate change and its effects has become increasingly evident with each passing day, especially in countries like India. There is a significant increase in the frequency of extreme heat waves and other climate variables. The milk produced by cattle goes through various transformations that affect the livestock's production potential, quality and reproductive capacity. It is crucial to prioritise measures that will strengthen the dairy industry's ability to withstand challenges. Hence, adaptation of appropriate measures towards climate resiliency is crucial for sustainability of dairy sector.

Keywords: Abiotic stress, Climate vulnerability, Dairy farming, Milk quality

Introduction

Milk and dairy products are nutritionally dense foods, offering both calories and high-quality protein along with a variety of critical micronutrients. The dairy industry sustains the means of subsistence for millions of individuals involved in its many interconnected networks worldwide. The global output of milk, consisting of around 81% cow milk, 15% buffalo milk and 4% goat, sheep and camel milk combined, is expected to increase by 1.6% year^{-1} during the next ten years. This growth is attributed to improvements in the amount of milk produced animal^{-1}. By 2033, milk production is forecast to reach 1085 million metric tonnes. This growth rate exceeds that of other primary agricultural commodities. India and Pakistan are expected to provide more than half of the rise in output, making up over 30% of global production in 2033 (Figure 1).

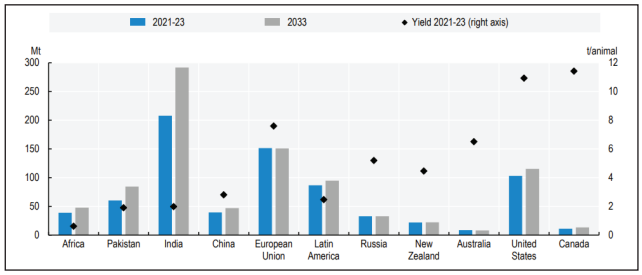

Figure 1: Milk production and yield in selected countries and regions

Climate change is a gradual and lasting change in climate on a global or regional scale. The adverse impacts of climate change are apparent through escalating temperatures, forest fires, sudden floods, droughts and so forth. It has already resulted in melting of ice caps in polar region, rising sea levels and increased frequency of extreme weather events. Dairy sector is sensitive to these changes, as the major components of dairy sector are livestock which are impacted by climate change due to their dependence on stable, long-term climatic conditions. It makes use of resources that are highly dependent on the environment for their seasonality and productivity. Changes to the

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environment affect the diseases that shall be exposed to the animals and in turn affect their health, growth and fertility. Climatic changes may also impact the amount and variety of feed available due to changes in the productivity and quality of hay, cereal and roughage crops. In essence, at the same time, this alters how the animals eat, overall health and metabolic rate. Directly perceived impacts of climate change on cattle include lowered feed resource efficiency, high risk of disease, heat stress, problems in breeding as well as attenuated production qualities. Some indirect implications will also arise from factors like GHG production, decreasing areas for grazing, as well as limited access to feed and fodder resources as well as competition for land use against crop farming.

Livestock is an integral part of rural livelihoods and the mainstay of the dairy sector. It usually serves as the social, cultural and economic lifeline of a community, thus very important in rural economies. Therefore, businesses and farmers have to adapt to the changes and hence become resilient. For one to adapt to current or future time in relation to climate change, one has to change practices, procedures, capital and infrastructure. On nutrition security, the resilience of the dairy sector is equally important. The stable supply of nutrients can be ensured to the increasing population through the consumption of milk and milk products since they represent an important source of some critical nutrients. It is, therefore, significant to make sure that the dairy industry stands strong against the impacts of climate change. This can enable reliable and nutritious food supplies, stable economies, sustainable practice, reduced greenhouse gas emissions and improved social well-being. Focusing efforts on actions that will enhance the resilience of the dairy industry cannot be emphasized enough, especially since all these aspects contribute to ensuring global food security.

Impact of Climate Change on the Dairy Sector

Increment in temperatures because of climate change is expected to accentuate heat stress. Heat stresses have direct and indirect impact on milk production and on animal health. It leads to decrease in milk production and quality as high temperature decrease feed intake. At the same time, mortality rate increases and fertility rate decreases. Apart from the direct effect on milk production and animal health through heat stress, climate change effects the feed crop production. Projected climate change effects are expected to have an impact on crop yield, growing seasons and crop quality, due to changes in temperature and rainfall. Climate change will also affect the growing seasons, which in turn will alter the harvest dates of crops. The expected rainfall changes and increasing temperatures would affect the cycle of water and cause a dearth of water. A change in these climate variables will lead to increased rates of evapotranspiration, thus leading to a projected rise in agricultural water needs. In addition, the rise in sea levels is predicted to result in the intrusion of seawater into freshwater reservoirs. This will have a significant impact on the well-being of crucial crops used for dairy cow feed, coastal agriculture and the availability of freshwater in agricultural coastal regions. As the average world temperature rises, some pathogens are likely to spread and reproduce more quickly. This will have adverse effect on the health of both dairy livestock and crops. Therefore, all the parameters linked with climate change are likely to alter the current management practices and render the production capacity.

Adaptive Strategies in Dairy Farming

Climate change challenges in livestock need much emphasis on adaptation policies. The dairy sector forms an important industry for food and nutrient security. Farmers' decisions about adopting the adaptation strategies are influenced by a number of factors including socio-economic, institutional and environmental factors. This is particularly appropriate for those farmers with lower adaptive capacity, who are more vulnerable to the harmful impacts of climate change. There is, then, a great need to create a deep understanding of their response behaviour to adaptation if so, be that programmes can be developed which maximize resilience and produce the best possible outcomes. The following are a few among the many adaptation strategies that can be adapted for developing climate resilient dairy sectors.

Diversification of the existing breeds to a heat-tolerant and disease-resistant breed is crucial for adaptation of the livestock due to environmental challenges. Over the decades, selective breeding has been practised, increasing the yielding capacity but resulting in increased susceptibility to diseases and disorders. For example, conserving indigenous breeds like Tharpakar and Gir, which can resist heat. Genomic selection is a very strong methodology that uses genomic data to quite accurately estimate the breeding value for animals. While traditional breeding methods rely on observable features and genetic relatedness, genomic selection takes it a step ahead in making full use of extensive information on genomics. Genomic selection utilizes specific genetic markers associated with advantageous features such as disease resistance, resistance to high temperatures and efficient feed utilization, so breeders can now manage to improve the accuracy of forecasts about the genetic capacity of an animal. Through the use of large amounts of genomic data, breeders can make decisions on animals with traits best suited to the existing environment in order to improve resilience and sustainability in the face of shifting climate patterns.

Another plausible approach could be the investigation of alternative species, such as goats. Goats possess advantageous traits that help them thrive in different climatic conditions, such as the ability to bear high temperatures, less requirement of water to fight back drought conditions, good growth on scarce pastures and resistance to various diseases. Thus, goat farming will ideally suit poor and disadvantaged farmers all over the world to ensure their livelihood and food security in the face of climate change challenges. However, there are two major challenges in goat production as enhancing productivity of indigenous breeds and genetic resource conservation. This current breeding program can also be turned into shifting the goat sector for low environmental impact by simply

adding traits on production, adaptation and low methane emission (Feleke *et al*, 2016).

Other alternatives to be implemented entail improving mobility, buying livestock insurance, keeping low debt obligations and growing drought-tolerant varieties of grass appeared, integration of livestock and crop rearing, supplemental feeding using concentrates, reduction in herd size, forage production, rotational grazing on pasture land to prevent degradation and formation and utilization of water harvesting systems like rainwater harvesting. The strategies adopted by farmers were observed to be influenced by factors such as farming experience, number of cattle kept, membership in organizations, total assets on the farm and education level (Thangadurai and Vijayakumar, 2022).

Technological Innovations

Precision Farming

Among the altering factors in cutting the emissions is the use of precision agriculture technologies. Technologies such as GPS, sensor and data analytics will efficiently make dairy producers use the resources available. For example, the application of sensor-based technologies will monitor soil health and its moisture levels. This consequently helps in applying fertilizers and irrigation efficiently and therefore reduces nitrous oxide emissions resulting from synthetic fertilizer application.

Use of Artificial Intelligence and Big Data

The emergence of Big Data and Artificial Intelligence (AI) has ability to transform the dairy farming industry by offering higher efficiency, enhanced and sustainable management techniques. These technologies tackle important issues in dairy production, such as maximising resource efficiency, enhancing herd well-being and establishing sustainability benchmarks. The implementation of Big Data in dairy farming entails the collection and analysis of vast amounts of data from diverse sources, such as sensor networks and animal health monitoring systems. By adopting this holistic strategy, farmers are able to make decisions based on data, thereby maximising productivity and ensuring sustainability. AI-powered predictive analytics in herd health revolutionise animal care by proactively anticipating health risks, hence improving preventive treatment. AI enhances feed composition and energy management by incorporating renewable energy sources such as solar or biogas, hence decreasing dependence on fossil fuels. Nevertheless, this transition also presents difficulties, such as the incorporation of AI into current agricultural systems, guaranteeing the accuracy of data and providing adequate training for farmers. To tackle these issues, it is necessary to create flexible and easy-to-use technology, establish uniform ways for collecting data and provide thorough training programmes for farmers.

Renewable Energy Integration

The entire dairy value chain is characterised by a high demand for energy, starting from the milk pooling sites at the village level and extending to the transportation of the final products. The utilisation of fossil fuels in dairy processing makes a substantial contribution to greenhouse gas emissions. Minimising the energy consumption of dairy processing is essential for ensuring the long-term sustainability of the sector. Efforts to reduce energy use in dairy processing involve shifting to sustainable energy sources, such as solar or wind power. The widespread utilisation of solar energy in the dairy value chain can greatly decrease operational expenses and guarantee the utilisation of environmentally friendly energy. The government is contemplating a solar initiative for the dairy industry and is likely to provide financial assistance for using solar systems. MNRE, UNDP and NDDB are jointly working towards adopting some viable energy solutions in the sector of dairying.

Policy and Institutional Support

The Rashtriya Gokul Mission is being implemented for the development and conservation of indigenous bovine breeds. It is said that indigenous breeds are more adaptable to our agro-climatic conditions, more resistant to most of the tropical diseases and can survive and give milk on inferior feed and fodder resources. Gujarat is already a state with an established network of dairy cooperatives, contributing 7.69% to the country's total milk production. Panchmahal district of the State implemented a unique and erstwhile programme in encouraging dairy farming; Dairy Vigyan Kendra (DVK), for training rural dairy farmers and improving their socio-economic conditions. It was reported that farmers who attended the DVK training recorded an increased income from dairy farming. Furthermore, the study points out the significant, positive impact of the DVK intervention on milk production at Panchmahal district. This example shows the possibilities of putting climate adaptation strategies into the design of trainings and therefore making the Indian dairy sector more resilient to climatic vulnerabilities (Misra *et al*., 2024).

Conclusion

Climate change impacts the dairy industry, affecting animal health, growth, fertility and feed availability. Direct effects include reduced feed resource efficiency, illness risk, heat stress, breeding issues and production quality. Indirect effects include greenhouse gas generation, reduced grazing grounds and crop farming competition. Dairy farming adaptations include heat-tolerant breeds, genomic selection and others. While, the technological advances like precision farming, AI and renewable energy integration can optimize resource utilization and reduce dairy processing energy usage. Hence, it becomes important to understand the dynamics of the situation and start preparing ourselves for the future. Sustainability will be the key in this context; as it helps to form the balance of life for all. Therefore, the dairy sector has the potential to combat the changing climate by making itself resilient through the adoption of options.

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