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Driving Inclusive and Sustainable Growth: White Revolution 2.0 in India's Dairy Sector: A Review

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ABSTRACT

India contributes more than 25% of global milk production, making it an essential component of rural lives and the greatest milk producer in the world. In 2024, the Ministry of Cooperation launched White Revolution 2.0 to modernize and grow the dairy industry, building upon the achievements of Operation Flood. The focus of the initiative is on strengthening dairy cooperative societies, promoting women empowerment, employment generation, sustainability and the establishment of specialized Multi-State Cooperative Societies for better input supply, circular economy integration and organized by-product management. This study is a narrative review and data collection is based on secondary data from government reports, research articles, statistics and policy documents related to the dairy industry in India. The review aims to assess the structural pattern in the dairy industry, cooperatives, productivity, sustainability and technological innovations, with a special focus on the developments under White Revolution 2.0 and its potential consequences for the environment and society. The review also indicates that the dairy industry in India has strong socioeconomic significance, but it has been facing some challenges such as low productivity, animal health, fragmented supply chain and the presence of the informal sector. The White Revolution 2.0 fills the gaps in the dairy industry by focusing on cooperative development, innovation, climate-smart dairy development, digitalization and value addition strategies. The development of the three Multi-State Cooperative Societies is also likely to enhance rural livelihoods, sustainability and long-term growth in the dairy industry in India by procuring one million liters of milk per day in the next five years.

Key words: Cattle economy, Climate-smart methods, Operation flood, Precision dairy farming, White revolution.

Milk is an important part of India's nutrition system because it contains high-quality animal protein as well as essential micronutrients like calcium, magnesium and potassium in easily absorbed forms. As a result, milk is widely regarded as a near-complete food that promotes growth, skeletal development and overall health in every age group. India possesses maintained its status as the leading producer of milk worldwide, accounting for more than 25% of total production. Over the past ten years, the dairy sector has become a critical pillar of food security, rural livelihoods and nutritional enhancement between 2014-2015 and 2023-2024, from 146.30 MT to 239.30 MT the country's milk production rose by 63.56% accompanied by a significant increase in per capita milk availability from 124 g to 471 g per day (Fig 1 and 2). Over the last eleven years, the industry has grown by about 70%, contributing approximately 5% the country's economy and giving more than 8 crore farmer's direct employment (National Accounts Statistics). Women's considerable involvement in milk production and procurement emphasizes the dairy sector's relevance as a driver of inclusive and gender-sensitive growth in India. These accomplishments represent increased productivity, institutional development and market integration, cementing dairy's position as a major contributor to agricultural growth and dietary diversity (National Dairy Development Board, 2023-24). Furthermore, the sector contributes significantly to exports, with animal product exports valued at Rs. 37,665.51 crores in 2023-24, owing largely to strong global demand for Indian buffalo meat, which accounts for more than 82% of total exports, while the leading milk-producing states are Uttar Pradesh Andhra Pradesh, Madhya Pradesh, Rajasthan and Gujarat

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(Sarkar and Dutta, 2020; Sonwane, 2018). Indigenous and non-descript cattle account for approximately 20% of the country's total milk output, while goat milk accounts for roughly 3% (Modi *et al*., 2025; GoG, 2024; Ministry of Agriculture and Farmers Welfare, 2020). Livestock rearing in India has evolved from a traditional activity to a dynamic "sunrise sector" that supports rural livelihoods and drives national economic growth (Sonavale *et al*., 2020), serving as the rural economy's backbone by providing supplementary income, employment opportunities and nutritional security (Sengupta, 2022). India also has the world's largest animal husbandry base, with 512.06 million livestock heads and the livestock sector accounts for 4.5% of total GVA and 25.8% of agricultural GVA (Kumar *et al*., 2021). The amazing success of the Amul model during Operation Flood (1970-1996) highlighted the usefulness of farmer-owned cooperatives in organizing production, assuring fair markets and safeguarding producers from exploitation (Gulati and Juneja, 2021). Furthermore, milk producer companies' relatively strong performance has been linked to sound governance practices, such as clear membership norms, strong member commitment and patronage, a link between equity and participation, effective and well-composed boards of directors and transparent, democratic decision-making processes (Singh, 2023; Kumar *et al*., 2022; Neti, 2019; Kanna and Amudha, 2022).

The Indian dairy industry is currently undergoing a profound technological transition, progressing beyond the foundational achievements of the White Revolution that established India as a leading global milk producer while responding to emerging market, safety and sustainability requirements that necessitate a new development path (Kumar and Parappurathu, 2019). The analysis critically examines the sector's digital advancement and proposes a model for understanding digital developments in the sector in terms of "White Revolution 2.0." The section on plans for phase development indicates how modern digital and automation technologies can enhance food safety, product quality, traceability, transparency and sustainability in the dairy sector value chain by 2025. Considering that dairy products are perishable in nature, supply chain efficiency is critical in ensuring consumer demands for product quality, price and timely delivery/loss reduction are met and food handling is seen as an essential aspect of supply chain efficiency (Fredriksson and Liljestrand, 2015; Tadesse and Gebresenbet, 2021). Substantial research has been conducted on the identification and management

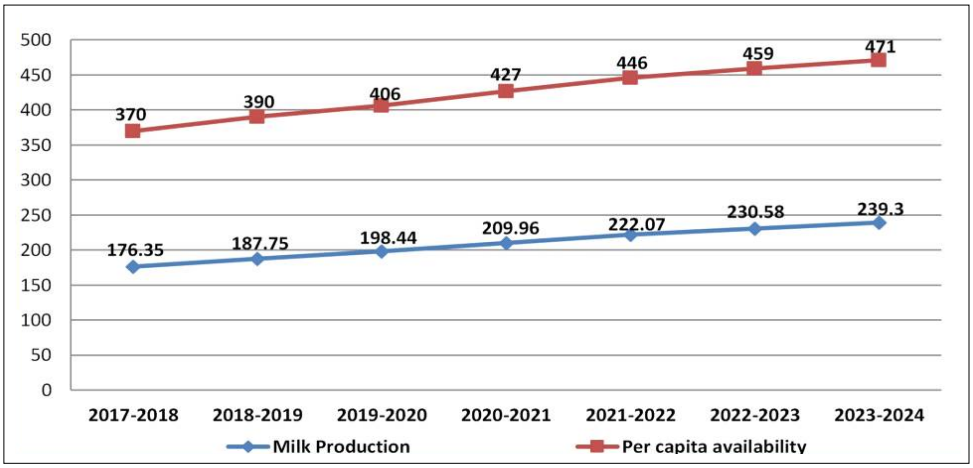


Fig 1: Milk production and per capita availability of milk in India.

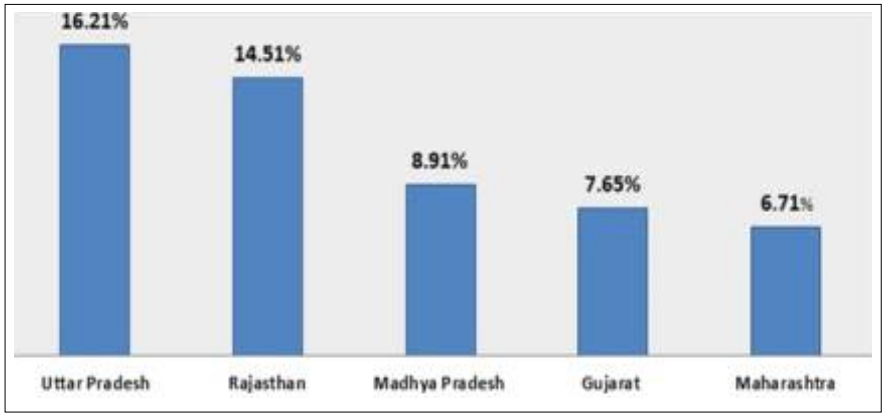


Fig 2: Top 5 milk producing states.

of critical processing parameters for ensuring dairy product safety and quality (Neokleous *et al*., 2022; Ribeiro *et al*., 2022). Dairy logistics cover both cold and ambient chain logistics, which require proper planning, execution and monitoring for successful management of dairy products from farms to customers (Hopkins and Hawking, 2018). In this regard, Industry 4.0 (I4.0) technologies are reportedly impacting dairy production and distribution systems, thereby facilitating predictive maintenance, intelligent equipment and trained manpower using 3D simulation tools and augmented reality-based virtual assistance (Monshizadeh *et al*., 2023). Across the world, almost 150 million dairy farming households are engaged in dairy farming, producing 965 million tons of milk in 2023 (FAO Food Outlook, 2021). Since 1998, India has been the world's largest producer and consumer of dairy products, accounting for roughly 25% of global milk production in 2022-23, surpassing the combined value of wheat and rice (National Accounts Statistics 2024). As the country prepares to pursue White Revolution 2.0 in accordance with the Hon'ble Prime Minister's vision of "Sahkar se Samridhi. The project is expected to solve important sectors concerns by empowering women, developing local milk production, expanding cooperative networks, improving dairy infrastructure, promoting a sustainable circular bio-economy and increasing milk exports. In the broader context of India's goal of becoming a $5 trillion economy, the third-largest global economy and a fully developed nation by 2047, it is critical to systematically explore and optimize the dairy sector's potential at both the national and grassroots levels (Fredriksson and Liljestrand, 2015).

White revolution

Operation Flood, (known as the White Revolution), started in the 1970s. under the direction of the NDDB and was led by Dr. Verghese Kurien, the visionary behind the AMUL model. Program attempted to duplicate the AMUL-based cooperative system throughout India, with a focus on forming strong cooperatives among milk producers to increase milk production, procurement, processing and marketing efficiency (Table 1). This institutional strategy transformed the dairy business, allowing India to becoming one of the top producers of milk worldwide.

White revolution 2.0

Operation Flood, often known as the first White Revolution by increasing their share of total milk procurement to 50%, notably by improving access to markets in underprivileged and unorganized areas. The "Margadarshika" scheme proposes establishing a panchayat- or village-level network of newly Multipurpose mechanized primary agricultural cooperative societies (MPACSs), with a financial support of Rs. 40,000 per society for dairy-related activities. White Revolution 2.0, which recognizes dairy foods as rich sources of important nutrients and functional components, was officially inaugurated in Sept. 2024 by the Home Minister. The campaign focuses on empowering women, creating jobs, increasing milk procurement and reducing malnutrition (Table 1).

Key components of the programme include

- Offering financial support to dairy producers in undeveloped areas, including cash credit without interest, multipurpose cooperative organizations and Primary Agricultural Credit organizations.
- Building dairy cooperatives to improve milk procurement. Currently, India has more than 260 milk unions and nearly 170,000 dairy cooperative organizations operating throughout the country.

Budget support (2024-25)

In the Union Budget for 2024-25, the Government of India granted INR 45.2 billion (USD 540 million) to the Department of Animal Husbandry and Dairying (DAHD), a 16% increase over the budget for 2023-24. Major dairy development programs under DAHD are centered on breed improvement, particularly through Rashtriya Gokul Mission (RGM), which received INR 7 billion (USD 84 million) for the year 2024-25. The scheme promotes the increase of genetic potential and the conservation of indigenous breeds by providing financial assistance of INR 5,000 (USD 60) every *in vitro* fertilization (IVF) operation, particularly for animals held by small and marginal farmers. Additional help includes a 50% discount on the price of sex-sorted semen and a 50% capital subsidy of up to INR 20 million (USD 239,000) for breed multiplication farms.

The white revolution 2.0 action plan of NDDB

Over the next five years, NDDB intends to build 56,000 new multipurpose dairy cooperative societies (DCSs), as well as strengthen 46,000 current societies by improving milk procurement and testing infrastructure. U.P., Odisha, Rajasthan and Andhra Pradesh are among the states with the highest priority for establishing new DCSs.

Funding

National Programme for Dairy Development 2.0 will be the key financing source for White Revolution 2.0, providing financial assistance for the establishment of methods for purchasing milk at the village level, facilities for chilling and initiatives to increase capacity. In addition, 1,000 Multipurpose Primary Agricultural Credit Cooperative Societies will get Rs. 40,000 to improve dairy cooperative infrastructure.

Pilot projects

A Rs. 3.8 crore pilot project was begun by NDDB in February 2023 to build up dairy cooperatives in previously untapped gram panchayats in Haryana, Madhya Pradesh and Karnataka. This campaign resulted in the formation of 79 dairy cooperative organizations, which now acquire over 15,000 litres of milk each day from nearly 2,500 farmers.

White revolution 2.0: Goals

Milk purchasing goal

Dairy cooperatives presently procure around 660 lakh kg of milk per day (2023-24). Under White Revolution 2.0, this amount is expected to skyrocket to approximately 1,007 lakh kg per day by 2028-29, showing a significant increase in cooperative-led milk collecting (Table 2).

Cooperative society expansion

The program aims to broaden the reach of cooperatives for dairy products, which now operate in approximately 70%

Table 1: A comparison of India's milk production during the white revolutions.

Parameter	Pre-white revolution (Before 1970)	White revolution 1.0 (Operation Flood, 1970-1996)	White revolution 2.0 (2024 Onwards)
Milk production level	About 22 million tonnes in 1970	Increased from 22 to 69 million tonnes by 1996	Exceeds 220 million tonnes; further growth envisaged Kumar *et al.* (2023), Chand, R. (2007), DAHD (2024).
Annual growth	Low growth rate (1-2%)	Moderately high growth (4-5%)	Higher growth targeted rate through technological and institutional support Kumar *et al.* (2023), Chand, (2007), DAHD (2024). GOI, (2024)
Per capita milk availability	Approximately 110 g/day	Increased to about 220 g/day	More than 471 g/day; expected to rise further Kumar *et al.*, (2023), Chand, (2007), DAHD (2024).
Production structure	Largely unorganized with dominance of local vendors	Expansion of cooperative-based production system	Strengthening of Multi-State cooperative societies (MSCS) Kumar *et al.* (2023), Chand, (2007), GOI, (2024) Patel, (1994).
Key strategy	Traditional practices with poor infrastructure	Cooperative procurement, milk grid system and rural linkage	Digitalization, precision dairy farming and sustainability-driven approach Chand, (2007), Kumar *et al.* (2023), GOI, (2024) Patel (1994). Singh *et al.* (2022).
Institutional support	Limited government intervention	Programme implemented by National Dairy Development	Led by Ministry of Cooperation with focus Board (NDDB) on expansion and modernization Chand, (2007). Patel, A. (1994). GOI, (2024)
Technology adoption	Negligible	Adoption of artificial insemination and veterinary services	Use of precision dairy tools, digital monitoring and climate-smart technologies Kumar *et al.* (2023), Chand (2007), Singh *et al.* (2022).
Socio-economic impact	Low contribution to rural income	Enhanced rural employment and increased participation of women	Focus on inclusive development, women empowerment and circular economy Chand and R. (2007), Kumar *et al.* (2023), GOI, (2024) Patel, (1994). Singh *et al.* (2022).
Sustainability focus	Not considered	Limited attention to environmental aspects	Emphasis on biogas, organic manure and scientific waste utilization Chand (2007), Kumar *et al.* (2023), Singh *et al.* (2022).

of districts and 30% of villages, by expanding cooperative services to a substantially wider portion of rural India.

Targeting new regions

To bridge the gap in regions, it has been proposed to form new multipurpose dairy cooperative societies in states like Uttar Pradesh, Odisha, Rajasthan and Andhra Pradesh to bring all the uncovered regions into the cooperative fold.

Strengthening existing cooperatives

Around 46,000 existing dairy cooperatives would be upgraded through improvements in the milk procurement system, testing facilities and other infrastructure to improve their efficiency and effectiveness.

Funding *via* NPDD 2.0

The National Programme for Dairy Development (NPDD) 2.0, which would facilitate the establishment of milk procurement systems, chilling facilities and capacity-building activities at the village level, would be the primary source of funding for White Revolution 2.0.

Strength of white revolution 2.0

Increased milk production

The scheme aims to increase milk procurement by about 50% by 2028-29, thus enhancing the availability of milk and milk products in the country.

Empowerment of dairy farmers

The increased cooperative membership will enable dairy farmers to gain access to wider markets, especially in regions where dairy farming was not covered earlier.

Women profession

With the dairy sector already supporting nearly 8.5 crore livelihoods and a high level of women's participation, White Revolution 2.0 is expected to further strengthen women's economic empowerment and workforce engagement.

trengthening dairy cooperatives

Establishing 56,000 new dairy cooperatives and upgrading 46,000 existing ones will greatly strengthen rural cooperatives and infrastructure.

Enhanced quality and productivity

Better quality will be ensured by introducing better milk procurement systems and modern testing equipment, which will also result in productivity increases.

Livelihood support

Employment and additional sources of income will be generated for rural populations, especially for marginalized and disadvantaged groups.

Growth in organized dairy industry

This programme will increase the proportion of milk handled by the organized sector, resulting in better quality and processing of milk produce.

Sustainable growth

White Revolution 2.0 will ensure sustainable growth of the dairy industry, resulting in better food security and an enhanced quality of life for rural populations.

The significance of dairy farming

Dairy farming in India is not just an age-old traditional form of farming; it is a backbone of Indian rural economy, a catalyst for social transformation in India and a resilient road to sustainable growth. The economic importance of dairy farming is multifaceted in the sense that it is a vital engine for economic growth and social development.

Economic and social empowerment

Boost rural incomes

Dairy farming can help in raising and stabilizing rural household incomes in an effective manner through fair milk prices, especially for women and small and marginal farms.

Table 2: Evolution and policy framework of India's dairy sector.

Aspect	Details	Significance	Citation
Global status	India contributes over 25% of global milk production	Establishes India as the world's leading milk producer.	Kumar *et al.* (2023)
Historical foundation	Operation Flood (White Revolution 1.0) launched in 1970	Strengthened dairy cooperatives; transformed India from milk-deficit to surplus nation.	Patel, (1994) Kumar *et al.* (2023)
New initiative (2024)	White Revolution 2.0 launched by Ministry of Cooperation	Focus on modernization, sustainability and cooperative expansion.	Government of India, (2024)
Policy focus areas	Cooperative strengthening, women empowerment, job creation	Promotes inclusive rural development.	Kumar *et al.* (2023) GOI, (2024)
Procurement target	1000 lakh litres/day within five years	Enhances rural income and dairy-based livelihoods.	GOI, (2024)
Institutional mechanism	Formation of Multi-state cooperative societies (MSCS)	Organized and structured dairy sector expansion.	GOI, (2024)

Boost employment

Dairy farming can generate employment opportunities for people through self-employment, where women contribute a substantial share to the workforce.

Provide affordable milk

Dairy farming ensures the availability of serving consumers with healthy milk and dairy products at fair and affordable costs. contributing to food and nutritional security.

Economic importance: The bedrock of rural livelihoods

- **The most precious resources in agriculture:** Milk is India's greatest agricultural commodity, accounting for more than 5% of national GDP.
- **Constant revenue source:** In contrast to seasonal agricultural commodities, dairy farming provides a consistent and ongoing source of revenue, serving as a safeguard for farmers' finances. This "white gold" helps rural families survive the dangers related to the monsoon variability and agricultural price volatility.
- **Employment creation:** The dairy field is a major source of career opportunities, supporting the families of over 80 million farmers. It generates jobs across an extensive transportation, processing, value chain, including milk collection, cold storage, packaging *etc.*
- India has become a major earner of foreign exchange an important dairy product exporter such as Butter oil, ghee and skim milk powder thereby earning valuable foreign exchange for the country.

Social importance: Equity and empowering

- **Equality of women:** Dairy farming is commonly referred to as the "feminine sector" of the Indian economy, with women accounting for more than 70% of the labor. Women who own and manage dairy cows have a separate revenue stream, which strengthens their role in making home decisions and community participation.
- **Poverty alleviation:** Dairy farming is extremely effective at eliminating poverty since it has low entry barriers. Even the landless laborers can bring up one or two animals, providing a source of income.
- **The amul cooperative model:** It is the cooperative success model that has revolutionized the distribution of wealth by providing peasants' collective bargaining power, ensuring that prices are reasonable and providing profit earned by the growers to the manufacturing and selling of the products.

Preventing malnutrition: The critical role of nutrition

- **Affordable Nutrition's Source:** Milk and dairy products offer an affordable source of vital nutrients such as vitamins, calcium and protein, especially for the large number of vegetarians in India.
- **Food Security:** The large size of the dairy industry in India ensures the country has a constant source of nutritious food, thus improving the food and nutritional security of the country.

Importance for agriculture and the environment

- **Integrated farming system:** Dairy farming is strongly linked to the country's farming systems. The practice of using animal dung as organic manure minimizes the usage of artificial fertilizers, thus promoting the practice of organic farming.
- **The renewable energy source:** Cow excreta form a vital source of biofuel, providing natural fuel for cooking as well as organic manure. This promotes the country's economy, reduces the chances of waste and minimizes carbon emissions in the country.
- **Utilisation of by-products:** Agricultural byproducts and crop leftovers, such as straw and stover are effectively used as reducing waste and increasing the total value and sustainability of farming operations.

Trends of the dairy sector

Homegrown scenario

- Over the earlier decade, India's milk output has expanded consistently at an average annual pace of roughly 6%, resulting in an increase of more than 5% in per capita milk availability. National milk production is projected to reach approximately 242 MT, with per capita availability estimated at around 475 grams per day (2023-24).
- Liquid milk sales by cooperatives have stabilized following a sharp post-COVID-19 increase. During the year 2023-24, average cooperative liquid milk sales stood at 438 lakh litres per day (LLPD), reflecting a growth of about 3%.
- National prices for conserved dairy products, including skimmed milk powder (SMP) and white butter, decreased this year. In March 2024, SMP prices averaged around ` 225 per kg, showing a nearly 24% reduction. White butter prices fell by almost 20% to approximately ` 320 per kg.
- Prices of SMP in the home nation continued to be above worldwide prices during 2023-24, although the difference decreased over time. On the other hand, prices of white butter in the home nation continued to be slightly lower than worldwide prices up until November 2023, although the difference grew due to a substantial increase in worldwide prices of butter while prices of white butter in the home nation continued at their original rates.
- In 2023-24, India's exports of milk products, including milk, amounted to ` 2.7 thousand crore, even during challenging international trade conditions for such preserved milk products.

Global scenario

- FAO estimates that worldwide milk output will reach 965 million tonnes in 2023, up 1.4% from 2022. This expansion was mostly driven by increased output in Asia, particularly in India and China.
- In 2023, global dairy commerce fell by 1% to 84.7 million tons (milk equivalent). China, the world's greatest importer, imported around 15.8 MT, representing a 9% year-on-year decrease due to greater local output and higher

inventory levels. During the same period, dairy exports from New Zealand rose by almost 9%, those from the European Union rose by about 6%, while exports from the United States fell by around 10%.

- The slowdown in global trade has impacted international dairy prices, particularly for SMP. Average SMP prices on the global dairy trade (GDT) platform fell from over USD 2,678 per MT in April 2023 to USD 2,343 per MT in September 2023, before recovering to almost USD 2,578 per MT in March, 2024.
- From April to November 2023, butter prices were between USD 4,700-5,200 per MT, with a significant increase in the latter few months of the year. By the end of March 2024, white butter prices had risen to USD 6,400 per MT.

Future potential in dairy sector

The dairy trade provides numerous opportunities for policy maker entrepreneurs and farmers with the potential to significantly increase rural incomes, employment and food security. At the same time, resolving current issues is critical to ensuring long-term and sustainable progress (Table 3).

Growing interest in dairy products

Population expansion and increasing per capita incomes are boosting demand for dairy products. Beyond liquid milk, demand for value-added goods such as butter, ghee and processed dairy foods is growing, providing opportunity for producers and processors to expand operations and satisfy changing market demands.

Creation of jobs and rural development

The dairy business has a significant potential to offer jobs, especially in rural areas organizations has the potential to empower smallholders, creation jobs and contribute significantly to rural youth.

Delivering value and creating variety

Demand for ice cream, cheese, yoghurt and other processed dairy products are gradually increasing. People are increasingly prepared to spend more for such goods, which opens up opportunities for diversification, increased profitability and entrepreneurial investment in value-added dairy sectors.

Export potential

India's enormous milk production base provides tremendous possibilities for growing dairy exports. Infrastructure improve- ments, quality assurance and conformity with international standards can all help to boost global market competitiveness. Indian dairy exports, which include ghee, cheese and skimmed milk powder have already acquired popularity in the Saudi Arabia, Bangladesh, U. S. A and UAE.

Rich in nutrients

Milk products provide an affordable and nutrient-rich food source for millions of people, particularly landless labourers, small and marginal farmers and women, thereby supporting nutritional security.

Technological advancement

Adoption of technologies such as enhanced milk testing and bulk milk coolers (BMCs) equipment and IoT-enabled systems can significantly improve milk quality, productivity and processing efficiency. Precision dairy farming using data analytics, automation and sensors can further improve the animal health management and farm performance.

Development of infrastructure

Existing gaps in dairy infrastructure present opportunities for investment in dairy processing factories and farms that are certified and organized and strengthened cold-chain logistics.

Paths for transformation: The beacon of opportunity

Increasing output with accurate dairy production

- **Opportunity:** Optimizing resource use and outputs through technology.
- **Platforms for Digital Health:** Mobile-based applications for veterinary services, disease monitoring and heat detection.
- **Formulation of balanced feed:** Promotion of low-cost, scientifically developed feeds and silage-making procedures customized to a certain region to reduce fodder shortages.

Table 3: Multi-state cooperative societies' (MSCS) organization and purpose.

MSCS category	Core functions	Expected outcomes	Sustainability dimension
MSCS - Input supply	Supply quality cattle feed, mineral mixtures, veterinary inputs	Improved milk yield and animal health	Efficient resource utilization Kumar *et al.* (2023)
MSCS - Organic and circular economy	Promote organic manure, biofert-ilizers, biogas; scientific cow dung utilization	Support natural farming; reduce waste	Circular economy and climate resilience Singh *et al.* (2022). Kaniamuthan, *et al.* (2025).
MSCS - By-product management	Organized management of hides, bones, horns of fallen animals	Environmental safety and value recovery	Responsible wastemanage-ment Sharma, *et al.* (2021).
Cooperative expansion	Strengthening dairy cooperative networks	Increased farmer participation	Inclusive and decentralized growth Kumar *et al.,* 2023) GOI, (2024)

- **Genetic Improvement:** Wider adoption of Using genomic selection and sex-sorted semen, a high-yielding national herd was soon developed.

Improvement of the institutional structure

- **Opportunities:** Transitioning from traditional cooperative models to more flexible and focused farmer institutions.
- **Farmer producer organization (FPOs):** Dairy-focused FPOs can pool resources, invest in shared infrastructure such as bulk milk coolers, bargain for lower costs and replicate collaborative success within a modern organizational framework.

Creating an effective and resilient supply chain

- **Opportunities:** Minimizing expenses after producing and enhancing product quality. Expenses after producing
- **Milk coolers at village level:** Installation of village-level cooling facilities to preserve milk quality and strengthen farmers' bargaining power.
- Investments in integrated cold-chain infrastructure, from villages to processing facilities, constitute cold chain logistics.
- **Blockchain technology for tracking:** Adoption of blockchain technology to ensuring traceability from the farm to the customer fosters brand loyalty and permits premium pricing for goods with guaranteed quality.

Gaining access to the value-added products (VAP) industry

- **Opportunity:** The organized VAP segment including yoghurt, cheese, probiotic drinks, whey protein and flavored milk is growing at an annual rate of 15-20%, significantly faster than liquid milk (Table 4).
- **Diversification:** Strong potential exists for cooperatives and entrepreneurs to improve margins by innovating and serving urban, health-conscious clients.

Encouragement of the circular economy and sustainability

- **Opportunity:** Converting waste into valuable resources.
- **Management of dairy waste:** Utilisation of dung for large-scale biogas and bio-CNG production, along with organic manure generation, providing additional income while lowering pollutants in the environment.
- **Practices that are climate-resilient:** Promotion combining water-efficient dairy production and drought-tolerant feed crops methods.

Important suggestions for interested parties include

For the government: Make it simpler for smallholders to obtain loans, promote private investment in rural dairy infrastructure and bolster initiatives to prevent and control animal diseases**.**

For processors: Adopt transparent and fair buying practices that invest and share value with farmers in value-added products and implement sustainable practices.

For farmers: Promote participation in farmer collectives such as FPOs and encourage adoption of improved animal management and husbandry practices.

Challenges and areas for improvement

Animal productivity is low: India's average milk production per cow is still well below the world average. For instance, an Indian crossbred cow produces around 7-8 kg of milk per day, whereas yields in developed countries often exceed 30 kg per day (Table 4). This gap is largely attributed to:

- **Lack of feed and forage:** Inadequate availability of superior notorious feed and heavy dependence on imbalanced and traditional feeding practices.
- **Genetic limitations:** A large proportion of the bovine population consists of low-yielding, non-descript cattle with limited genetic potential.

Organised vs unorganised sector

The unorganised sector continues to dominate milk production and marketing, highlighting the need for greater integration of dairy cooperatives and formal institutions to increase their share in the organised market (Fig 3 and 4).

Quality standards

Meeting domestic as well as international quality and safety standards requires substantial investment in quality control systems, testing infrastructure and strict adherence to hygienic handling and processing practices.
Animal Health and Breeding Services:

Services for animal health and breeding

Insufficient infrastructure for veterinary care and low knowledge about preventive healthcare, including timely vaccination, contribute to the prevalence of animal diseases such as Foot and Mouth Disease, adversely affecting productivity.

Administration

Weak governance structures and excessive intervention by State governments in cooperative functioning often undermine democratic processes and reduce the efficiency. and autonomy of dairy cooperatives.

Restricted storage and processing

Insufficient facilities for marketing, value addition, processing and storage constrain farmers' ability to realise better prices, thereby affecting overall profitability.

Price volatility and market fluctuations

The lack of steady and profitable milk pricing exposes dairy farmers to income uncertainty, making long-term planning and investment in improved practices increasingly difficult.

The current study is entirely based on secondary data sources. Information and data have been collected from various official publications and annual reports of the national dairy development board (NDDB), statistical databases of the department of animal husbandry and dairying (DAHD), Ministry of Fisheries, Animal Husbandry and Dairying, Government of India. Basic Animal Husbandry Statistics and National Accounts Statistics. Government policy documents on White Revolution 2.0 and National

Programme for Dairy Development (NPDD) 2.0. Peer-reviewed research articles, journals, books and reports related to dairy development, cooperative models, animal productivity and dairy supply chains. Relevant information available on various recognized institutional websites.

Methods: The research design is based on a descriptive and analytical method using a systematic review approach.

Data collection: The secondary data was accumulated from reliable sources of government publications, research papers and reports.

Data compilation and organization: The data was organized in various forms such as production trends, cooperative development, technology advancement, policy initiatives, challenges and opportunities.

Comparative and trend analysis: Analysis of milk production trends, procurement targets, sectoral growth rates and global comparisons was done using available statistical data.

Policy review approach: Various components of White Revolution 2.0 were analyzed to evaluate their possible impacts on productivity, sustainability and rural livelihoods.

Synthesis: Results from various sources were combined to give a comprehensive overview of the current situation, transformation process and prospects of white revolution in India. The reliability of the method is achieved through the use of reliable secondary data. It provides a structured understanding of the evolutionary process and prospects of White Revolution 2.0.

The review points out that India contributes to the world's milk production by over 25%, thus reaffirming India's position as the world's largest milk-producing country. The launch of the White Revolution 2.0 in 2024 by the Ministry of Cooperation is a policy paradigm shift to further consolidate the dairy industry's institutional, technological and socio-economic foundations. The findings show that the new policy initiative is a continuation of the

Table 4: White revolution 2.0's challenges, innovations and prospects.

Dimension	Current challenges	Proposed solutions/innovations	Long-term impact
Productivity	Low milk yield per animal	Precision dairy farming, genetic improvement	Higher production efficiency (Kumar *et al.*, 2023)
Animal health	Disease outbreaks, limited veterinary access	Digital health monitoring, vaccination programs	Reduced mortality and improved herd quality (Singh *et al.*, 2022).
Supply chain	Fragmented and informal systems	Digital platforms, cold chain expansion	Improved transparency and reduced losses (Birthal *et al.,* 2005).
Value addition	Limited processing at village level	Dairy diversification and branding	Higher farmer income (Kumar *et al.,* 2023), Patel, (1994)
Environmental concerns	Methane emissions, waste mismanagement	Climate-smart practices, biogas systems	Sustainable and eco-friendly growth Singh *et al.* (2022), Kaniamuthan *et al.* (2025).
Social inclusion	Gender gaps, limited youth engagement	Women-led cooperatives, employment programs	Inclusive rural trans-formation Patel A, (1994), GOI, (2024)

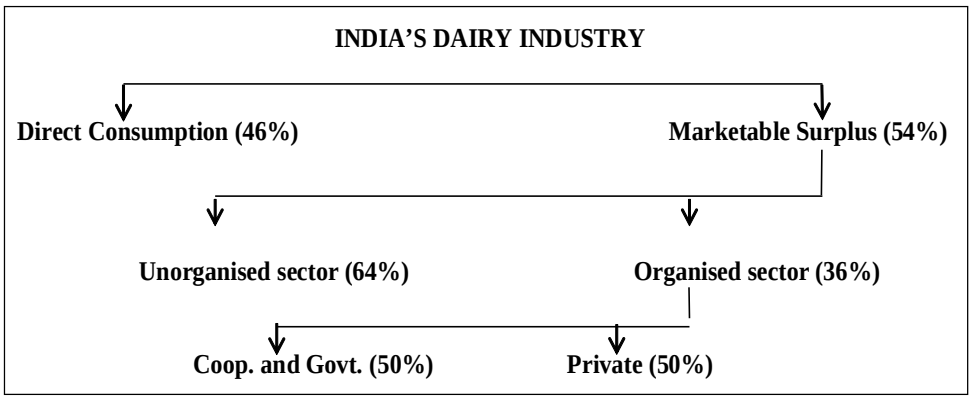


Fig 3: Details of India's dairy industry.

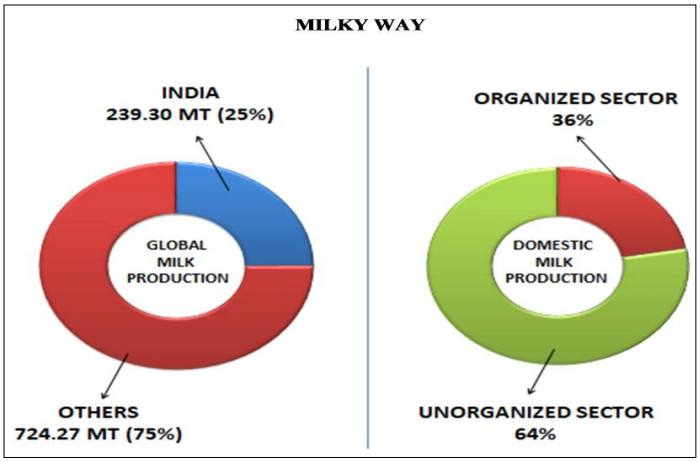


Fig 4: India's contribution to global and domestic milk production.

success of the Operation Flood program by focusing on the development of cooperatives, women's participation, employment generation and sustainability of the environment. The significant structural reform of the policy is the formation of three Multi-State Cooperative Societies (MSCS) to:

1. Ensure the supply of quality cattle feed, mineral mixtures and essential dairy inputs.
2. Promote organic manure, biofertilizers, biogas production and scientific utilization of cow dung and agricultural residues to strengthen circular economy practices.
3. Facilitate organized and environmentally responsible management of by-products such as hides, bones and horns from fallen animals.

The proposal to procure one million liters of milk daily through dairy cooperatives within five years is projected to significantly enhance rural income stability and improve smallholder participation in formal markets. The review further identifies growing integration of precision dairy technologies, digital platforms, climate-smart agricultural practices and value-added dairy processing as key drivers of sectoral modernization. Despite its global leadership in total milk output, the Indian dairy sector continues to face structural constraints including low per-animal productivity, inadequate veterinary infrastructure, fragmented supply chains and dominance of informal marketing channels.

The results indicate that White Revolution 2.0 is a critical juncture in Indian dairy development policy. While the initial phase of the revolution concentrated on raising dairy output and cooperative organizational structure, the second phase has a higher priority on sustainability, technology and inclusive growth. This is a significant change from volume-driven growth to value-driven and efficiency-driven growth. The establishment of specialized MSCS organizations resolves existing inefficiencies in input supply chains and by-product management. By implementing cattle feed quality management and promoting scientific waste management, Indian dairy growth is now aligned with sustainability targets. The addition of biogas and organic fertilizers complements rural energy and soil security, respectively and reinforces circular economy ideals.

Women empowerment and cooperative expansion are likely to have significant socioeconomic implications. This is because a considerable part of rural dairy workforces in India are female. Cooperative expansion can therefore have a favorable impact on rural women. However, for White Revolution 2.0 to be successful, existing productivity issues must be resolved. Indian dairy productivity, measured by average milk yield per animal, is still lagging compared to global standards. This is mainly because Indian dairy farmers are constrained by existing breeds, nutritional requirements and access to high-end veterinary services.

CONCLUSION

India's dairy industry, which has been boosted by the success of the first white revolution spearheaded by Dr. Verghese Kurien with the support of the National Dairy Development Board, has become the largest milk producer in the world. Yet, there are challenges like low productivity, gaps in the supply chain, quality and climate change, which necessitate a new strategy for the dairy industry. The white revolution 2.0, which focuses on cooperative movements, technology, women's empowerment, infrastructure and sustainability, can be seen as a transformative journey for the dairy industry, which can ensure inclusive, sustainable and productive growth for the dairy sector of India, making it competitive on the world stage.

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Disclaimers

The perspectives given in this article are those of the writers alone and may not be the official opinions of the organization with which they are associated. The authors are not liable for any direct or indirect costs incurred by using this content.

Informed consent

The present study is a review of secondary data and published literature related to India's dairy sector. No primary data were collected from human participants or animals; therefore, informed consent was not applicable.

Conflict of interest

The authors claim that there are no conflicts of interest associated with its publishing. Furthermore, outside funding or support had no impact on the choice of literature, analysis and interpretation of results, decision to publish, or paper preparation.

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