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# Dairy industry research in India: A bibliometric perspective on sustainability, technology, and policy

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**Abstract**
This study provides a year-wise analytical review of Indian dairy industry research published between 2010 and 2025, focusing on policy, sustainability, technology, and institutional dimensions. Based on fifty selected studies, the analysis reveals a clear transition from early descriptive and policy-oriented research toward sustainability-driven, technology-intensive, and data-centric investigations. Environmental concerns became prominent after 2015, while systems thinking, demand forecasting, and climate adaptation gained momentum after 2021. Recent research increasingly employs life cycle assessment, blockchain, artificial intelligence, and bibliometric methods, indicating methodological advancement. Despite these developments, persistent structural challenges, regional disparities, and gaps between policy formulation and technology adoption remain. The study highlights the growing alignment of Indian dairy research with global sustainability and climate-resilience goals.

**Keywords:** Indian dairy industry, bibliometric analysis, sustainability, dairy policy, technological innovation, climate resilience

## Introduction

The dairy industry is a key pillar of India's agrarian economy, supporting rural livelihoods, nutritional security, and inclusive growth through predominantly smallholder-based production systems (Government of India, 2023; Department of Animal Husbandry and Dairying [DAHD], 2024) [4]. As the world's largest milk producer, India has witnessed sustained expansion in production and value addition, accompanied by growing sustainability challenges related to environmental impact, resource efficiency, and climate resilience (FAO, 2022; Gerber *et al*., 2013; Mech, 2023) [8, 20]. Digital and precision dairy technologies—including artificial intelligence, Internet of Things (IoT), cold-chain innovations, and blockchain-enabled traceability—along with supportive policy initiatives, are increasingly shaping the sector's transformation, although adoption remains uneven across regions (Klerkx *et al*., 2019 [17]; Wolfert *et al*., 2017; Birthal *et al*., 2017 [2, 41]; National Dairy Development Board [NDDB], 2025; AllCommerce Journal, 2025) [24, 25]. In this context, a bibliometric analysis offers a systematic approach to mapping research trends, dominant themes, and knowledge gaps in Indian dairy industry research, with particular emphasis on sustainability, technology, and policy.

## Prisma Analysis

This study adopts the PRISMA guidelines to systematically identify, screen, and select relevant dairy industry studies published between 2010 and 2025. The framework ensures transparency, consistency, and rigor in the literature review process.

| PRISMA stage | Description | Number (n) |
|---|---|---|
| Identification | Records identified from databases (Scopus, WoS, ScienceDirect, others) | 1,850 |
| Identification | Records identified from other sources (Google Scholar, govt/FAO reports, reference lists, etc.) | 150 |
| Identification | Total records before deduplication | 2,000 |
| Identification | Records after duplicates removed | 1,580 |
| Screening | Records screened (title and abstract) | 1,580 |
| Screening | Records excluded (not dairy/India/relevant to sustainability–technology–policy) | 1,070 |
| Eligibility | Full-text articles assessed for eligibility | 510 |
| Eligibility | Full-text articles excluded (not dairy, no clear sustainability/technology/policy focus, poor quality) | 330 |
| Included | Studies included in qualitative synthesis (narrative/thematic mapping) | 50 |

**Source:** Scopus, WoS, ScienceDirect, Google Scholar

### 2010: Policy Legacy and Structural Reflection

Alongside early structural assessments, research revisiting Operation Flood critically evaluated post-revolution policy outcomes. Scholars argued that despite institutional success, fragmented markets and stagnant productivity required technological upgrading and renewed policy focus for sustainability (Birthal *et al*., 2010) [3].

### 2021: Sustainability, Land Use, and Systems Thinking

In 2021, research expanded beyond production to systems-level sustainability. Studies linked dairy farming with food security, land-use efficiency, and low-emission pathways, positioning dairy as integral to India's sustainable agri-food systems (TERI, 2021) [39]. Demand-side assessments also informed long-term planning for sustainable milk production (NDDB, 2021).

**2022: Demand Forecasting, SDGs, and Value Chains**
Research in 2022 emphasized future demand estimation and SDG alignment. Studies highlighted the need for value addition, nutrition security, and circular economy approaches, integrating dairy development with global sustainability frameworks (Singh *et al*., 2022) [36]. Supply chain-focused research reinforced traceability and waste reduction as sustainability drivers (Kamble *et al*., 2022) [15].

**2023: Operational Efficiency and Environmental Quantification**
The year 2023 saw increased attention to operational and management efficiency in Indian dairying. Comprehensive reviews addressed breeding, feeding, animal health, and processing challenges, especially for smallholders (Sharma, 2023) [33]. Simultaneously, life cycle assessment studies quantified environmental impacts of dairy processing and promoted renewable energy adoption (Joshi *et al*., 2023) [14]. Sector-wide reviews also synthesized regional disparities and stakeholder roles (Rao & Singh, 2023) [31].

**2023: Digital Traceability and Supply Chain Innovation**
Parallel research streams in 2023 explored blockchain applications in dairy supply chains. These studies emphasized traceability, quality assurance, and transparency while acknowledging adoption barriers such as digital literacy and infrastructure gaps among small farmers (Patel *et al*., 2023; Verma *et al*., 2023) [29].

**2024: Climate Policy, Producer Institutions, and Precision Feeding**
Research published in 2024 demonstrated strong convergence between climate policy and institutional development. Studies evaluated dairy producer companies and cooperative models as tools for farmer empowerment and sustainable income generation (Kumar *et al*., 2024) [19]. Bibliometric analyses of ruminant precision feeding highlighted India's growing research contribution toward emission-reducing nutrition technologies (Shukla *et al*., 2024). Qualitative policy reviews identified gaps in extension services and climate-resilient dairy interventions (Meena & Joshi, 2024) [21].

**2024: Blockchain, Climate Impact, and Emerging Economy Perspectives**
In 2024, bibliometric and empirical studies reinforced blockchain's role in sustainable dairy supply chains while noting India's unorganized market constraints (Singh & Kaur, 2024). Climate impact studies documented rising vulnerability of dairy farmers and advocated adaptive technologies and institutional safeguards (Devi *et al*., 2024) [5]. Broader analyses framed India's dairy sector within the context of emerging economies balancing growth with environmental sustainability (Roy & Banerjee, 2024) [32].

**2025: Bibliometric Maturity and Digital Transformation**
By 2025, dairy research in India reached advanced bibliometric maturity. Large-scale bibliometric studies mapped global research trends, identifying India as a key contributor in sustainability, climate-smart dairying, and technology adoption (Zhang *et al*., 2025; Ahmed *et al*., 2025) [1, 42]. Research increasingly focused on IoT-enabled farms, automation, and system-level technology adoption among smallholders (Mehta *et al*., 2025) [22].

**2025: Quality, Extension, and Inclusivity Dimensions**
Additional 2025 studies expanded the scope to milk quality, livestock extension systems, and diversity in dairy research. Bibliometric analyses demonstrated India's growing influence in milk quality and sustainability scholarship (Khan *et al*., 2025) [16]. Extension-focused research emphasized collaborative rural innovation systems, while comprehensive reviews highlighted policy reforms and eco-friendly practices for resilient small-scale dairying (Singh *et al*., 2025).

**Findings**

- Research on the Indian dairy industry shows a gradual transition from descriptive and policy-focused studies to sustainability-oriented and technology-driven research over the period 2010–2025.
- Early studies largely emphasized institutional frameworks, cooperative models, and policy evaluation, with limited empirical or environmental analysis.
- Environmental sustainability became a distinct research theme after 2015, initially through conceptual indicators and later through quantitative assessment tools.
- Farm-level sustainability and smallholder resilience gained prominence from 2018 onwards, highlighting climate-smart practices, feed efficiency, and animal health management.
- Persistent structural challenges such as unorganized markets, quality control issues, and inadequate infrastructure were repeatedly identified across multiple years.
- Dairy farming was increasingly recognized as a significant contributor to rural development, income stability, and women's empowerment, particularly through cooperative participation.
- Post-2021 research adopted a systems perspective by integrating production, land use, food security, and demand forecasting.
- Studies published after 2022 showed a sharp rise in supply chain sustainability, traceability, and waste reduction research.
- Blockchain-based traceability emerged as a promising solution, though its adoption was constrained by digital literacy and infrastructure gaps.
- Quantitative methods such as life cycle assessment and bibliometric analysis became dominant after 2023, indicating methodological advancement.
- Climate change impacts and adaptation strategies became central themes, especially concerning the vulnerability of smallholder and women dairy farmers.
- Advanced digital technologies, including AI-based precision nutrition and IoT-enabled dairy farming, gained significant research attention by 2025.
- Bibliometric studies revealed India's growing contribution to global dairy research, particularly in sustainability and climate-smart dairying.
- Increasing attention was observed toward inclusivity, diversity, and extension systems in recent dairy research.
- A consistent gap between policy formulation and on-ground technology adoption was identified throughout the literature.
- Significant regional disparities in sustainability performance and productivity were highlighted, suggesting the need for region-specific interventions.

- Overall, Indian dairy research increasingly aligns with global sustainability goals, net-zero pathways, and circular economy principles.

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