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Review Article

Assessment of Food Safety Regulation and Assurance System in Bangladesh's Milk Value Chain: Addressing Discrepancies and Strategies for Improvement

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Abstract

This study assesses the food safety regulation and assurance systems in Bangladesh's milk value chain, identifying discrepancies and proposing strategies for improvement. Conducted in three phases, it begins with a comprehensive review of secondary sources and consultations with experts, leading to the development and validation of checklists based on international food safety standards such as the World Organization for Animal Health (WOAH), Codex Alimentarius Commission (CAC), Hazard Analysis and Critical Control Points (HACCP), Good Animal Husbandry Practices (GAHP), Good Hygiene Practices (GHP), and the Global GAP system. These standards were harmonized with national regulations, and data were collected using actor-specific checklists via a mobile application. The final phase involved field observations, stakeholder workshops, and expert panel discussions, using triangulation and Delphi techniques to validate findings and develop improvement strategies. The study reveals distinct challenges in both the formal and informal milk marketing sectors, with the informal sector often bypassing essential safety measures. Even within the formal sector, small and medium-scale operations struggle with maintaining adequate safety protocols. Specific concerns included the lack of registration and licensing, especially for cattle and buffalo farms, and the absence of certification for milk collectors. While chilling centers and sweetmeat shops showed moderate compliance with regulatory standards, significant gaps remain in biosecurity measures, waste management, animal housing, and record-keeping. Challenges in animal health management, such as improper disposal of veterinary waste and inadequate isolation of sick animals, were prevalent. Concerns about poor hygienic practices during milking, insufficient cool chain facilities, and inconsistent use of quality control measures

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were also noted. Only a small proportion of chilling plants and sweetmeat shops followed proper labeling and traceability protocols, posing risks to consumer safety. To address these issues, the study recommends strengthening the regulatory framework, improving laboratory testing, and ensuring comprehensive record-keeping. A theory of change approach is proposed, focusing on capacity building, harmonizing regulations with international standards, and engaging stakeholders to improve food safety outcomes. The findings underscore the urgent need to address critical gaps in the food safety system in Bangladesh's dairy sector to safeguard public health and promote the sustainability of the industry.

Keywords: Milk Value Chain, Food Safety Regulations, Dairy Sector Compliance, Biosecurity, Hygiene, and Sustainability

Introduction

The dairy sector in Bangladesh is primarily driven by small and marginal farmers, with few large-scale commercial farms. In recent years, this sector has transitioned from traditional, subsistence-oriented practices to a more market-driven, technology-based approach to meet rising consumer demands both domestically and internationally (Nahar et al., 2022; Rashid and Miah, 2017). Dairy farming predominantly involves cattle, though recent government initiatives have also spurred interest in buffalo as important milk producers. This shift highlights the growing significance of the dairy sector in Bangladesh's economy.

Economic Contribution

The livestock sector is crucial to Bangladesh's economy, with its contribution to agricultural GDP at 13.10% as of 2020-21. It employs around 20% of the population directly and another 50% indirectly. According to the Department of Livestock Services (DLS, 2022), Bangladesh has approximately 24.7 million cattle, 1.5 million buffalo, and 26.77 million goats. Of the 8.72 million milking cows, 53% are indigenous, while 47% are crossbred, primarily with Holstein Friesian, Sahiwal, and Sindhi breeds.

Technological Advancements

Bangladesh's dairy sector is advancing through smart dairy farming, integrating artificial intelligence, IoT, robotics, machine learning, and automation to meet the demands of the Fourth Industrial Revolution (Hassan et al., 2024; Mahbuba, 2024; Rahman, 2023ac). Leading mega-farms such as Masco Dairy Farm, Dutch Dairy Farm, and Eon Group have adopted these technologies to monitor animal health, feed intake, drug application, and breeding. This technological shift supports safe milk production, satisfying local demand and potentially expanding to export markets. The government's Dairy Development Board Act, 2022, aims to foster policy development and sectoral growth.

Current Challenges

Despite technological progress, smallholder farmers still dominate the sector, comprising over 70% of dairy farmers and producing 70-80% of the country's milk. Bangladesh's current milk production of 13.07 million metric tons (MMT) falls short of the 15.67 MMT required, resulting in a 16% deficit (DLS, 2022). The complex milk value chain, involving procurement, transportation, processing, storage, and distribution, presents challenges in ensuring both quantity and quality.

Food Safety Issues

Food safety is a critical concern in Bangladesh, with around 26 million people suffering from foodborne illnesses each year, leading to a 2% GDP loss (Huda, 2023). Milk, a dietary staple, faces contamination risks from pathogens, chemical additives, and environmental pollutants throughout the value chain. Tests have revealed milk adulteration with substances like sodium carbonate and nitrates, alongside microbial contamination (Sultana et al., 2024). Unsafe milk products pose severe health risks, particularly for children. Therefore, adherence to international standards, such as WOAH, CAC, and HACCP, is essential for improving safety across the value chain (Rahman, 2023bc; Ruegg, 2003; Reneau et al., 1998).

Government and International Initiatives

Bangladesh's expanding economy has led to increased demand for high-value animal protein. The government, with World Bank support, has initiated the Livestock and Dairy Development Project (LDDP), focusing on sustainable production with quality and safety assurances. UNIDO's collaboration aims to enhance regulatory frameworks for food safety in animal-origin products.

Study Objectives

This study aims to identify gaps in food safety practices across the milk value chain, assess regulatory compliance, and suggest improvements. By addressing these objectives, the study will contribute to safer food practices, supporting consumer health and the growth of Bangladesh's dairy sector.

Methodology

The study was designed to evaluate food safety practices within the milk value chain in Bangladesh, employing a multi-phase methodology to achieve comprehensive and reliable findings. The research process was divided into three phases, each incorporating specific activities and methodological steps tailored to meet the study's objectives. Triangulation methods were utilized to ensure validity and credibility, drawing upon multiple datasets, research methods, theories, and investigators (Rahman et al., 2018; Denzin, 1970; Lauri, 2011). Additionally, the Delphi technique was used to gather consensus from experts across multiple rounds of questioning, enhancing the accuracy and rigor of the conclusions (Sablatzky, 2022).

Phase I: Initial Planning and Preparation of Data Collection Tools

The first phase focused on creating a solid foundation for the study, starting with an extensive review of secondary sources. These included government censuses, project reports, relevant Acts and Rules, as well as international food safety standards like the World Organization of Animal Health (WOAH), Codex Alimentarius Commission (CAC), Hazard Analysis and Critical Control Points (HACCP), and Good Animal Husbandry Practices (GAHP). To enrich the understanding of the milk value chain, consultations with experts were held to create a value chain map. This mapping facilitated the development of actor-specific checklists for assessing food safety practices across various points in the value chain, including dairy cattle farmers, dairy buffalo farmers, chilling centers, milk collectors, and sweetmeat shops.

After refinement by experts, these checklists were digitized into the ODK/Kobo Toolbox mobile application, enabling efficient data collection. Study locations were selected based on dairy farming prevalence, covering subdistrict and District levels across six divisions. Sixteen enumerators from 16 subdistrict were trained to collect food safety information, providing valuable insights into the state of the milk value chain despite resource limitations. In each subdistrict, 5 respondents for each actor were randomly selected, in this way 20 respondents for four actors were considered and finally from the 16 subdistricts, 320 respondents were interview for the study.

Phase II: Data Collection and Management

During the second phase, 16 enumerators conducted data collection using the Kobo Toolbox application. Prior to field deployment, a debriefing session introduced them to the study's objectives, and a four-day field test was conducted to validate the checklists. After harmonizing field test feedback, final data collection was completed within 15 days across 16 subdistricts, focusing on each actor in the milk value chain. Data was centrally monitored and later exported to Excel for analysis, providing a quantitative basis for understanding food safety practices.

Phase III: Report Preparation

In the final phase, data analysis was followed by verification through field observations and a stakeholder workshop. Expert panel discussions and team meetings were conducted to validate food safety findings across the milk value chain. These discussions helped resolve discrepancies and enrich the data with qualitative insights gathered through focus group discussions (FGDs) on key topics like biosecurity, hygiene, traceability, disease control, and maintenance of the cool chain. The findings were presented in a workshop to identify food safety gaps, map the value chain, and discuss support mechanisms to mitigate hazards. Observations and insights from field visits were integrated into a draft report, finalized to represent a comprehensive overview of food safety practices within the milk value chain.

This methodologically rigorous study offers valuable insights into the challenges and gaps in food safety practices in Bangladesh's dairy industry and provides a framework for enhancing food safety standards across the value chain.

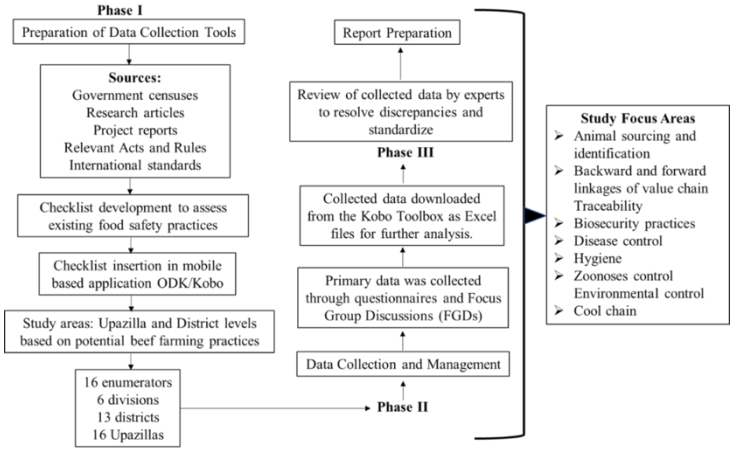

Fig. 1. Study methodology

Result And Discussion

Mapping of milk value chain in Bangladesh

The milk value chain in Bangladesh consists of two primary marketing channels: the formal and informal sectors. In the informal sector, milk is either sold raw or used in dairy products without significant processing. This sector primarily serves peri-urban and urban consumers, where raw milk is highly valued and rarely goes to chilling or pasteurization centers, instead being consumed directly or used by sweetmeat shops to produce dairy-based goods.

The formal sector, in contrast, processes milk and distributes it in Ultra-Heat Treated (UHT) or pasteurized forms, along with other value-added dairy products like butter, ghee, yogurt, and cheese. Major dairy companies, such as Milk Vita, Arong, Akiz, and Pran, manage processing facilities that utilize advanced cooling and transport technologies to ensure product safety and quality. According to observations by Sadek Agro, 57% of milk is used as drinking milk, while the remaining 43% is used for different value-added milk products. Under the brand name Shahi Mithai, 35% of the milk is utilized for manufacturing fermented milk (Labang), 25% for various sweetmeats, 20% for cheese, and 20% for ghee. American Dairy Limited (ADL) reports 80% of milk is used by sweetmeat shops for value-added products. Shwapno's best-selling item is cheese, sourced from companies like Milk Vita, Arong, Akiz, and Pran, though food safety standards need improvement in small and medium-scale productions.

Dairy farms in Bangladesh vary significantly in size and practices, impacting food safety standards. Mega dairy farms (with over 100 cattle) make up 2% of the sector

and follow advanced safety protocols with minimal food safety risk. Large farms (30-100 cattle), comprising 18% of the sector, also employ good practices but face medium safety risks. Medium farms (6-30 cattle), making up 45% of farms, exhibit some safety practices but are moderately risky, while small farms (1-5 cattle), which represent 35% of the sector, often lack proper food safety protocols, posing higher risks. These various farms follow distinct value chains based on farm size, with milk eventually reaching consumers via retailers, supermarkets, or direct delivery, indicating a diverse yet stratified value chain structure in Bangladesh.

Food safety practices in milk value chain

The study evaluated food safety practices across the dairy value chain, involving dairy farmers (cattle and buffalo), chilling centers, milk collectors (Goyala), sweetmeat shops, and feed processors. During a stakeholder meeting, discrepancies emerged, with 22% of dairy cattle farmers, 11% of buffalo farmers, 33% of milk collectors, 15% of chilling centers, 28% of sweetmeat shops, and 32% of feed processors disagreeing with initial data. Expert panel discussions resolved these differences, ensuring accuracy.

Registration and licensing

Registration and licensing are critical for food safety and quality in the dairy sector. Farm registration, particularly when integrated with traceability systems, enhances disease control and compliance with safety standards (Lin, 2021; Kumperščak, 2019). Although 24% of dairy cattle farms are registered, no registration has started for buffalo farms, revealing gaps in regulatory oversight. Milk collectors ("Goyalas") also lack certification, posing potential health risks. However, milk chilling plants and sweetmeat shops show strong compliance—87% of chilling plants and 80% of sweetmeat shops meet licensing and safety requirements. Chilling plants follow standards by holding various licenses (sanitary, environmental, industry, fire safety, trade, and BSTI certificates), while sweetmeat shops meet standards through trade licenses, sanitary certificates, and BSTI packaging compliance.

The livestock feed sector also demonstrates significant compliance. Feed companies, regulated by District Livestock Officers of DLS, must obtain trade licenses and adhere to global food safety practices, including Hazard Analysis Critical Control Point (HACCP) systems, hygiene, supplier verification, and recall plans, ensuring food safety and traceability (Nyokabi et al., 2023). This regulatory adherence across the dairy value chain underscores the importance of certification and oversight in protecting public health.

Animal Housing

Animal housing is essential for ensuring animal welfare and food safety by supporting health, productivity, and well-being. Manteca et al. (2021) found that enriched environments reducing stress-related pathogens positively impact food safety. While commercial dairy farms generally meet standards for ventilation and

flooring, family-run farms face challenges. Although 76% of these farms provide sufficient space for cattle movement, only 72% have brick floors, and 4% still use muddy floors, notably in extensive systems like the Shajadpur dairy hub. Inadequate ventilation and flooring affect both animal health and milk safety. Buffalo farms face greater challenges in meeting these housing standards, impacting animal welfare and the safety of dairy products. Fraser (2008) emphasizes that appropriate housing conditions, including space, flooring, and ventilation, are vital for animal health, which directly influences dairy quality and safety, underscoring the need for standard adherence in sustainable dairy farming.

Biosecurity and Hygienic Measures

Biosecurity and hygiene measures are critical for preventing disease outbreaks in livestock farms, protecting food safety (Goldstein et al., 2021). Despite the importance, many farms lack essential biosecurity practices like foot baths and fenced entries, increasing disease risks (Wong and Chang, 2017). Only 64% of farmers isolate sick animals, and 70% lack proper storage for medicines, which compromises the efficacy of treatments. Proper isolation and storage facilities are crucial for effective disease management. Improper disposal of syringes, with only 20% burned safely, poses environmental and public health risks. Regarding hygiene, 80% of milk collectors follow good practices by feeding cattle post-milking, reducing microbial risks (Feyisa et al., 2024; Deddefo et al., 2023). However, only 30% of farmers and 50% of collectors adhere to hygiene protocols, including washing udders and utensils before milking, posing contamination risks (Barkema et al., 1999). Disposal of spoiled milk is also a concern, with 80% of collectors discarding it improperly. At chilling plants, 46% use safe water, while 85% of sweetmeat shops use disinfectants for cleaning, and 75% ensure safe water use. However, only 30% of workers wear protective clothing, indicating a need for improved hygiene practices across the industry.

Inspection and Record Keeping

Effective record-keeping is crucial for tracking animal health, feed usage, and farm management practices, but current standards among dairy cattle and buffalo farmers are inadequate. For dairy cattle farms, while 32% keep farm animal records, 36% document treatments/vaccinations, and 56% record feed purchases, there is a notable lack of laboratory testing records for feed contaminants, such as chemicals or pesticides. Buffalo farms show even poorer record-keeping, with only animal counts documented, 6.67% of treatments recorded, and 13.33% of feed purchases tracked, and similarly, no records of feed laboratory testing are available. These documentation gaps undermine food safety and traceability, risking contaminated feed entering the food chain undetected (Balaine et al., 2020; Sudarshan et al., 2017). Although 40% of chilling centers receive regular inspections, no official inspection records or observation letters are issued, with inspectors providing only oral advice. This lack of formal documentation and the limited record-keeping (13% of plants) for

safety tests present significant challenges to maintaining consistent standards and water quality in dairy production.

Cool Chain Facilities

Maintaining a robust cool chain is vital for milk safety; however, only 10% of milk collectors (Goyala) have access to cooling facilities, which significantly increases spoilage risks during transportation, typically lasting 2.4 ± 1.42 hours (Sharma et al., 2012; Gran et al., 2002). Additionally, while 45% of sweet meat entrepreneurs employ cool vans, ensuring milk quality during transport, only 64% of sweet meat shops utilize refrigeration for storage. The remainder relies on glass enclosures, raising potential spoilage and health concerns (Desessa et al., 2020; Omore et al., 2005). Expanding access to cooling facilities and improving storage practices are essential to enhance dairy safety and reduce public health risks.

Animal Health Management

Effective disease management is critical for food safety in the milk value chain. Practices among dairy farmers show considerable variation, with 32% of dairy cattle farmers isolating sick animals, 6% selling them, 19% consulting registered veterinarians, and 43% relying on local health workers. In contrast, only 13% of dairy buffalo farmers isolate sick animals, 28% sell them, 37% consult veterinarians, and 22% rely on local health workers. The sale of sick animals poses a major risk to public health by potentially introducing diseases into the food supply (Spigarelli et al., 2021). Furthermore, inadequate isolation—68% in cattle and 87% in buffalo—heightens the risk of disease spread on farms, affecting both animal welfare and food safety.

Additionally, 36% of dairy cattle farmers are advised to avoid selling milk after administering certain drugs, observing withdrawal periods and avoiding steroid-treated milk, while only 13% of buffalo farmers receive similar guidance. This gap in milk safety advice, with lower adherence among buffalo farmers, raises concerns given buffalo milk's popularity and the potential health risks of drug residues. This disparity underscores a need for better veterinary support and education on disease management, as milk safety practices remain limited in Kenya, aligning with other studies (Feyisa et al., 2024)

Environmental Management

Proper manure management is essential to prevent contamination of animal housing and feed storage areas. Despite this, many farmers fail to keep manure well-separated, with only 24% of dairy cattle and 33% of buffalo manure heaped away from clean areas. This increases the risk of contamination and associated food safety issues. Less than half of chilling centers have adequate waste disposal systems, and improper disposal leads to some waste being discarded in common water bodies

(7%), posing significant environmental and public health risks. Spoiled milk and milk products are often disposed of in drains (55%), ponds (27%), or buried (15%), with 3% returned to farmers. Effective disposal methods at farms and chilling and processing plants are crucial for preventing environmental contamination and protecting public health. Studies by Jiang et al. (2014), Fan et al. (2017), and Ehmann et al. (2017) emphasize the environmental risks of poor manure management, supporting the need for improvements in these practices.

Laboratory Facility and Testing

To ensure the safety and quality of water, animal feed, milk, and milk products, laboratory testing for contaminants is critical, especially given the public health risks from contaminated water and feed (Todd, 2020). Routine testing for chemicals, pesticides, and contaminants in feed is essential to uphold food safety standards. Hashem et al. (2022) found low but detectable levels of heavy metals (e.g., Pb, Cr, Cd, Zn, Cu) in Bangladesh's livestock feed, underscoring the need for continuous monitoring despite concentrations being below maximum residue levels (MRLs). Milk adulteration remains a serious concern, with reports indicating frequent additions of water, detergent, urea, and other substances, which can lead to health issues like renal failure and vomiting (The Dhaka Tribune, 2023). While chilling plants have on-site testing labs for milk quality assurance, the absence of rapid testing at collection points poses food safety risks, as contaminated milk could enter the supply chain undetected.

Support and Subsidies

The discussion on improving compliance with food safety practices centers around the need for government subsidies to support farmers in the responsible use of antibiotics and veterinary drugs during animal illness. Ensuring that withdrawal periods are observed is critical, as it helps prevent harmful residues from entering the food chain. This aligns with the studies of Haque et al. (2018) and Shashikumar et al. (2018), which highlight a widespread lack of farmer awareness regarding the consequences of improper drug use. These studies emphasize the need for both education and financial support to ensure food safety compliance. Islam et al. (2020) further explore this issue by examining the awareness levels among dairy farmers in Bangladesh, specifically regarding the proper use of antibiotics and the significance of withdrawal periods. Their findings suggest that financial incentives, such as government subsidies, could play a pivotal role in improving compliance with food safety standards and minimizing antibiotic residues in dairy products.

Quality Control and Traceability

In the milk and dairy sector, food labeling is essential for safety, traceability, and consumer transparency. Proper labeling, with unique identifiers like chemical composition, manufacturer details, and expiration dates, is crucial for preventing foodborne illnesses. Only 15% of chilling plants currently meet adequate labeling

standards, highlighting gaps in compliance. Bai et al. (2023) emphasize that traceability in cold chain systems reduces safety risks and minimizes product loss, aligning with U.S. FDA (2023) and Grace (2015) regulations mandating food product labeling.

A study of sweet meat shops revealed that only 20% fully comply with labeling standards, while 55% show partial compliance and 25% lack adherence, posing risks to consumer health. In addition, 80% of these shops source raw milk from village markets, with only 5% holding farm contracts, complicating traceability. Despite 90% maintaining dedicated dairy production spaces, milk testing practices vary: while 75% of large shops test each batch, only 20% retain proper records.

Milk allergens, such as casein and whey proteins, present serious risks, underscored by studies highlighting the need for accurate allergen labeling and monitoring (Chavan et al., 2024). Cross-contamination risks emphasize the importance of worker training; Zavala and Revoredo (2022) report that 60% of milk processing workers lack such training, which is critical for consistent food safety standards, as Ruegg (2003) notes. In the EU, Regulation (EU) No. 1169/2011 sets comprehensive labeling requirements, underscoring harmonized protocols as essential for safety and traceability (European Union,2011).

Food Safety Regulatory Framework of the Milk Value Chain

The food safety regulatory framework for the milk value chain in Bangladesh is comprehensive but fragmented, with challenges in uniform implementation. Key legislation, such as the Food Safety Act of 2013, and oversight by the Bangladesh Food Safety Authority (BFSA) set essential standards. However, compliance is better under the Department of Livestock Services (DLS) for the Fish Feed and Animal Feed Act (2010) and Animal Feed Rules (2013), though enforcement at the farm level remains inadequate, especially among smaller milk producers facing financial and technical challenges (Bashar, 2017; Haque et al., 2022). Similar issues are seen in India and Kenya, where informal sectors and infrastructure gaps, such as inadequate cold chain systems, compromise milk safety (Kumar et al., 2020; Muriuki, 2019). In Kenya, up to 80% of milk is supplied through informal markets, often bypassing formal regulatory frameworks (Muriuki, 2019; Omore et al., 2021). Bangladesh's initiatives, like UNIDO's gap assessment, show promise but face coordination challenges among stakeholders. Haque et al. (2022) note poor communication between operators, regulators, and support organizations, hindering effective safety protocol implementation. The Dairy Development Board Act of 2022 aims to address these challenges, with sustained collaboration and training needed to improve milk quality, safety, and competitiveness in the industry (Chowdhury, 2017; Rahman et al., 2023c).

3.4. Strategies for Improvement

i. Strengthening Regulatory Frameworks

- Update and Enforce Food Safety Laws: Modernize food safety regulations specific to the dairy industry, ensuring enforcement of standards for milk quality, hygiene, and residue limits.
- Establish Clear Guidelines: Develop actionable guidelines covering all aspects of food safety from producers to retailers.

ii. Capacity Building and Training

- Training for Dairy Farmers: Regular training on animal husbandry, milking hygiene, and proper use of veterinary drugs to minimize contamination risks.
- Skill Development for Handlers: Train handlers, processors, and distributors on hygienic practices in handling, transportation, and storage.

iii. Infrastructure Development

- Improve Milking and Storage Facilities: Invest in quality milking equipment and storage facilities to reduce contamination risks.
- Enhance Cold Chain Management: Strengthen cold chain infrastructure for consistent milk quality from farm to consumer.

iv. Monitoring and Surveillance

- Implement Routine Testing: Regular milk testing for contaminants at multiple points along the value chain.
- Strengthen Traceability Systems: Implement systems for tracking milk from farm to consumer for rapid issue resolution.

v. Public Awareness and Consumer Education

- Consumer Education Campaigns: Launch awareness campaigns on the importance of chill milk benefit and safe milk handling.
- Promote Safe Consumption Practices: Educate consumers on safe storage practices at home.

vi. Collaboration and Stakeholder Engagement

- Multi-stakeholder Partnerships: Foster collaboration among government agencies, cooperatives, private sector, and NGOs for a unified approach.
- Engage with Dairy Cooperatives: Work with cooperatives to monitor food safety at the grassroots level.

vii. Research and Innovation

- Invest in Research: Support initiatives to identify risks and develop innovative solutions for food safety.
- Adopt New Technologies: Encourage the use of rapid testing kits and blockchain for traceability.

viii. Economic Incentives and Support

- Provide Incentives for Compliance: Offer financial incentives for farmers and processors complying with standards.
- Support Smallholders: Targeted support for smallholders to upgrade practices and facilities.

ix. Policy and Advocacy

- Advocate for Policy Support: Work with policymakers to prioritize food safety within national agendas.
- Develop Risk-based Approaches: Advocate for risk-based regulation focusing on high-risk areas.

x. Continuous Improvement

- Regular Review and Update of Practices: Continuously monitor and adapt food safety practices.
- Feedback Loops: Establish feedback mechanisms for continuous learning and improvement.

Theory of Change

Enhancing the food safety regulatory framework for the milk value chain in Bangladesh, a theory of change approach focuses on strengthening institutional capacity, improving regulatory standards, and fostering stakeholder collaboration. The theory posits that by first investing in training and resources for regulatory bodies and local dairy producers, the government can ensure more rigorous enforcement of safety standards. Next, updating and harmonizing regulations with international best practices will address gaps and inconsistencies in the current framework. Engaging with stakeholders, including dairy farmers, processors, and consumers, through awareness campaigns and feedback mechanisms will promote adherence to safety protocols and encourage transparency. Ultimately, these combined efforts will lead to a more robust food safety system, reducing contamination risks and improving public health outcomes across the milk value chain. Last but not least, several assumptions underlie this theory of change and need to be considered in implementing our change strategy (Ruth 2015).

Conclusion

In conclusion, the assessment of food safety regulation and assurance systems in Bangladesh's milk value chain reveals critical discrepancies that need to be addressed through a comprehensive and coordinated approach. A thorough gap analysis of existing policies, infrastructure, and practices is essential to improving dairy farm management, ensuring proper animal health care, and enhancing milking hygiene. Strengthening regulatory frameworks, fostering collaboration between government

agencies, private stakeholders, and international organizations, and investing in infrastructure such as cold chain facilities and testing laboratories are vital for preserving milk quality. Additionally, promoting technology adoption for traceability and raising consumer awareness on food safety can further bolster efforts to ensure safer dairy products and increase the competitiveness of Bangladesh's dairy industry in the global market.

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