



The Future of Dairy Farming in India: From Milk Production to Smart, Sustainable and Profitable Dairying

*Vivek Kumar Singh, Sanchitpal Singh, Umashankar Rawat and Vineet Kumar Pandey
PhD Scholars, ICAR-Indian Veterinary Research Institute (IVRI), Izatnagar,
Bareilly, Uttar Pradesh, India

*Corresponding Author's email: vivekvet02@gmail.com

Dairy farming has long been an integral part of India's agricultural economy. For millions of rural households, milk production provides regular income, employment and nutritional security. Unlike seasonal crop cultivation, dairy farming can generate cash flow throughout the year, making it an important livelihood activity for small and marginal farmers, landless labourers and rural women. India is the world's largest milk-producing country. According to the Department of Animal Husbandry and Dairying, national milk production reached approximately 239.30 million tonnes in 2023-24, compared with 222.07 million tonnes in 2021-22. Per capita milk availability increased to 471 grams per day in 2023-24 [1]. These figures reflect the importance of dairy farming in India's food system and the continuing expansion of the sector. However, the future of dairy farming cannot depend on increasing the number of animals alone. Rising feed costs, low productivity in many animals, heat stress, infectious diseases, inadequate fodder supplies and fluctuating milk prices continue to affect profitability. At the same time, changing consumer expectations are increasing the demand for safe milk, quality dairy products, traceability and sustainable production. The next phase of Indian dairying must therefore focus on producing more milk efficiently, improving animal health and welfare, reducing avoidable production losses and ensuring that farmers receive a fair return. Advances in animal genetics, precision dairy farming, digital technologies, balanced nutrition and organized milk marketing can help transform the sector. The future lies not simply in producing more milk, but in building a dairy industry that is productive, environmentally responsible, technologically advanced and economically rewarding for farmers.

Genetic improvement: Building the foundation of future dairying

Animal genetics will remain one of the most important drivers of dairy development. Milk production, fertility, disease resistance, longevity and adaptation to environmental conditions are influenced by genetic potential as well as nutrition, management and health. India possesses diverse indigenous cattle breeds, including Gir, Sahiwal, Red Sindhi, Tharparkar and Rath, alongside important buffalo breeds such as Murrah, Mehsana and Jaffarabadi. These resources provide opportunities to improve dairy productivity while preserving valuable adaptive characteristics. Future breeding programmes must move beyond selecting animals solely for high milk yield. Excessive emphasis on production without adequate attention to fertility, udder health, longevity and heat tolerance can increase management difficulties and reduce the productive life of animals. A more balanced breeding objective should combine milk yield with reproductive efficiency, disease resistance, feed efficiency, animal welfare and adaptability to local conditions. Technologies such as artificial insemination, progeny testing, genomic selection, sex-sorted semen and embryo-based breeding can accelerate genetic improvement when used appropriately. The Rashtriya Gokul Mission supports the genetic improvement and conservation of indigenous bovine breeds and promotes modern reproductive technologies [2]. Genomic selection is particularly promising

because genetic merit can be estimated using DNA information alongside performance and pedigree records. This can help identify superior breeding animals earlier and shorten the time required to make breeding decisions. Nevertheless, genetic technologies must be supported by reliable animal identification, accurate performance recording, trained personnel and affordable access for farmers. High-yielding animals also require appropriate feeding, housing and veterinary care to express their genetic potential. The future of Indian dairying will depend on combining scientific breeding with locally suitable production systems rather than adopting a single breeding strategy for every region.

Precision dairy farming: The emergence of smart dairy farms

One of the major developments expected to shape dairy farming is precision livestock farming. This approach uses sensors, digital devices, automated equipment and data analysis to monitor individual animals and improve farm management. Traditional dairy management often relies on visual observation and the experience of the farmer. Although this knowledge remains valuable, certain changes in animal health, activity and reproduction can be difficult to identify early, particularly in larger herds. Modern technologies can help bridge this gap. Wearable activity sensors can assist in identifying changes associated with oestrus, while temperature and rumination monitoring can provide early indications of health problems. Automated milk recording can help farmers track production and identify unusual changes in individual animals. Digital systems can also maintain records of breeding, vaccination, disease treatment, milk yield and feed intake. When these records are interpreted correctly, farmers can make more informed decisions about breeding, feeding and health management. Artificial intelligence may further assist in analysing these data, identifying abnormal patterns and generating alerts. For example, a system may flag a cow showing reduced activity and milk production, prompting the farmer to examine the animal before the condition becomes more serious. However, smart dairy farming does not necessarily mean expensive robots and fully automated facilities. Even basic digital records, mobile-based advisory services, milk analysers and reliable animal identification can improve management on small farms. The principal challenge is making these technologies affordable, reliable and accessible to Indian dairy farmers, particularly those operating small herds. Technology should simplify decision-making rather than create additional costs or dependence on complicated equipment.

Better nutrition and fodder security

Feed and fodder availability will remain among the most important determinants of dairy productivity and profitability. Animals with high genetic potential cannot produce efficiently when their diets do not provide sufficient energy, protein, minerals and vitamins. Many Indian dairy farmers face seasonal shortages of green fodder, dependence on crop residues and rising costs of purchased concentrate feeds. These constraints can reduce milk yield, impair fertility and increase the time required for animals to recover after calving. Future dairy development must place greater emphasis on balanced ration formulation, fodder cultivation, silage making, hay production and efficient use of locally available feed resources. Scientific ration balancing helps match nutrient supply with an animal's requirements according to body weight, stage of lactation, milk yield and physiological condition. Mineral mixtures and other supplements should be selected according to actual dietary deficiencies rather than used indiscriminately. Crop-livestock integration can also improve feed availability. Suitable crop residues may be used as feed, while fodder crops can be incorporated into crop rotations. Silage and hay can help farmers preserve surplus fodder during periods of abundance for use during lean seasons. Future research may further improve the use of locally available feed ingredients, agricultural by-products and alternative protein sources, provided their nutritional value, safety and economic suitability are established. Digital feeding systems and automated feeders may improve ration delivery in larger farms. For smallholders, practical ration-balancing tools and access to trained animal nutritionists may provide greater benefits at a lower cost. Ultimately, better nutrition is not

merely a means of increasing milk yield. It is essential for reproductive efficiency, animal health, longevity and the economic sustainability of dairy farming.

Climate-resilient dairy farming

Climate change is emerging as a major challenge for dairy production in India. High ambient temperatures and humidity can cause heat stress, affecting feed intake, milk production, fertility and animal welfare. Heat stress can also increase the risk of health problems and reduce the productive lifespan of dairy animals. The future of dairy farming will require production systems that can withstand increasingly variable climatic conditions. Improved housing is an important starting point. Proper ventilation, shade, clean drinking water and suitable roof materials can help reduce heat exposure. Fans and sprinklers may be useful in hot conditions where water and electricity are available, provided they are managed appropriately. Breeding programmes should also consider heat tolerance alongside production traits. Indigenous breeds and locally adapted crossbred populations may offer useful genetic resources for developing animals suited to different climatic regions. However, heat tolerance and productivity must be evaluated scientifically for each production environment. Climate resilience also requires reliable fodder supplies, water conservation and improved manure management. Farmers can reduce some risks by storing fodder, diversifying feed resources and adopting suitable crop-livestock systems. Renewable energy offers additional opportunities. Solar power can support milk chilling, water pumping and other dairy operations, potentially reducing dependence on conventional energy sources. The effectiveness of these interventions will depend on investment costs, local conditions and access to technical services. A climate-resilient dairy sector must combine animal-level interventions with improvements in housing, feeding, water management and farm infrastructure.

Animal health, disease prevention and welfare

The profitability of a dairy farm depends not only on milk yield but also on the health and productive lifespan of its animals. Diseases can cause reduced milk production, treatment expenses, reproductive losses and, in severe cases, animal mortality. Future dairy farming must increasingly emphasize preventive healthcare rather than relying exclusively on treatment after disease develops. Regular veterinary examinations, vaccination according to local disease-control programmes, parasite management, hygienic milking and appropriate nutrition are essential. Newly purchased animals should be managed carefully, with suitable quarantine and health checks to reduce the risk of introducing infections. Digital health records can help farmers monitor vaccination, treatment, breeding and calving histories. Early-warning systems may also improve disease surveillance when supported by reliable veterinary networks. Animal welfare deserves equal attention. Comfortable housing, adequate space, clean bedding, appropriate handling, access to water and the prevention of unnecessary pain or stress are important for both ethical and productive reasons. India's Livestock Health and Disease Control Programme and related animal-health initiatives provide an institutional framework for disease prevention and control [3]. Continued investment in veterinary infrastructure, diagnostic laboratories and trained personnel will be essential as dairy production becomes more intensive and interconnected.

Value addition and changing consumer demand

The future of dairying will depend not only on how much milk India produces but also on how effectively milk is processed, marketed and converted into products that consumers value. Milk can be transformed into curd, paneer, cheese, ghee, butter, yoghurt, milk powder and other products. Appropriate processing extends shelf life, reduces certain forms of post-harvest loss and creates opportunities for higher-value markets. Consumer demand is also evolving. Food safety, product quality, convenience, traceability and nutritional information are becoming increasingly important. Dairy enterprises that maintain consistent quality and transparent production practices may be better positioned to meet these expectations. Small

dairy farmers can benefit from value addition through cooperatives, farmer-producer organizations and producer-owned processing units. Collective facilities can help overcome the financial and technical barriers that prevent individual farmers from processing milk economically. However, value addition does not guarantee higher profits. Processing requires suitable infrastructure, hygiene, packaging, regulatory compliance, reliable markets and effective business management. The future will therefore require stronger links between milk producers, processors, retailers and consumers. Farmers should receive clear information about milk quality requirements and payment systems, while producer organizations should help them participate more effectively in the dairy value chain.

Digitalization and traceability of milk

Digital technology can improve transparency and efficiency throughout the dairy supply chain. From animal identification to milk collection, processing and distribution, reliable records can help establish where milk originates and how it is handled. At the farm level, digital systems can maintain animal histories, milk production records, breeding information and health data. At milk collection centres, automated weighing and testing equipment can improve the recording of milk quantity and composition. These systems can support quality-based payments, reduce recordkeeping errors and improve confidence between farmers and dairy organizations. Digital traceability can also help identify the source of quality problems and improve food safety. As these systems develop, data protection, affordability and access for small producers will remain important considerations. India's National Digital Livestock Mission and the Bharat Pashudhan digital platform represent steps towards improving livestock identification and information management [4]. Their long-term value will depend on the accuracy of the data, effective implementation and practical benefits for farmers.

Cooperatives, farmer-producer organizations and inclusive dairy development

India's dairy sector has developed substantially through cooperative institutions that connect milk producers with organized collection, processing and marketing networks. The cooperative model enables small producers to pool milk, share infrastructure and reach markets that might otherwise be inaccessible to individual households. Farmer-producer organizations and milk producer companies can provide additional opportunities for collective procurement, marketing and business development. These institutions will remain important in the future, particularly as dairy farming becomes more technology-driven and quality-conscious. They can support farmers through access to veterinary services, artificial insemination, balanced feeding advice, milk testing, chilling facilities and training. Collective purchasing may also reduce the cost of inputs, while organized marketing can improve market access. Women are central to India's dairy economy and perform a substantial share of livestock-related work. Greater access to training, credit, digital tools, veterinary services and decision-making opportunities can strengthen their economic position. Young people can also contribute by developing dairy-related enterprises in animal health services, feed production, milk processing, equipment maintenance and digital advisory services. Future dairy development should therefore focus not only on technological advancement but also on ensuring that its benefits reach smallholders, women and rural youth.

Government initiatives shaping the future of dairying

Government programmes can support dairy development by improving animal genetics, infrastructure, disease control, processing and market access. The Rashtriya Gokul Mission focuses on indigenous bovine breed development, genetic improvement and the use of modern reproductive technologies. It provides a framework for improving productivity while conserving important indigenous genetic resources [2]. The National Programme for Dairy Development (NPDD) supports organized milk procurement, milk chilling, processing, testing facilities and producer institutions. These investments can improve milk quality and strengthen the connection between farmers and markets [5]. The Animal Husbandry

Infrastructure Development Fund (AHIDF) has supported investment in eligible livestock-sector infrastructure, including dairy processing and value addition. Farmers and enterprises should consult current official guidelines to determine the schemes and financial assistance available to them [6]. The Livestock Health and Disease Control Programme supports animal-health interventions and disease control, while digital livestock initiatives aim to improve identification and recordkeeping. The effectiveness of these programmes will depend on their implementation, accessibility, coordination between institutions and ability to address the actual needs of dairy farmers. Policy support should encourage productivity and innovation while maintaining animal welfare, environmental responsibility and fair returns to milk producers.

Sustainable and environmentally responsible dairy farming

As the dairy sector expands, environmental sustainability will become increasingly important. Dairy farming requires feed, water, energy and land, while livestock production generates manure and emissions that need appropriate management. Future dairy systems should improve resource-use efficiency rather than pursue higher production at any cost. Balanced feeding can improve animal productivity and reduce the amount of feed required per unit of milk. Better reproductive management and animal health can reduce avoidable losses, while appropriate manure management can improve nutrient recycling. Biogas systems can convert suitable animal waste into energy, and the resulting digestate can be used as a nutrient source when properly managed. Solar energy may support farm operations, while water-efficient cleaning systems and rainwater harvesting can help conserve water. Breeding for balanced productivity, fertility, longevity and adaptation can also improve the efficiency of milk production over an animal's lifetime. These measures require economic evaluation and technical support. Environmental improvements are most likely to be sustained when they also provide practical benefits to farmers.

Conclusion: A smarter and more sustainable future

The future of dairy farming in India will be shaped by the ability to combine traditional livestock knowledge with scientific innovation. Genetic improvement, precision dairy farming, balanced nutrition, preventive healthcare, climate-resilient management and digital technologies offer important opportunities to strengthen productivity and profitability. At the same time, the sector must address environmental concerns, improve milk quality, expand value addition and ensure that small and marginal farmers benefit from technological progress. India's strength lies in its large network of dairy farmers, indigenous animal genetic resources, cooperative institutions and growing scientific capabilities. These advantages can support a transition towards more efficient and resilient dairy production. The objective should not be to transform every farm into a highly automated commercial unit. Rather, it should be to provide every dairy farmer with access to appropriate technology, quality inputs, reliable veterinary services, fair markets and useful scientific information. The future of Indian dairying will depend on producing better, not merely producing more. By prioritizing animal health, farmer profitability, sustainable resource use and inclusive development, India can strengthen its position as a global dairy leader while improving the livelihoods of the people who sustain the sector.

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