Traceability in the Indian Dairy Industry: Concept and Practice

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Abstract

The rise in milk adulteration and contamination, fraud incidents, and improper handling necessitates effective traceability systems in the Indian dairy industry. Thus, this review investigates current trends, associated challenges, traceability, and its fundamental applications to address food safety and quality issues. The paper covers the evolution of milk adulteration and contamination detection techniques from conventional to emerging. Such information and analytical technologies can improve transparency and safety in the dairy industry by implementing effective traceability systems. This review will help understand the challenges and future opportunities associated with the current situation in the Indian dairy industry.

Keywords: Decentralized systems; Food traceability; Dairy industry; Food Safety; Adulteration; Dairy technology.

INTRODUCTION

Tracking the flow of a food product and its components up and down the supply chain to prevent unhealthy types of food from reaching consumers is referred to as traceability (Millard *et al*., 2015). The idea of traceability began with the Bovine Spongiform Encephalopathy (BSE) epidemic in cows in the 1980s, which prompted the need for a regulation to trace and track food quality and safety throughout supply chains (Smith and Bradley 2003). Food traceability specifications in regulatory bodies such as the European Union (EU), US Food And Drug Administration (FDA), Food Safety and Standard Authority of India (FSSAI), etc., focus on digital traceability (Borit 2016). Traceability is a critical bridge for information sharing, such as system design, component specifications, methods, bills of materials, and so on, both inside and between stakeholders. Traceability improves supply chain transparency by correctly maintaining product-related information (Gobbi and Massa 2015). Traceability has gained considerable attention in many industries, including the food sector. The reports suggest thousands of people worldwide have become infected after consuming adulterated and contaminated food items over the last few years (Khanna *et al.* 2022). Dairy products are one such category of food that has seen significant adulteration and contamination. In the past few years, increased demand from dairy consumers has added significant complexity to the industry (Tan and Ngan 2020).

Consumers have become more selective and willing to pay more for food safety, sustainability, and ethically produced food. These requirements necessitate transparency in the dairy supply chain. Highly perishable food products, like dairy, require a transparent and decentralized traceability system to ensure food safety and quality. In the future food business, transparency and traceability will be among the most important determining factors for selecting food brands (Poinski 2017). Situations such as BSE increased occurrences of food-borne diseases,

and food adulteration changed customer perceptions. To regain customer trust, the dairy sector has been pushed to transform; traceability is a practical component of this initiative. The dairy industry has already acknowledged food safeguards, hygiene, safety, and quality by implementing management systems, including Hazard Analysis and Critical Control Points (HACCP) and International Organization for Standards (ISO) (ISO 2000). The main objective of traceability in dairy was to ensure that consumers regain or boost their confidence by stopping or restricting the propagation of food safety incidents (Pang *et al*. 2015).

The Indian government has started collaborating with state and central governments bodies such as FSSAI, GS1(Global Standards) India, Agricultural and Processed Food Products Export Development Authority (APEDA), National Bank For Agriculture And Rural Development (NABARD), Farmer Producer Organizations (FPO), Reliance industry and ITC's eChaupal. Traceability minimizes both internal and external expenses, such as medical expenses for consumers and product recalls for manufacturers (Abbott 1991; Hobbs *et al.* 2005), decreases the labor cost, reduces waste, minimizes inventory levels and frauds (Biederman 2006), and reduces costs such as transport, storage, and maintenance (Yong-Dong *et al*. 2009). India's existing laws related to food need extra infrastructure. Adopting an appropriate traceability system to enhance and transform the dairy supply chain is necessary to control food incidents and fraud in the Indian dairy industry (Yadav *et al*. 2020). Food safety and quality, wastage, and environmental and logistics are further challenges for the Indian dairy industry. Inadequate infrastructure, improper milk handling practices, and plant maintenance lead to wastage.

Thus, this review explores openings for traceability in the Indian dairy industry. It also sought to identify the need for traceability implementation, particularly in the Indian context. The paper is structured as follows. Section 2, traceability: an overview explains traceability, its types,

functionality, and existing methods. Section 3, Indian dairy industry: an overview presents an overview of the Indian dairy industry, organized and unorganized sectors, current traceability status in the Indian dairy industry, traditional methods used for traceability, milk production challenges & opportunities in the Indian dairy industry, and food authenticity and integrity in the Indian dairy industry. Section 4, milk adulteration & contamination discusses milk adulteration, contamination, and detection techniques along with related global and India-based incidents. The final section concludes and discusses future directions.

TRACEABILITY: AN OVERVIEW

Traceability

Many definitions of traceability for food products ist in regulatory standards and research articles (Moe 1998; Golan *et al.* 2004). The researchers have analyzed how traceability is defined in regulations, international standards, dictionaries, and highly cited research articles (Olsen and Borit 2013). After examining the identified problems with most of these definitions, the authors presented a modified definition, which will be the foundation for the discussion and analysis. When it comes to the perception of researchers on definitions of traceability, most articles generally refereed Moe (1998), who defines traceability as *"Traceability is the ability to track a product batch and its history through the whole, or part, of a production chain from harvest through transport, storage, processing, distribution, and sales."*

The main thing is which definition is perfect or should be used as a standard, so there doesn't exist such an ideal definition. However, ISO 8402 is the one that considers all necessary properties (ISO 1994). But a description can be presented by combining some of the above-discussed definitions, such as *"The ability to access any or all information relating to that which is under consideration, throughout its entire life cycle, through recorded identifications".*

Traceability can be classified according to the direction of information recall: backward, internal, and forward traceability (Perez-Aloe *et al.* 2007). Tracing or backward traceability is the capability, during any point in the supply chain, to determine the source and properties of the product depending on one or more specific criteria based on the direction in which data is retrieved in the chain. Tracking or forward traceability, on the other hand, is the capability to determine the location of products based on one or more given criteria at any stage in the supply chain. Information management must support both kinds of traceability, as their performance is inversely proportional to each other and does not always imply the effectiveness of the other (Kelepouris *et al*. 2007). Farm-to-fork traceability necessarily involves effectively implementing internal and external traceability systems. The external traceability system deals with product identification details. In contrast, the internal system covers all other information, such as origin details of raw materials used during processing, packaging details, lot numbers, and further details about the industry (Tan and Ngan 2020).

Some examples include Radio Frequency Identification (RFID) tracking, GS1 coding, and tags that can be read or scanned by humans or machines. Uniqueness is essential, so there is no confusion over which specific product is being considered. Key data elements (KDEs) and Critical tracking events (CTEs) are important traceability components.

Functions of Traceability

Producers who track and trace the record of their entire manufacturing process, from raw materials to final items, can achieve a significant competitive edge in the industry. The industry should always keep track of the overall life span of every process, whether receiving, adding value, production, or distribution. For such a traceability system to function effectively on the consumer end, each package should provide a relevant number pointing to a specific process, and the

consumer can check that unique number, which might be a number of a work order, shipment id, or anything that can verify the process (Mladenov 2018).

Methods & Applications of Traceability

Traceability in the food supply chain was traditionally used to avoid or reduce the propagation of food safety incidents (Pang *et al*. 2015). Technological innovations, including industry 4.0 technologies, would create traceability quicker, more accurately, and less costly and record data quickly and effectively for the business's benefit (Sterling *et al*. 2015; Huang and Yang 2009). The physical ability to record, manufacture, and supply dairy products worldwide has increased significantly in the last few decades. Regrettably, a rise in digital technologies has not equalled this growth in physical capabilities.

The recognition that today's digital technologies and information records can add value to a product or customer experience while lowering production costs has transformed the impact of information management in industries. This study observed that getting an advantage of digital information and systems is restricted to industries already on the leading edge of innovation by using industry 4.0 technologies. Proper needs or guidelines are absent for data collection and transmission in the dairy industry, which is required for traceability. This leads to industries needing to form one-to-one information sharing with their partners and consumers, increasing costs and the chances of errors. One such lack of cooperation is significant and prevents industries all along the supply chain from collaborating. It increases business costs and risks. Industries' ability to collaborate with other supply chain stakeholders to enhance their efficiency, reduce wastage, integrate sustainability initiatives, and encourage innovation to address the changing consumer demands is impacted by a lack of cooperation (Sterling *et al*. 2015). Traceability is now becoming progressively important throughout the globe. The authors have identified some general traceability applications presented in Fig. 1.

Through traceability, many industries are taking care of the issues related to food safety and security, and it is helping the supply chains to become transparent. Many sectors have reduced waste management by establishing an effective traceability system. A partnership among stakeholders in supply chains has become more effective due to transparency and well-managed information flow. It has also reduced food recall issues and increased consumer reassurance (Bosona and Gebresenbet 2013).

INDIAN DAIRY INDUSTRY: CURRENT STATUS

Based on production statistics from the Food and Agriculture Organisation Corporate Statistical Database (FAOSTAT), India produced 24 % of the world's milk in 2021–2022, making it the top milk producer globally (Press Information Bureau 2023). India's liquid milk production is expected to reach 207 million metric tonnes (MMT) in the market year (January-December) 2023, upward compared to previously updated MY 2022 figures of 202.5 MMT by 2%. As per prediction reports, India will consume 86.5 MMT of fluid milk in 2023, up slightly from the 85 MMT consumed in 2022 (Mani 2022). Due to disease outbreak restrictions, Value-Added Products (VAPs) and sales decreased in 2020-21. Yet, a rise in the consumption of liquid milk and VAPs is expected due to the consistency of food delivery and increased family consumption. This will also result in higher procurement costs (Imarc Group 2022). According to a study by the National Dairy Development Board (NDDB), India’s demand for milk and milk products will reach 266.5 MMT in 2030 (Naik and Abraham 2022). Uttar Pradesh (16%), Rajasthan (13%), Madhya Pradesh (9%), Andhra Pradesh (8%), and Gujarat (7%) are India's five largest milk-producing states, which produce more than half of total countrywide production (Mani 2021). Indians are becoming more inclined towards milk intake in their quest for a higher protein intake. Even though India is a leading milk producer, still only a small amount of milk and other dairy products are exported from India. As

per Foreign Agriculture Service (FAS) forecast, only 10,000 metric tons of liquid milk was estimated to export in 2023, almost the same as in 2022 (Mani 2022). Given the high domestic consumption, exports are low. Investment is required to boost exports and production in Indian dairy, particularly for small and marginal dairy farmers (Doni 2019).

Organized and Unorganized Sector

The dairy industry in India is categorized into two types: organized and unorganized. The organized sector includes milk cooperatives such as state cooperatives, private dairy companies, and modern dairy farms, given in Fig 2. The organized sector represents structured supply chains, proper management, and compliance with regulatory standards. The unorganized sector includes producers at the farm level, middlemen like milkmen, and contractors who sell milk directly to consumers. India's installed milk processing capacity is 2.5 million liters/day at producer companies, 73.3 million liters/day in the private sector and 66.3 million liters/day in Indian dairy cooperatives (Mani 2022). This system has extensive procurement and distribution networks that begin at milk collection and chilling facilities at the village level. These facilities collect milk, processed in dairy plants, pasteurized, standardized, branded, packaged, and prepared for some value-added products. As per the report by the Office of Agricultural Affairs in 2022, approx. 48% of the total milk produced was sold to consumers directly in rural areas or consumed at the producer level, and 52% of the total milk produced was expected to process and sold by milk cooperatives and unorganized parties such as milkmen or contractors (Mani 2022). According to a report by IMARC Group, the Indian dairy market expects to reach INR 31,185.7 billion by 2028, with a 13.2% growth rate from 2023-28 (Imarc Group 2022).

Functioning of the Indian Dairy Industry

The stakeholders associated with the Indian dairy industry includes farmers/producers, collector, transporters, processors, distributors, retailers, and consumer. As discussed per the functioning of

organized and unorganized sectors, four possible cases are adopted in the Indian dairy system (Thakur *et al*. 2021). All four scenarios are given below:

1. Dairy farmers → Milk Supply → Collection centers → Dairy processing units → Packed Milk → Retailers.
2. Dairy farmers → Milk Supply → Dairy processing units → Direct sale → Consumers
3. Dairy farmers → Milk Supply → Private Vendors → Dairy processing units → Direct sale → Consumers
4. Dairy farmers → Milk Supply → Consumers

In India, milk producers are engaged with different stakeholders. Both organized and unorganized sectors follow the collection process given above. Private players' involvement in the dairy industry in India has risen significantly. The potential and scale of the industry in India have attracted domestic and global players to the dairy sector. Many entities, such as state cooperatives and private sectors, contribute significantly to developing the Indian dairy industry. Dairy products are being consumed widely across the globe. Knowing this fact, a trace and track system, or origin-to-destination traceability system for the dairy supply chain, must be addressed (Tan and Ngan 2020). Few solutions are available in the Indian dairy supply chain, allowing consumers to self-validate their purchased products, such as QR codes, but limited information is provided to consumers (Kasten 2019). These types of solutions can be altered or manipulated.

Challenges & Opportunites in Indian Dairy Industry

Since the end of the 1990s, India has emerged among the top producers and consumers of milk and milk products globally. The dairy sector is integral to the Indian economy and contributes significantly to employment in rural areas. A significant amount of milk is being consumed at the domestic level. The dairy industry is essential in India because it enormously impacts the population's socioeconomic status (Mani 2021). Following it in mind, the Government of India

introduced the National Dairy Programme to increase cattle productivity and milk production and thus optimize farmer incomes. Administrations are making strategic investments to upgrade milk procurement facilities in rural areas of India. The production and consumption of milk-related value-added products (VAP) in India have increased significantly recently (Imarc Group 2022). Despite having the largest dairy animal population and a variety of government programs, India produces less milk per animal than countries like the United States and the United Kingdom (Khanna *et al.* 2022). The lack of technological interventions, non-scientific methods, ineffective cattle breeding, poor management techniques, and many other factors have all contributed to the slow growth of the Indian dairy industry.

Additionally, most Indian dairy industry is unorganized, making it difficult to adopt new technologies and compete in highly competitive markets. The Indian dairy industry has become the playground for multiple frauds because of its unorganized sector (Vp *et al.* 2022). There are a lot of challenges associated with the current dairy system in the Indian context associated with both organized and unorganized sectors. Table 1 briefly outlines some significant challenges related to different dairy segments.

Usually, small-scale farmers adopt unethical practices such as feeding poor feed, utilizing unsterile tools for fertility treatment, failing to offer timely veterinary care, and, most important, committing fraud by watering down the milk. Poor infrastructure for milk collecting, transport, and manufacturing is also a challenge for the industry. Most storage areas are either a few hours away from the dairy farms or do not have the necessary electricity infrastructure to sustain the cold storage. Due to this lacking, milk quality degrades until it reaches the consumer (Pant *et al*. 2019). The lack of connections between the various supply chain participants has resulted in an inadequate supply of dairy items and increased prices. The Indian dairy market relies heavily on

physical handling, which leads to hygienic issues and human errors. Small- and medium-scale regulatory bodies are absent from the supply chains, which allows adulterated dairy products to enter the system. Most of the technology in the Indian dairy supply chains is lacking, making it impossible to adapt to shifting consumer habits and international export initiatives. All stakeholders are responsible for ensuring a food product is suitable for consumption. Utilizing integrated technological solutions will simplify managing or dealing with the challenges mentioned in Table 1. With proper traceability measures, the dairy industry will guarantee last-mile product delivery, quality control measures, inventory optimization, fault analysis, and pricing optimization.

To increase milk production and ensure quality, more investment is required for training and educating local farmers and improving infrastructure for milk collection, transport, and processing. Farmers must be educated about employing technical and hygienic animal husbandry practices. An effective traceability system can serve as a bridge between the dairy industry and the challenges associated with it in the current scenario. Practical implementation of a traceability system will provide transparency, ensure safety and quality, and ensure data sharing, optimization, waste management, and real-time monitoring throughout complete dairy operations. Technological adoption will open doors for many opportunities for every stakeholder associated with the Indian dairy system.

Existing Traceability Measures in Indian Dairy Industry

Traceability in dairy is described as the potential to track the flow of milk or milk products via various phases from start to end, that is, production to distribution. Different from the past, it has been observed that there needs to be better coordination between stakeholders. Information flow between these stakeholders is almost negligible (Shingh *et al.* 2020). The selective nature of users towards safe and hygienic food necessitates transparency throughout the dairy supply chain, from

producers to consumers (Daftary 2019). Dairy foods are among the most famous food worldwide, including a variety of milk sourced from animals such as buffalo, goats, cattle, camels, and sheep. Products containing milk as the primary ingredient include butter, cheese, curd, or ice cream (Rajendran and Mohanty 2004). It is well-known that dairy products are essential for the nutrition and health of persons of different ages, including those particularly vulnerable to diseases, such as newborns and aged people (Doni 2019). However, quality and safety have been significant concerns for the dairy industry. It was observed that milk and milk products are the sources of the most common food-borne pathogens that affect countless lives each year due to inappropriate milk handling, hygienic practices, and adulterated dairy products intentionally caused by humans (Allard *et al*. 2018).

Various methods have been used to improve supply chain traceability, from simple paper-based processes to advanced digital technologies (Wang and Li 2007). Many developing countries still prefer keeping records on paper instead of using the latest technology to perform traceability in supply chains; India is one of them. With the increasing complexity of food safety issues, conventional methods for traceability in the dairy industry are unsatisfactory and appear to be generations behind developed countries (R Badia-Melis *et al*. 2015). It also provides a chance for performance improvements by utilizing cutting-edge technologies. Traceability has emerged as an essential supply chain factor among almost sectors over the last few decades and is widely used in various scenarios (Aung and Chang 2014). It is now one of the most reliable and consistent solutions for organizations seeking a framework for real-time tracking of products and production and acquiring related data to handle company operations and comply with laws (Machado *et al*. 2018).

Several researchers tried to explore traceability in food supply chains. Still, it has been observed that traceability and its applications were overlooked in the dairy industry, particularly given the highly perishable nature of its products (Vp *et al*. 2022). The traceability in the dairy industry is still unexplored (Shingh *et al.* 2020). There are only theoretical models with no implementation or validation. There is no study with proper validation and implementation in the Indian context (Tan and Ngan 2020). Some use cases are the same as the dairy industry, but still, a decentralized system has yet to be reported to date in the dairy industry for information management (Tan *et al*. 2020). Supply chains in the Indian context still lack digital traceability implementations, especially in the dairy industry (Agrawal and Pal 2019). In light of the considerable increment in safety and security issues, the government needs traceability implementation and formulation of regulatory standards for traceability implementation (Yadav *et al*. 2020). Some significant factors, such as cost, the scale of the industry, and lack of awareness among stakeholders, affect traceability implementation (Wang *et al*. 2020). Many private dairy companies in India currently use automated and digital technologies; however, product tracing, quality measurements, and data management are not at par with decentralization and transparency. In the Indian dairy industry, the unorganized sector is the primary factor responsible for the delay in adopting digital traceability measures. But for now, the organized sector can be an excellent start to adopt digital traceable measures through the dairy industry.

Technological innovations in product identification, data gathering, and information sharing are required to implement traceability in food supply chains. Even though a traceability system includes the whole supply chain, it must incorporate each stakeholder in the most effective way possible to function correctly. Most existing technology solutions used for product identifiers and data collection in India are as follows: alphanumeric codes, holograms, barcodes, RFID tags, and

geographical indication (GI) tags. Before implementation, a proper decentralized traceability system requires knowledge of the industry along with a framework to integrate operational activities with technology. Indeed, innovative and effective traceability systems can reduce human error, enhance awareness levels about food quality standards, and save money at various points along the supply chain. The food traceability industry in India is rising as consumers and policymakers become more aware of the importance of food safety. Fig. 3 shows some existing technologies used in India (Badia-Melis *et al*. 2015; Cantero *et al*. 2008).

Figure 3 demonstrates how existing technologies tackle food safety and security issues. Smaller firms and manufacturers rely on simple paper and a pen for accounting, inventory data, and data transfer with supply chain partners. Because there is no electronic recording and reporting system, it is impossible to circulate the data to the stakeholders involved in the food supply chain. Thus, details such as the product batch number, date of manufacturing, details related to the shipment, and details about quantity and ingredients, which are handled manually, are unavailable (Karippacheril *et al.* 2011). Local food delivery people have moved ahead and are now employing an alphanumeric code system imprinted on sustainable packaging to recognize and serve their customers quickly (Narayan 2016). Researchers explored how to use GPS/GIS traceability to optimize the effectiveness of high-quality milk production and the significant role of traceability systems during transportation and raw milk treatment (Pant *et al.* 2015). Some major food manufacturers, such as Dabur, Amul, ITC, Hindustan Unilever, Kohinoor, Godrej Beverages & Foods, Mother Dairies, etc., use quick response (QR) code and barcode techniques to build better solutions while also developing customer confidence.

Furthermore, the expanding retail sector is responsible for the emergence of this industry, with distributors and manufacturers being urged to use the barcode system for their items. Several

Indian dairies utilize RFID technology, including Amul dairy, which tags livestock on its own Anand farm in Gujarat. The Govardhan and the Chitale dairy tag livestock to track and collect information about health issues (Swedberg 2010). Although India is progressing toward developing technological solutions, evaluating its significance is difficult due to the need for more data and reports from leading food businesses and research labs (Pradhan *et al*. 2015). Implementing industry 4.0 technologies in the perishables industry, like dairy, is still considered new (Dash *et al*. 2022).

Importance of Food Authenticity and Integrity in Indian Dairy Industry

Food fraud involves many intentional fraudulent activities, generally with purposeful and financial inspiration, including adding, diluting, counterfeiting, or misrepresenting food, food components, or packaging for food, as well as making misleading or inaccurate claims about a product. Food integrity and authenticity are essential to maintaining the quality and reliability of products in the Indian dairy industry. The precise depiction of a dairy product, including its source of origin, ingredients composition, and processing methods, is called authenticity. It involves offering authentic dairy products that comply with the established regulations and are without adulteration or illegal practices in the Indian dairy industry (Chousou and Mattas 2021). In contrast, integrity includes retaining the product's associated attributes, nutrient content, and hygiene practices through the manufacturing, processing, and distribution chains (Fritsche 2018). Several measures are taken to ensure food integrity and authenticity in the Indian dairy industry, as described in Table 2.

By addressing these factors, the Indian dairy industry may develop consumer confidence, encourage the adoption of sustainable practices, and contribute to the general welfare of people across the country by maintaining food authenticity and integrity. Integrated traceability systems using digital technologies can address most of the factors in Table 2.

MILK ADULTERATION AND CONTAMINATION

Milk is referred to as a perfect dairy food because it contains a variety of nutritional ingredients. It provides carbohydrates, fats, proteins, minerals, and vitamins, all essential to human life and wellness. Millions of people have consumed this throughout the globe because of its high nutritional content (Poonia *et al.* 2017). It has resulted in a significant rise in global milk consumer demand, which is unfortunately unable to be met due to decreased supply and production. The disparity between milk supply and demand has led to adulteration, an unethical practice. Figure 4, level 2 shows all the purposes which are the main reasons to use adulterants, such as to increase the shelf life, maintain density and thickness, increase fat, SNF, protein, and volume of milk, and make synthetic milk. Level 3 listed various adulterants used for different purposes listed in Level 2. Milk adulteration, or the addition of exogenous material to milk, was first reported in 1958, with the Swill Milk Scandal resulting in nearly 8000 deaths (Xin and Stone 2008). Milk adulteration has evolved into a common practice carried out fearless in all areas of the world from a financial point of view. Melamine contamination in infant food was a factor in the Chinese milk scandal in 2008. This was a wake-up call for all regulatory bodies to create strict guidelines to prevent food adulteration and its derivatives (Yang *et al.* 2009).

The lack of adequate and quick detection methods for milk adulterants is one of the primary causes of the continued prevalence of milk fraud practices. Figure 4 shows the commonly used adulterants and their function. Milk is believed to be an excellent substrate for the growth of microbes, so strict hygiene protocols are necessary for its production and supply chain. Although pasteurization eliminates most viruses, pathogens, and bacteria, microbial contamination may occur. Pathogens associated with milk consumption include *Escherichia coli, Listeria monocytogenes, Staphylococcus aureus, Campylobacter, Salmonella*, and others (Apera and Mullan 2021).

These harmful microbes in milk may be fatal, especially for those who consume raw milk. As a result, the microbe composition of raw milk is regarded as critical for milk processing. Various regulatory authorities have established acceptable microbial count limits. Increasing cases of adulteration and contamination are pointing toward the need for an effective traceability system for the dairy industry.

Methods Used for Adulteration Detection

Advancement in methods for adulteration detection over the past few decades has seen considerable growth in the dairy industry. The frequent adulteration of dairy products has resulted in severe adverse effects for consumers. To ensure the quality and safety of dairy products, it becomes essential to have reliable techniques for detecting adulteration (Hayes *et al*. 2023). Initially, adulteration in dairy products was detected based on sensory analysis, including smell and taste. However, this method was subjective and unreliable (Korel and Balaban 2002). As technology developed, analytical methods were developed for detecting the existence of particular adulterants in milk and other dairy products. Chemical analysis was used to create the first techniques for detecting adulteration using chemical reagents for specific adulterants (Poonia *et al.* 2017). Table 3 presents a brief overview of milk adulteration and contamination techniques developed till now, including spectroscopic, spectrometry, chromatographic, microbial analysis, DNA-based, biosensors, electric tongue, electric nose, hyperspectral imaging, artificial intelligence-based, machine learning-based, and other industry 4.0 technologies based techniques.

As technology progressed, analytical methods were developed to detect specific adulterants in dairy products. Chemical analysis was used to develop the first analytical technique for detecting adulteration in dairy products. Chemical reagents were used in these methods to detect the existence of particular components that include skim milk powder or added water. These methods were limited in detecting certain adulterants and could result in inaccurate findings (Sowmya and

Ponnusamy, 2021). With the introduction of spectroscopic techniques in the 1980s, a new era of adulteration detection in the dairy industry began. Fourier Transform Infrared (FTIR) and Nuclear Magnetic Resonance (NMR) spectroscopic techniques have been developed to detect various adulterants with high accuracy (Li *et al.* 2017; Valand *et al.* 2020). These methods worked by analyzing the unique spectral fingerprint of a sample and comparing it to a known spectra database for pure dairy products. If the sample had a different spectrum, it was flagged as adulterated.

More recently, molecular biology techniques such as Polymerase Chain Reaction (PCR) and DNA sequencing have been used for adulteration detection in the dairy industry. These methods identify specific DNA sequences in a sample and compare them to a database of known sequences for pure dairy products (Wu *et al*. 2022). This method is highly accurate and can detect even small amounts of adulteration. Overall, the evolution of development in methods used for adulteration detection in the dairy industry has been driven by technological advancements (Ye *et al.* 2022). Biosensors are additionally used to detect milk adulterants, including urea, melamine, non-milk fat, formaldehyde, exogenous proteins, etc. The biosensors have been developed to improve various adulterants' sensitivity, specificity, and low detection limits (Hao *et al.* 2016). Table 3 summarises some of the biosensors available for detecting milk adulterants. Then technology-based methods, such as the electric nose and electric tongue, were rapid detection methods with minimal sample preparation (Mohamed *et al*. 2018; Patel *et al*. 2019). As technology continues to improve, new and more accurate methods for detecting adulteration will likely be developed, ensuring the safety and quality of dairy products for consumers. Industry 4.0-based techniques, such as decentralized traceability based on IoT and blockchain, are also potential solutions to stop adulteration at very early stages and trace the source of adulteration (Khanna *et al.* 2022).

Need for Traceability in the Indian Dairy Industry

Ignorance and the lack of a traceability system have already resulted in numerous tragic incidents over the last decade, raising serious concerns among the public, businesses, community activists, authorities, and non-governmental organizations (NGOs) (Sinkovics *et al.* 2016; Comba *et al.* 2013). Unfortunately, because of adulteration associated with the processing, handling, and transportation of milk, the milk intake in the market today might be fatal to human health (Phau *et al*. 2015). Milk-related incidents have increased recently during the previous few decades throughout the world. In developing nations such as China, India, and Pakistan, milk-related incidences are very high (Mu *et al*. 2014). Table 4(a) overviews some milk adulteration and fraud cases globally, whereas Table 4(b) presents milk adulteration and contamination cases in the Indian context. Such fraud activities are not limited to Tables 4(a) and 4(b) because authors referred to only authentic sources available in the literature. According to research conducted by FSSAI, 68.4 % of milk in India does not meet legal standards (FSSAI 2018). Incidents related to milk, such as the lethal milk crisis in China in 2008, when Chinese suppliers added melamine, used to manufacture plastic, into powdered milk to artificially raise protein levels, resulting in the cause poison of 300,000 children (Wang *et al.* 2011). In India, detergent was found in one of the milk samples collected from Mother Dairy's collection centres, as per the information given by the UP Food and Drug Administration (FSSAI 2018). Also, 160 items were recalled in the United States in 2018 owing to undisclosed allergies, with milk accounting for one-third of the recalls (Montgomery *et al*. 2020). These occurrences have raised concerns about the traceability of milk-related products or the dairy supply chain. Many milk adulteration and contamination incidents globally could have been prevented with traceability systems implemented effectively.

Public health safety is not the only reason for dairy traceability concerns. Numerous issues involve quality management, waste reduction, reducing carbon emission, information sharing, better

management, animal welfare, industrial optimization, and many other benefits associated with a transparent and traceable dairy supply chain. Even so, ensuring this as a system is challenging because there is no appropriate system to manage the data to upgrade the functioning of traceability to its maximum potential. For example, in December 2018, about 11 people died at a feast in Karnataka, and it was suspected that the food served there was contaminated and had an instant effect on those who consumed it. Another example of food poisoning involving schoolchildren brought on by a mid-day meal program was recently reported in Bihar (FSSAI 2018). To deal with such incidents and to provide better consumer satisfaction, the Indian dairy industry needs an effective traceability system (Mor *et al.* 2018).

CONCLUSION

Milk adulteration and fraud are becoming common issues in emerging economies because of the absence of awareness and proper guidelines by food safety regulatory bodies. Adding water to milk is one of the simplest ways responsible for fraud. Besides that, if the water is polluted with biological or chemical hazards, the health threats to the consumer are increased. This review discusses production challenges in the Indian dairy industry along with the current traceability status in the dairy industry. The findings indicate the need for decentralized traceability systems, where implementing an effective traceability system can prevent dairy contamination and fraud. Since milk contains various nutrients, scammers use various adulterants to boost its nutritional value. The most common adulterants are presented in Figure 4. The literature indicates that adulteration and contamination problems exist globally in the dairy industry. Despite many adulteration and contamination detection techniques, fraud cases have increased exponentially. Addressing the dairy industry's fraudulent activity and contamination problems is an extensive task. Therefore, the authors explored that traceability could potentially solve such problems.

Implementing a digital technologies-based traceability system can prevent and trace the origin of adulteration and contamination, saving time and cost. The intervention of digital technologies within existing infrastructure can benefit all stakeholders. This can further take the Indian dairy industry to the "White Revolution 2.0", the digitalization paradigm for the dairy supply chain. Adopting cutting-edge technologies integrated with a farm-to-fork traceability system is thus critical for the Indian dairy industry. It will create a transparent system and potentially revolutionize the dairy industry by addressing milk quality and safety issues. This study can be expanded to identify the potential of traceability techniques and essential factors of implementation. The potential applications of digital traceability can be explored by identifying the challenges associated with the current dairy system. The traceability measures should be practical, developed and implemented.

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DATA AVAILABILITY STATEMENT

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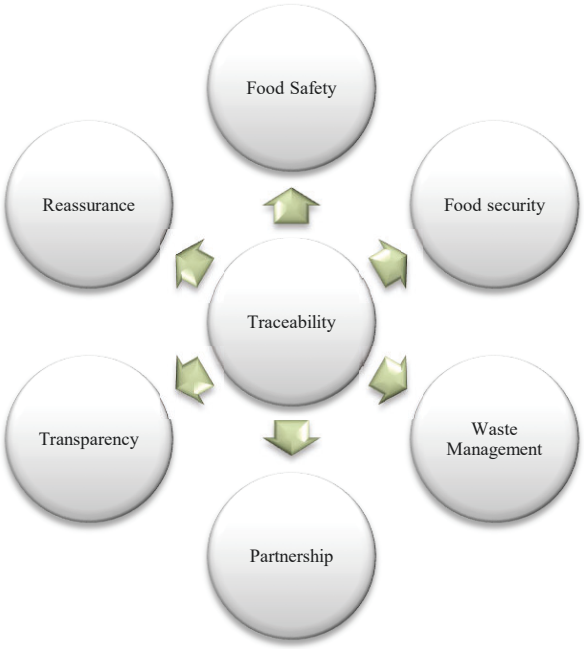

Figure 1. Applications of Traceability

- Gujarat Co-operative Milk Marketing Federation Ltd
- Mother Dairy Fruits & Vegetables Pvt Limited
- Karnataka Co-operative Milk Producers Federation Limited
- Rajasthan Cooperative Dairy Federation Ltd (RCDF)
- Tamil Nadu Cooperative Milk Producers Federation Ltd (TCMPF)
- Punjab State Cooperative Milk Producers Federation Ltd (MILKFED)
- Orissa State Cooperative Milk Producers Federation Ltd (OMFED)
- Maharashtra Rajya Sahakari Dudh Mahasangh Maraydit (Mahasangh)
- Bihar State Co-operative Milk Producers Federation Ltd. (COMFED)
- Haryana Dairy Development Cooperative Federation Ltd. (HDDCF)
- Madhya Pradesh State Cooperative Dairy Federation Ltd. (MPCDF)
- Pradeshik Cooperative Dairy Federation Ltd (PCDF)
- Nestle India Limited
- Hatsun Agro Product Limited
- Tirumala Milk Products Pvt Ltd.
- Milk Food Limited
- Heritage Foods India Limited
- VRS Foods Limited
- Bhole Baba Dairy Industries Ltd.
- Kwality Ltd.
- Sterling Agro Industries Limited
- Parag Milk Foods Limited
- SMC Foods Limited

Figure 2. Some Major Milk Co-operatives and Private Dairy Companies in India

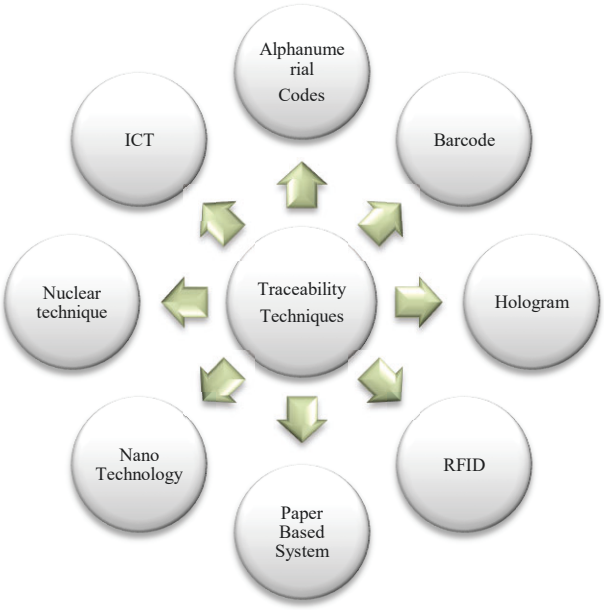

Figure 3. Technologies used for Existing Traceability Measures

Figure 4. Additives and Adulterants

Table 1: Challenges Associated with Indian Dairy Industry

Dairy Area	Challenges Associated	References
Production	• Lack of policy related to animal welfare • Lack of awareness about the quality of feed • Low price • Lack of resources • Lack of awareness about safety and hygiene practices • High risk of contamination	(Mor *et al.* 2018; Lokhorst *et al.* 2019; Pant *et al.* 2019; Sharma *et al.* 2019; Jabir *et al.* 2020; Shingh *et al.* 2020;

	• Low productivity and profitability	Thakur *et al.* 2021; Malik *et al.* 2022; Nirmala *et al.* 2022; Vp *et al.* 2022)
Procurement	• High risk of adulteration • Unregulated quality standards • Improper management • Manual data management • Lack of transparency in milk testing and pricing	
Transportation	• Environmental Factors • Road Infrastructure • Loading and Unloading Practices • Certification • Communication between Supplier, transporter, and Receiver.	
Processing	• Lack of traceability system • Safety and hygienic issues • Less processing facilities • Unhygienic conditions for milk processing • Lack of transparency • Wastage problem • Nutrient Degradation	
Warehousing, Distribution and Retailer	• Low investment in infrastructure • Lack of resources • Lack of cold storage facilities • Lack of data management	
Consumer	• Consumption patterns • Product preferences • High demands fluctuations • Quality expectations	
Management	• Lack of proper data management • Lack of coordination among stakeholders	

	• Lack of technological intervention • Lack of information sharing
Regulations	• Lack of regulations related to adoption of new technologies • Lack of promotional initiatives • Lack of policies to maintain necessary data

Table 2. Factors to Ensure Food Authenticity and Integrity

Factors	**Description**
Quality Control Measures	Reliable quality control measures to guarantee safety, authenticity, and quality including testing for adulterants, contaminants, and external materials.
Hygiene and Sanitation:	To prevent contaminants and preserve the integrity of the product, complete compliance with hygienic practices and sanitation standards throughout the production of milk, processing, and packaging is required.
Supply Chain Management	To reduce the chance of contaminants or counterfeiting, every aspect of the dairy industry from production to distribution needs proper management.
Collaboration and Partnerships	Coordination among stakeholders in the dairy industry, and policymakers to share information and resources are necessary to ensure food authenticity and integrity.
Continuous Monitoring and Enforcement	Real-time monitoring, compliance with regulations, and timely inspections are necessary to identify illegal activities to maintain the integrity of the dairy industry.
Traceability Systems	Need for a practical traceability system to trace the products from farm to fork to ensure transparency, accountability, and detection of fraudulent activities.
Sustainable Practices	Adopting sustainable practices will ensure a sustainable future.
Accreditation and Certification	Regular certification for compliance with regulatory stands will boost consumer trust regarding the product's safety, quality, and authenticity.

Regulatory Framework	Regulations and guidelines related to product quality, manufacturing process and all necessary aspects should be regularly updated and implemented to ensure quality and authenticity.
Consumer Awareness and Education	Awareness programs related to dairy products' quality and safety aspects are important to empower and promote dairy products.

Table 3: Recent Developments in Milk Adulteration and Contamination Detection Techniques

Category	**Subcategory**	**Adulterant Detected**	**References**
Spectroscopic techniques	UV-Visible Spectroscopy	Melamine, Detergents, Vegetable Oils, Urea, Water	(Sowmya and Ponnusamy, 2021)
	Infrared (IR) Spectroscopy	Melamine, Urea, Vegetable oils	(Santos *et al.* 2013)
	Nuclear Magnetic Resonance (NMR) Spectroscopy	Artificial Sweeteners, Chemical composition analysis, adulterants responsible for molecular structural changes	(Li *et al.* 2017; Santos *et al.* 2016)
	NIR Spectroscopy	Water, Melamine, Vegetable Oils	(Cattaneo and Holroyd, 2013; Huang *et al.* 2014; Khan *et al.* 2021)
	FTIR Spectroscopy	Melamine analogue, Urea, Thickening Agents, Whey	(Andrade *et al.* 2019; Cirak *et al.* 2018; Coitinho *et al.* 2017; Hansen and Holroyd 2019; Pax *et al.* 2019; Valand *et al.* 2020)
	Raman Spectroscopy	Synthetic Dyes, Chemical contaminants	(Khan *et al.* 2015; Miyaoka *et al.* 2020)
	Fluorescence Spectroscopy	Antibiotics, Chemical contaminants	(Alizadeh Sani *et al.* 2023; Tasci *et al.* 2022)

Spectrometry	Mass Spectrometry	Pesticides, Antibiotics, Melamine, Synthetic Dyes	(Cozzolino *et al.* 2001; Goriainov *et al.* 2020; Kuckova *et al.* 2019)
	Rapid Evaporative Ionisation Mass Spectrometry (REIMS)	urea, formaldehyde, hydrogen peroxide, and ammonium sulphate	(Murphy *et al.* 2021)
	Inductively Coupled Plasma Mass Spectrometry (ICP-MS)	Pesticides and herbicides	(Herwig *et al.* 2011)
	Atomic Absorption Spectroscopy (AAS)	Heavy metals (e.g., lead, cadmium)	(Sowmya *et al.* 2015)
Chromatographic Techniques	Gas Chromatography (GC)	Urea, Fatty Acids, Antibodies, Melamine, Aflatoxins, Synthetic Dyes	(Amrutha Kala 2013; Goriainov *et al.* 2020; Ishaq and Nawaz 2018; Kim *et al.* 2016)
	Gas Chromatography, Mass Spectrometry (GC-MS)	Fatty Acids, Synthetic Dyes, Pesticides,	(Matraszek-Zuchowska *et al.* 2017; Poonia *et al.* 2017)
	Liquid Chromatography (LC)	Environmental pollutants (e.g., polychlorinated biphenyls, dioxins)	(Ji *et al.* 2023; Li and Zhao 2014)
	Liquid Chromatography, Mass Spectrometry (LC-MS)	Melamine analogue, Growth hormones, Antibiotics, Artificial sweeteners	(Czerwenka *et al.* 2010; Ji *et al.* 2023; Liu *et al.* 2014; Strashnov *et al.* 2021)
	High-Performance Liquid Chromatography (HPLC)	Antibodies, Detergents, Synthetic Dyes, Aflatoxins, Pesticides, Water, Maltodextrin, Artificial Sweeteners	(Fernandes *et al.* 2017; Ivanova *et al.* 2019; Li and Zhao 2014; Vera-Bravo *et al.* 2022)
	Thin Layer Chromatography (TLC)	Synthetic Dyes, Melamine, Water, Oils, Mycotoxins, Polysorbates	(Grzelak *et al.* 2009; Petkovska *et al.* 2006; Upadhyay *et al.* 2014)
	Ion Chromatography	Sulphates, Nitrites,	(Wei *et al.* 2022)

		Phosphates, Nitrates	
Microbiological Analysis	Total Plate Count (TPC), Standard Plate Count Method	Bacterial load, Pathogenic bacteria	(Cassoli *et al.* 2007)
	Coliform and E. coli Detection	Fecal contamination	(Spagnolo *et al.* 2022)
	Yeast and Mold Counts	Fungal contamination	(Wooding *et al.* 1970)
	Specific Pathogen Detection	Salmonella, Listeria, E. coli, etc.	(Joubrane *et al.* 2022)
Enzyme-Based Assays	Alkaline Phosphatase Test	Pasteurization verification	(Rampling *et al.* 2004)
	Colorimetric Assays	Synthetic Dyes, Contaminants	(Fotouhi *et al.* 2023; Jigyasa and Rajput 2018; Vantasin *et al.* 2013)
	Proteinase Enzyme Activity Test	Adulterants used for protein enhancement, starch	(Fotouhi *et al.* 2023)
	ELISA (Enzyme-Linked Immunosorbent Assay)	Allergens, Viruses, Bovine viral pathogens, Mycotoxins, Antibiotics	(Isengard *et al.* 2012; Ren *et al.* 2014; Sun *et al.* 2013)
	Immunoblotting (Western blot)	Whey proteins Powders	(Natale *et al.* 2004)
DNA-Based Techniques	Polymerase Chain Reaction (PCR)	Genetic identification (e.g., GMOs), Bacteria (e.g., Salmonella, Escherichia coli), Viral contaminants,	(Hazra *et al.* 2018; Wu *et al.* 2022)
	Real-Time PCR (qPCR)	Bacterial or viral load, Fungi (e.g., molds, yeasts)	(Jung *et al.* 2011)
	Next-Generation Sequencing	Bacterial Contamination	(Miura *et al.* 2019)
	Single Nucleotide Polymorphism (SNP) Analysis	Detection of genetic variations in milk	(Ye *et al.* 2022)
Others	pH Measurement	Acidity, Alkalinity	(Aydogdu *et al.* 2023)

	Freezing Point Cryoscopic Method	Watering down	(Rohm 1993; Moreira *et al.* 2016)
	Titration Methods	Acid value, Peroxide value, Water	(Castaneda *et al.* 1987; Colinas *et al.* 2006; Reis Lima *et al.* 2004)
	Capillary Electrophoresis	Artificial Sweetners	(Trimboli *et al.* 2019)
	Dilution Tests	Water, Whey, reconstituted milk	(Korel and Balaban 2002; Strashnov *et al.* 2021)
Sensory Evaluation	Organoleptic Assessment	Sensory defects (e.g., off-flavors, odors).	(Korel and Balaban 2002)
Biosensors	SPR	Melamine	(Wu *et al.* 2013)
	Electrochemical	Melamine	(Guo *et al.* 2010; He and Yang 2018)
	Aptamer Based	Melamine	(Hao *et al.* 2016; Kaneko *et al.* 2018)
	Piezoelectric	Urea	(Renny *et al.* 2005)
	Potentiometric	Urea	(Trivedi *et al.* 2009)
	Thermistor	Urea	(Mishra *et al.* 2010; Naik *et al.* 2015)
	Electrochemical	Urea and melamine	(Ezhilan *et al.* 2017)
	Amperometric	Salicylic acid	(Zavar *et al.* 2013)
	Electrochemical	Hydrogen peroxide	(Akyilmaz *et al.* 2017)
	Amperometric	Benzoic acid	(Shan *et al.* 2007)
	Optical	Soy, pea and wheat protein	(Haasnoot and Verheijen 2001)
	SPR	Exogenous whey	(Haasnoot *et al.* 2006)
	QCM	Cow milk in goat's milk	(Durante *et al.* 2016; Sakti *et al.* 2016)
	Optical	Formaldehyde	(Durante *et al.* 2016)
Electrical Conductivity	Electrical conductivity	Water, Conductive substances	(Hwang *et al.* 2022)

Measurement			
Filtration and Visual Inspection	Filtration Methods, Visual Inspection, Microscopic Examination (e.g., Magnification, Staining Techniques)	Colour, Consistency, Foreign objects, Hair, Insects, Dust	(Guo *et al.* 2010; Xu *et al.* 2020)
Electronic Nose	Gas Sensor Arrays	Odor profiling, Volatile compounds	(Mohamed *et al*. 2018; Tan and Xu 2020)
Electronic Tongue	Sensor Arrays	Taste and flavour profiling	(Patel *et al.* 2019)
Hyperspectral Imaging	Imaging Techniques, Spectral Analysis	Chemical composition, Adulterants, Contaminants, Foreign matter	(Chen *et al*. 2013; Gowen *et al.* 2011)
Machine Vision	Optical Imaging	Visual inspection, Defect detection	(Zhu *et al*. 2021)
Internet of Things (IoT)	Sensor Networks	Temperature, Humidity, Contamination levels	(Gupta and Rakesh 2018)
	Cloud-Based Analytics	Trend analysis, Anomaly detection	(Balamurugan *et al.* 2022; Jachimczyk *et al.* 2021)
Blockchain Technology	Distributed Ledger	Traceability, Authentication	(Dasaklis *et al.* 2022; Khanna *et al.* 2022)
Artificial Intelligence (AI)	Pattern Recognition	Adulterant classification, Contamination	(Pawar and Panchal 2019)
	Predictive Models	Spoilage prediction, Quality deviations	(Roupas 2008)
Big Data Analytics	Data Integration	Sensor data, Lab test results, Supply chain	(Jiménez-Carvelo *et al.* 2019; Lokhorst *et al.* 2019)
	Data Mining	Pattern identification, Correlation analysis	(Hayes *et al.* 2023; Jiménez-Carvelo *et al.* 2019)
Robotics and	Robotic Systems	Sample collection,	(Floren *et al.* 2016; Rodenburg

Automation		Automated processes	2017)
Wireless Sensor Networks (WSN)	Sensor Nodes	Real-time monitoring, Remote control	(Alfian *et al.* 2017)
Augmented Reality (AR)	Simulation and Visualization	Training, Quality assessment	(Hurst *et al.* 2021)

Table 4(a): Incidents Related to Dairy Product Adulteration & Contamination (Global Context)

Product	**Contaminant**	**Problem**	**Place**	**Reference**
Milk	Campylobacter	A warning regarding the intake of raw milk in California has been issued. Six people have reported becoming sick after consuming raw milk contaminated with campylobacteriosis.	USA	(Montgomery *et al*. 2020)
		one of the most prevalent causes of bacterial diarrhea in the United States and around the world	USA	(Fitzgerald 2015)
		Bulk tank milk and other milk operations were found to have the highest of 45.9 % contamination with campylobacter in east dairies in the US	USA	(Del Collo *et al.* 2017)
		Approx. 13 samples were found with the presence of 9.3% in raw milk in randomly selected retail stores in Iran	Iran	(Rahimi *et al.* 2013)

Product	Contaminant	Problem	Place	Reference
		Samples collected from three cities in Pakistan were found contaminated, with the highest percentage of 48%.	Pakistan	(Hussain *et al.* 2007)
		11% of 912 samples collected from dairies were found contaminated with campylobacter.	Ethiopia	(Admasie *et al.* 2023)
Milk	E. *Coli*	26 samples were recorded with the presence of E. Coli from 109 samples.	Indonesia	(Ariyanti *et al.* 2022)
Milk	Melamine	Urinary stone caused due to consummation of melamine-tainted products.	China	(Wang *et al.* 2011)
Milk	Melamine	9 samples out of 40 of milk powder were found positive for melamine.	Uruguay	(Garcia Londono *et al.* 2018)
Milk	Water	During examination, 3 milk tankers were found contaminated with 50%, 41%, and 21% water in 10,000 L, 20,000 L, and 2000 L, respectively.	Pakistan	(Montgomery *et al.* 2020)
Milk	Detergents, starch, water, urea, formalin	Investigation for adulteration in 5 districts found major samples adulterated with various adulterants.	Pakistan	(Nawaz *et al.* 2022)
Milk	Radiation	Levels of radiation in milk from cows up to 140 miles around Chernobyl are still	Ukraine	(Montgomery *et al.* 2020)

Product	Contaminant	Problem	Place	Reference
		above the acceptable limit set by the government. Limits for minors are expected to remain in place until 2040 at the earliest.		
Milk	Polluted/Contaminated water	Around 55 dairy cows died because of contaminants in the water system at the dairy farm. The milk was discarded before reaching the producer as soon as the animals got sick.	England	(Montgomery *et al.* 2020)
Milk	Melamine, formalin	10 samples of milk brands were collected to test for formalin and melamine in the Savar markets.	Bangladesh	(Moonajilin *et al.* 2018)
Milk	Water, starch, cane sugar, sodium bicarbonate, formalin	50 samples collected from five areas of Barisal district were found to be 100% adulterated with water, and other adulterants were also detected in many samples.	Bangladesh	(Chanda *et al.* 2013)

Table 4(b): Incidents Related to Dairy Product Adulteration & Contamination (Indian Context)

Product	Contaminant	Problem	Place	Reference
Milk and Milk Products	E. *Coli, Staphylococcus aureus*	Around 25 samples out of 135 were found contaminated. Burfi had the highest contamination.	India	(Kumar and Prasad 2010)

Product	Contaminant	Problem	Place	Reference
Milk	Milk powder (skimmed), Starch, Urea, Sodium chloride, formalin, detergents	Milk samples were tested and found adulterated with various compounds. Investigation founds poor and unhygienic handling and storage conditions.	India	(Kumar *et al.* 2015)
Milk	Ammonium sulphate, sucrose, urea, starch	Most of the samples tested positive, collected from 5 locations near Delhi.	India	(Roy *et al.* 2017)
Milk	Urea, starch, detergent, water	Out of 1650 samples, 99 had urea, 132 had soda, 32 had starch, and 878 had water.	India	(Sanjita *et al.* 2017)
Milk	Water, milk powder, and others	According to official investigations, almost 30% of the milk distributed in India is found to be adulterated. 2307 of the 7717 samples that were tested have failed the regulatory standards.	India	(FSSAI 2018)
Milk	Water	Water addition to milk and sale of milk in branded pouches	India	(FSSAI 2018)
Milk	Hydrogen peroxide, urea, detergent	12 samples were found adulterated	India	(FSSAI 2018)
Milk	Aflatoxin M1	Around 368 samples from three states were found positive for presence of Aflatoxin M1. Tamil Nadu, Delhi and Kerala were top three states with Aflatoxin M1 presence.	India	(FSSAI 2018)

Product	Contaminant	Problem	Place	Reference
Milk	Antibiotics residues	Around 1.2% samples were found positive for antibiotics residues presence including most samples from Madhya Pradesh.	India	(FSSAI 2018)
Milk	Maltodextrin	Around 156 samples containing Maltodextrin and 78 samples sugar were found positive out of 6432 samples.	India	(FSSAI 2018)