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Technology Adoption In Dairy Cooperatives: A Comprehensive Review

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Abstract:

The integration of new technologies, such as automated systems for milk collection, telecommunications and computer technologies (ICT), blockchain technology for traceability, AI for herd management, and renewable energy sources, enhances the efficiency, sustainability, and transparency of dairy cooperatives in developing countries such as India, thus improving the lives of people in rural areas (FAO, 2019; NDDB, 2020). This paper seeks to tackle how digitalization and new technologies, like AI and blockchain, are transforming processes throughout the value chain, including but not limited to, the collection and processing of milk to the actual supply chain and customer relationship systems in dairy cooperatives. In addition, the paper examines the policy frameworks that subsidize the National Digital Livestock Mission. The role of the NDDB, other stakeholders, and government programs, including e-GOPALA, on policy and institutional support (Ministry of Fisheries, Animal Husbandry and Dairying, 2021) toward digital conversion is discussed. Startups and the private sector foster innovation through entrepreneurship which increases technological access everywhere. Moreover, gaps in adoption across regions are examined, using examples from more developed provinces such as Gujarat and Karnataka.

In-depth analysis of the literature reveals challenges such as inadequate infrastructure, stubbornness to adopt new approaches, unavailability of skillful workers, region-based customization, and long-term sustainability planning. Case studies from India (Amul, Milma, COMFED, KMF) and global examples (Kenya Dairy Board, Netherlands, New Zealand) illustrate notable lessons and benchmarks. The review synthesizes literature from various sources to argue that adopting environment-friendly technologies will help advance dairy cooperatives. Focusing on closing the digital gap, improving the certified training framework, and enabling farmers school makes innovation work for development. It increases income for rural areas and helps in overall rural development. This document is aimed at the policymakers of the dairy sector, cooperative managers, scholars, and practitioners engaged in development work in the sector and have an interest in exploring technologies for equitable development in the cooperative dairy industry.

Keywords: Dairy cooperatives, Technology adoption, ICT, AI, Milk supply chain, Rural development, Sustainable agriculture, Women empowerment, Digital tools

Introduction

Particularly in agricultural nations like India, dairy cooperatives are essential to the socio- profitable structure of pastoral husbandry. Comprising milk directors who combine their coffers to gather, manufacture, and vend milk and dairy products, these cooperatives are Members, generally smallholder growers, benefits from pooled structure, bettered request access, and group logrolling strength. Dairy cooperatives play a part in pastoral development, food security, women commission, and community structure in addition to their profitable conditioning. Significant expansion in the Indian dairy assiduity has been seen substantially because of the collaborative movement gaining traction with Operation Flood. The conventional collaborative model, however, needs technological integration to stay applicable and competitive in the face of ultramodern issues including urbanization, request volatility, and climate change. Technological developments give answers to enhance milk yield (Sharma & Thaker, 2022), guarantee quality control, simplify processes, and boost traceability. Adopting technology in dairy cooperatives is not just about modernizing infrastructure; it also means rethinking how cooperatives run and interact with their members. Technology is changing every aspect of the dairy value chain from the digitalisation of milk procurement systems to the application of large data analysis for decision-making. Birthal et al. (2005) claim that by increasing dairy operations more efficient and profitable, modern technology can greatly improve rural lifestyles. Thus, developing policies and plans that support inclusive and sustainable growth in the dairy sector depends on a knowledge of the many aspects of technology adoption—including its facilitators, obstacles, and effects.

Objective of the Study:

- To analyze the types and impact of technology adopted in dairy cooperatives.
- To examine policy and institutional frameworks that support tech adoption.
- To identify barriers and enablers to digital transformation.
- To highlight successful case studies and global best practices for India.

Methodology

This is a narrative review based on secondary sources including academic journals, government reports, cooperative data, and international development publications. A systematic search was conducted through databases such as Scopus, Google Scholar, and government portals. The review includes literature primarily from 2005 to 2024, with emphasis on Indian case studies and global benchmarks relevant to cooperatives.

Selection Criteria:

- Relevance to dairy cooperatives and technology.
- Recent developments in ICT, AI, blockchain, and sustainable practices.
- Case studies with measurable outcomes.

Development of Dairy Cooperatives

The start of the dairy cooperative movement in India can be linked to the National Dairy Development Board (NDDB) under Verghese Kurien's direction launching Operation Flood in 1970. This program transformed India from a milk-deficient country into the world's greatest milk producer, hence marking a major turning point. Indian dairy cooperatives have evolved from conventional, labor-ferocious businesses to ultramodern (Kurien, 2005; NDDB, 2020), technology-enabled companies throughout the times. Relinquishment of a wide range of technologies — including electronic milk analyzers, automated milk collection systems, enhanced cold chain logistics, and mobile-grounded fiscal platforms — defines this development. piecemeal from simplifying processes, these technological interventions have bettered openness, traceability, and responsibility inside the collaborative structure (Kurien, 2005; Chand, 2017).

Policy Support for Technology Adoption by Drivers

Numerous connected rudiments propel technological relinquishment in dairy cooperatives. First, profitable provocations are important. Technologies perfecting milk yield and quality help collaborative members to earn further (Rao et al., 2017). Second, government programs and support programs including the Digital India design, e-NAM(Electronic National Agriculture Market) (GoI, 2019; NDDB, 2020) , and public Dairy Plan have established an enabling terrain for digital metamorphosis (GoI, 2019). These regulations seek to update dairy infrastructure, enhance animal genetics, and encourage sustainable practices. For example, under the National Dairy Plan, cooperatives get financial assistance for bulk milk coolers, automatic milk collection systems, and chilling infrastructure (NDDB, 2020). Working with state governments, the Department of Animal Husbandry and Dairying improves extension services and veterinary care via digital channels. Schemes such as e-GOPALA offer market linkages (Ministry of Fisheries, Animal Husbandry and Dairying, 2021), AI-based breeding recommendations, and real-time livestock management assistance. By creating native technology, running pilot projects, and offering scientific training to cooperative members, research institutions like ICAR-National Dairy Research Institute and agricultural universities greatly help (Singh & Rai, 2021). These integrated initiatives build a whole ecosystem encouraging the inclusive and sustainable adoption of technology in the dairy industry (ICAR-NDRI, 2021).

Types of Technologies Adopted

From milk production and collecting to processing, distribution, and customer involvement, technology use in dairy cooperatives covers the whole dairy value chain. The primary technologies used are explained in depth below:

Milk Collection and Testing:

Some of the most revolutionary technology in the collecting process are Electronic Milk Analyzers (NDDB, 2020; Sharma & Thaker, 2022) and Automated Milk Collection Units (AMCUs). By eliminating human mistake and conflicts, AMCUs automatically weigh milk, check it for fat and SNF (Solids-Not-Fat), and produce receipts for farmers. By guaranteeing openness in quality-based pricing, the analyzers help to foster confidence between the cooperative and the farmer.

Processing and Storage Technologies:

Cooperatives put money into technology including bulk milk refrigerators, pasteurization equipment, and chilling tanks to preserve milk quality and safety. Especially in distant rural areas where access to power and transportation might be erratic, these gadgets are absolutely vital in reducing spoilage. Advanced cooperatives use homogenizers, separators, and packaging machinery to further process milk into value-added products.

Information and Communication Technology (ICT):

ICT technologies encompass member feedback websites, SMS notifications of training sessions, and mobile phone applications for the purchase of milk and payment notification. Such devices promote transparency and engagement among cooperative groups and their members. There are cooperatives that have applied digital dashboards to track financial performance, logistics, and procurement information in real time.

Supply Chain and Logistics Technologies

GPS tracking of milk tankers ensures timely delivery and safety enroute. By tracking milk quality throughout the entire supply chain, certain cooperatives have employed blockchain technology traces and establish consumer confidence (World Bank, 2020; Kenya Dairy Board, 2022).

Farmer Support Services

Without having to go long distances, farmers can consult experts on cattle breeding, nutrition, and health through veterinary telemedicine. Online learning platforms address best practices, animal husbandry, and climate-smart agriculture. Through predictive analytics solutions for feed planning and lactation management, a number of cooperatives contribute to raising production.

Sustainable and Renewable Technologies

Dairy companies have high energy requirements, therefore cooperatives are increasingly adopting renewable technology like solar-powered chilling plants, biogas plants, and energy-saving milking machines. These innovations not only reduce operating expenses but also favor environmental sustainability.

Artificial Intelligence and Data Analytics:

Monitoring of herd health, automated disease identification, and optimum feeding plans are all undertaken with the application of artificial intelligence and machine learning among other innovative technologies. With the application of data analytics technologies, cooperatives are able to make informed decisions to improve the delivery of service and production.

Issues in Technology Adoption

Although the benefits appear promising, some problems prevent dairy cooperatives from appropriately using technology. Low digital expertise among rural farmers, inadequate infrastructure including inconsistent electricity and internet connection, and unwillingness to adapt are major challenges. Financial constraints often prevent small cooperatives from investing in modern technology (Rao et al., 2017; NITI Aayog, 2020), especially if first installation costs are high. A lack of trained individuals to operate and maintain technical systems also contributes low tools. Cultural factors including gender roles and traditional farming practices could also influence the pace and extent of adoption. Often excluded from training programs and decision-making processes, women who are significant in dairy farming restrict the prospects of inclusive innovation. Furthermore, technical solutions are frequently created in a top-down approach ignoring regional and local needs. This results in waste of resources and low adoption rates. Meeting these challenges calls for capacity-building initiatives, targeted subsidies, inclusive training programs, and public-private collaborations. Moreover, long-term maintenance strategies and region-specific technology customization are required to guarantee sustainability. Field demonstrations and awareness campaigns can also enable farmers to personally experience the advantages of using contemporary technologies.

Digital Literacy and Capacity Building

Digital literacy is important with respect to the use of new technologies in the dairy cooperatives. Several rural farmers, especially women and old age people, are not accustomed to operating digital devices, mobile applications, and even making transactions over the internet. This is a makeshift technological solution that is only useful for some and fails to work for most people. For this reason, training programs should add digital aspects of learning to the scope of traditional services offered by extension officers. Complete teaching manuals that combine theoretical lessons with practical training could help farmers gain confidence applying ICT tools. Initiatives such as the Common Service Centers (CSC), Rural Digital Literacy Missions, and Training Vans equipped with ICT tools have proven to be effective in solving these issues (GoI, 2019). Forms of led community instruction where knowledgeable people go into their community to teach digitally proficient farmers are also beneficial. Also, teaching people of the younger generation through the formal education system the basics of ICT in the rural parts of the country would produce future dairy business owners who know their way around technology.

Gender and Inclusivity in Technology Access

Dairy farming offers women substantial roles as they participate in feeding, milking, and general animal care. They are, however, primarily absent from training, cooperatives' management, and technological opportunities. It is important to bridge this gap in order to foster greater equity and efficiency towards technology usage. A female-focused approach addressing such barriers as inadequate interfaces, trainers that ignore gender dynamics, and women extension workers is bound to improve participation. Women's economic empowerment has largely resulted from self-help groups (FAO, 2019; NITI Aayog, 2020). They can also be used as tools to market technology. Command and local language mobile applications greatly enhance participation of semi-literate females in digital activities. Gender equal changeable policies to support female participation in the board of directors of the cooperative society and other policy making organs need to be introduced.

Private Sector Involvement and Startups

Private initiatives like start-ups, technology companies, and social enterprises are actively driving innovations in the dairy sector. For instance, Startups are putting AI to use in farm management through apps like herd management AI, and have created cloud-based inventory systems. These solutions are relatively inexpensive, scalable, and can be used in rural settings. The combination of private companies with those of cooperatives can foster innovation through the implementation of pilot projects, offering technical instruction, and partnering with other entities to develop products. Government initiatives like the ones offered under Startup India and Agri-Infra Fund in addition to the Atal Innovation remember support such synergistic undertakings (GoI, 2019; NITI Aayog, 2020). Moreover, dairy tech solutions that have significant impact are able to gain funding from impact investors and CSR activities for scaling when paired with these cooperatives. These partnerships are poised to modernize the dairy cooperatives against a backdrop of sustainability.

Global Best Practices and Lessons for India

A number of countries across the world integrate technology with dairy farming, and each of them has something to offer in terms of best practices. In New Zealand, automated milking systems increase productivity, while genetic monitoring improves the herd management's animal husbandry medicine. The Netherlands has pioneered precision dairy farming, which incorporates GIS, sensors, and data analysis into information management for optimal resource allocation. The use of climate-controlled sheds with real-time monitoring systems has further aided efficiency in Israel's arid regions. Contextual innovation can help India adopt some of this technology. For example, low power GPS sensors can solve the energy crisis for use in

remote powered villages. Indian cooperatives can make strides in the global best practice understudy for training, data privacy, and cooperative governance. Technology transfer and mutual learning can be supported through international partnerships via trade fairs, research networks, and other development aid.

Challenges in Adoption

Instead of being fully embraced in dairy cooperatives, technology has potential yet runs into numerous obstacles. One such issue if the very low digital literacy rate found among rural farmers, as many do not know how to operate modern tools and platforms. Moreover, lack of consistent electricity and internet in far-off locations poses infrastructural problems as well. Often, small cooperatives are inhibited by high upfront costs that come with advanced technology. In addition, there is an insufficient amount of trained personnel capable of operating and performing maintenance on advanced technical machinery. Furthermore, social and cultural factors, such as the exclusion of women from training sessions and leadership roles, greatly hinder the inclusivity of tech-based initiatives. Many regions also have a lack of local focused technological solutions which leads to inadequate adoption rates. In order to address these issues, modification is needed in training initiatives, policy frameworks, financial motivation, inclusive community demonstrations, and policies that promote the participatory development of women in the community.

Ethical and Data Privacy Considerations

As dairy cooperatives utilize increasingly digital tools, they need to deal with problems with data protection and ethical utilization of technology. If there aren't enough safety measures in location, as applications and measurements that collect farmers' and their animals' personal information could be exploited. Cooperatives must develop data protection rules, ensure upfront data usage permission, and engage with tech providers who comply with privacy laws. Also, farmers' privacy deserves to be safeguards regardless of what anonymized data has been made available to the public.

Regional Disparities in Technology Adoption

Tech adoption across Indian cooperatives is uneven. While Gujarat and Karnataka have achieved significant digital transformation, states like Bihar and Jharkhand lag due to infrastructural, financial, and awareness issues. Tailored regional policies and targeted support schemes are essential to address this imbalance. State-level dairy federations should be empowered to run localized pilot projects (NDDB, 2020; NABARD, 2021).

Table-1: contains info related to technology types

Technology Type	Function	Key Benefits	Barriers
AMCU & Milk Analyzers	Milk collection & quality testing	Transparency, accuracy	Initial cost, lack of training
ICT tools (Apps, SMS)	Communication, payments	Engagement, traceability	Low digital literacy
AI & ML	Health monitoring, feed optimization	Efficiency, disease prevention	Lack of skilled operators

Blockchain	Supply chain transparency	Trust, traceability	High cost, awareness gap
Renewable Tech	Solar chillers, biogas	Sustainability, cost-saving	Installation and maintenance

Case Studies and Best Practices

Amul Dairy Cooperative (Gujarat):

Amul is one of the foremost examples of effective technology use. Its consolidated data system, strong cold chain, GPS-tracked logistics, and AMCUs have been put into use. Amul's mobile apps enable farmer input, payment, and veterinarian assistance. Amul also puts money into ongoing development and training initiatives to enable its members, notably women and young people. It has worked with ICT developers to increase quality control, automate processes, and strengthen milk traceability -Cite with existing sources Amul: (NDDB, 2020; Sharma & Thaker, 2022).

Milma (Kerala):

Milma has included ICT, mobile-based farmer training, and women-centric self-help groups (SHGs) into procurement. Their emphasis on solar chillers has helped to encourage sustainability. Milma's collaboration with local IT companies and agricultural institutions has generated innovative concepts for production tracking and real-time animal monitoring. They have also conducted a blockchain pilot to promote transparency in the milk supply chain - Cite with existing sources Milma: (Singh & Rai, 2021).

Bihar State Milk Co-operative Federation (COMFED):

COMFED has stressed mobile apps and veterinary telemedicine to manage cow health and reproductive cycles. Their pilot blockchain initiative for milk traceability is under expansion. They also run nutritional awareness campaigns and offer balanced feed to boost cattle output. Field-level farmer education is a cooperative endeavor of COMFED and Krishi Vigyan Kendra's (KVKs). It has also run cooperatives and maximized services using data analytic methods chain -Cite with existing sources COMFED: (ICAR-NDRI, 2021).

KMF (Karnataka Milk Federation):

KMF has introduced smart milk ATMs, biosecurity technologies, and artificial intelligence-based disease detection in its member dairies. Their community-based strategy calls for building village-level knowledge hubs. KMF combines gender-focused training courses with cellphone notifications for breeding cycles and health check-ups -Cite with existing sources KMF: (Sharma & Thaker, 2022)

International Case: Kenya Dairy Board:

Dairy cooperatives in Kenya have embraced mobile money services such as M-Pesa to improve financial inclusion. ICT-based advising services provide real-time information on feed and disease control, hence boosting farmer resilience. Collaborations with technology companies have aided in the creation of integrated weather-based decision support systems and farmer-centric applications. Cooperatives have combined solar cold chain systems and the Kenya Dairy Board has backed AI-based animal health forecasting tools - Cite with existing sources Kenya: (Kenya Dairy Board, 2022).

Institutional and Policy Support

The deployment of technology in dairy cooperatives is mostly driven by policy and institutional assistance. Government programs such as the National Digital Livestock Mission, Rashtriya Gokul Mission, and Atmanirbhar Bharat schemes offer financial and technical support for the digitalization of dairy infrastructure. State-level dairy federations and NABARD (National Bank for Agriculture and Rural Development) provide grants and concessional loans to cooperatives. NDDB and NDRI are among institutions that run pilot programs, create local technologies, and offer capacity-building assistance. Multilateral organizations such as the World Bank and FAO also offer technical support, financing, and knowledge sharing tools. Important actions are strengthening cooperative governance, creating ICT skill curricula, and encouraging creative alliances between tech start-ups and cooperatives.

Effect of Technology Adoption

By enhancing efficiency, transparency, and member revenue, the integration of technology has greatly revolutionized dairy cooperatives. Technological developments have improved milk yield and quality (Singh & Rai, 2021; Sharma & Thaker, 2022), streamlined cold chain operations, and strengthened payment systems. Digital dashboards and traceability solutions have improved management capacity and fostered consumer confidence. Improved animal health through veterinary telemedicine and e-learning tools increases production. Social impacts include increased women's participation in decision-making and access to financial and technical resources. From an environmental perspective, new processing technologies and integration with renewable energy have reduced the carbon footprint of the sector. FAO (2019) and World Bank (2020) research finds evidence that digitized dairy systems are less vulnerable to market shocks and climate risk. Greater acceptance and positive impacts have also been shaped to a great extent by community-level digital literacy efforts and localized language content.

Future Directions

The adoption of new technologies in dairy cooperatives is still growing. However, the use of artificial intelligence, blockchain, and the Internet of Things (IoT) offers great potential (Sharma & Thaker, 2022; FAO, 2019). These new technologies can enable smart farm management, real-time supply chain tracking, and even provide fresh predictive health diagnostics. For example, AI programs are able to predict livestock diseases while optimizing feed per head and helping make effective breeding decisions. Additionally, quality control using blockchain enhances milk traceability throughout the supply chain. The digital divide presents challenges, as local speaking rural operators require focused attention and investment in infrastructure, mobile access, and even region specific content. The community can bridge the digital divide through vernacular mobile applications, interactive voice response systems, literacy and digital skills, and community training programs. Farmers need to be included in all aspects of the technology from design to piloting to scaling to ensure solutions work in the reality on the ground. This approach is referred to as co-innovation and it requires increased emphasis. The policy frameworks need to be adjusted to incorporate incubation centers, innovation grants, and partnerships with agritech businesses to foster cooperatives. Encouraging Academic-Industry collaborations can accelerate the development of scalable and sustainable locally tailored innovations. Socially progressive measures along with aimed attention assists in bridging the gap of social equity and technology access. Dairy cooperatives can adopt sustainable agricultural practices like renewable energy, climate-adaptive feedstock silos, and nutrient-rich excrement control systems. Therefore, the emphasis should shift to climate-smart dairy technologies that are geared towards fulfilling the goals of production and environmental sustainability.

Conclusion

Through enhancing production, efficiency, and sustainability, technology uptake has emerged as a major force in dairy cooperative future making. Cooperatives have been able to streamline operations, improve milk quality, and deliver improved services to members through digital and mechanical technologies—such as automated milk collection systems, digital record-keeping, veterinary teleconsultation platforms, and renewable energy sources—integration. Such transformations are of particular importance in the Indian context because the dairy sector supports millions of rural families. Despite these benefits, numerous issues continue to limit the pace and scope of adoption. These include economic barriers, gendered disparities in the use of technology, inadequate digital literacy among farmers, and infrastructure constraints. Addressing these barriers requires sustained policy interventions, economic support, and participatory training programs. In addition, prevention of marginalization of smallholder and vulnerable groups relies on equitable access and development of friendly solutions. Embracing technology has also had social and environmental impact. The members have grown to be more trusting due to greater openness, decision-making based on data, and enhanced traceability of milk. Simultaneously, solar-powered chilling systems and biogas plants among the green technologies are assisting in the conservation of the environment. Ultimately, the study demonstrates that technology is an enacting force that may promote inclusion, empowerment, and sustainable rural development instead of an instrument for financial gain.

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