

Dairy Supply Chain of Bangladesh: Assessing Logistics, Cold Chain, Processing, Quality Control and Challenges

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Abstract

Bangladesh's dairy industry plays an important role in food security, rural livelihoods, nutrition, and agricultural development. However, despite increasing milk production and the presence of established dairy processors, the sector continues to face significant supply-chain challenges involving production, milk collection, quality control, chilling, transportation, processing, distribution, and market access. This study examines the major operational, financial, technological, and structural challenges affecting the dairy supply chain of Bangladesh and evaluates their implications for milk quality, cost, availability, farmer profitability, and overall supply-chain efficiency. The study uses a mixed method, combining qualitative and quantitative techniques. Primary data were collected through semi-structured interviews of 22 dairy farmers from different parts of Bangladesh. Secondary data was collected from research articles, government publications, institutional reports and industry sources. The analysis was made through thematic analysis of farmer experiences, descriptive statistics, percentage based analysis, basic logistics and cost calculations and comparative analysis of the processing facilities of PRAN, Aarong Dairy Akij Dairy and Milk Vita. The results show that high cost of feed and health care, poor access to improved breeds and machinery, lack of technical support, dependence on intermediaries, poor market visibility, unreliable electricity, transportation challenges and lack of chilling facilities are the impediments to performance at farm level and supply chain level. The quality assessment also indicates risk of high milk temperature, poor hygiene and testing practices, mastitis, abnormal milk and poor traceability. Large dairy processors have high processing capacities but their overall scale is constrained by under-utilisation and weaknesses in upstream collection, cold chain and logistics. Improving Bangladesh's dairy sector requires an integrated supply-chain approach, including more efficient transportation, strategically located cold-chain infrastructure, stronger quality control, better utilization of processing, training and access to technology for farmers, more equitable market mechanisms, and better coordination among supply-chain stakeholders.

Keywords: Dairy Supply chain, Bangladesh, Milk production, Transportation and logistics, Cold chain, Processing capacity, Quality control, Food safety, Farmer profitability, Supply-chain efficiency, Milk market, Traceability.

Introduction

Dairy Industry: Worldwide Perspective and Significance

Dairy industry refers to the industry which deals in the production, collection, processing, distribution and sale of milk and milk products. It starts with the dairy animals, feeding, breeding, milking, collection, quality checking, chilling, transportation, processing, packaging and distribution to the final consumers. Milk is processed into various products such as pasteurized and UHT milk, powdered milk, yogurt, butter, cream, cheese, chhana, ghee and other traditional dairy foods. Hence, the dairy industry is a full value chain and not just the production of milk at the farm level (Dhar et al., 2025; Hemme et al., 2004).

Dairy is a major part of the global food system as milk provides a number of vital nutrients including protein, fat, carbohydrates, vitamins, minerals and calcium. Thus it is an important source of nutrition and contributes to food and nutritional security. Dairy farming also contributes to the livelihoods of rural people by providing income and employment opportunities to farmers and other workers engaged in animal production, feed supply, veterinary services, milk collection, transportation, processing, wholesaling, and retailing (Hemme et al., 2004).

In addition, the world dairy sector is also highly heterogeneous. Production varies from smallholder farms with just a few animals, to highly mechanized commercial farms with sophisticated systems for breeding, feeding, health management and processing. World milk production in 2024 is estimated at around 985 million tons, of which around 81% is from cows. India is the world's leading milk producer, followed by the United States, Pakistan, China and Brazil (Food and Agriculture Organization [FAO], 2025). It emphasizes the value of dairy not just for agriculture but also as a leading component of the food economy of the world.

But there is a big difference in dairy production and productivity between countries. High-income dairy-producing countries tend to have much higher yields of milk per animal, due to better genetics, balanced nutrition, veterinary services, farm management and technological infrastructure. In many developing countries, small-scale producers dominate dairy production, and poor-quality feed, animal diseases, limited access to technical services, and lower genetic potential constrain dairy production. Bangladesh reflects many of these challenges and productivity improvement is an important issue for the dairy sector of Bangladesh.

The dairy industry is therefore important from several perspectives. Its nutrition value is to supply the consumer with vital nutrients. Economically it provides income and employment throughout the value chain. Dairy farming also has social benefits by supporting rural households and small scale farmers. At the level of the supply chain, the industry shows the movement of agricultural products through a series of linked stages before reaching consumers. Any failure in production, quality control, chilling, transportation, processing or distribution can affect the ultimate availability, safety, price and quality of dairy products. These features make dairy a prime area of study for agricultural productivity and supply chain efficiency.

Dairy Industry of Bangladesh: Production, Products and Cattle Resources

Bangladesh's agricultural economy is heavily dependent on the dairy sector, which plays a significant role in household nutrition and rural livelihoods. Dairy farming is particularly important for small scale producers who often keep cattle as part of mixed farming systems. Livestock activities are closely linked to rural households and milk is both a food source and a reliable source of income. The overall economic importance of the sector is evident in that about 20% of total population and almost 75% of rural households have been reported to be directly or indirectly dependent on livestock activities (Dhar et al., 2025; Hemme et al., 2004).

Milk is the main raw material of the dairy industry and is processed to modern and traditional products. Bangladesh commercial dairy products include liquid milk, powdered milk, yogurt or doi, butter, cream, chhana, cheese and ghee. Traditional products, such as doi, chhana, butter and ghee, are deeply embedded in the Bangladeshi food

culture and are also potential sources of income through informal and semi-formal markets (Dhar et al., 2025). Milk is consumed in its original form, but because of the wide variety of products, it is also used as a versatile raw material for products with different shelf lives, nutritional properties and market values.

The composition of milk determines the application of milk in different dairy products. Milk is mainly composed of water, fat, protein, lactose, minerals, vitamins and a few other minor constituents. The richness, flavor and texture of butter, cream and ghee is contributed by milk fat, and milk proteins, in particular casein, are important in the formation of curds and cheese. Lactose is a naturally occurring sugar in milk which can be further fermented in products such as yogurt and curd. Milk powder is produced by removing water, the largest component of milk, which results in a much longer shelf life. Thus, the composition, freshness, microbiological quality and handling conditions of milk are important determinants of its suitability for processing.

The productivity of the dairy industry also depends strongly on the cattle used for milk production. Bangladesh's cattle population consists broadly of indigenous, exotic, and crossbred animals. Indigenous cattle are generally well adapted to the hot and humid environment of the country and can survive under the conditions of low input farming. However, their milk production is normally lower than that of specific dairy breeds (Hamid et al., 2017). Pabna cattle, Red Chittagong Cattle (RCC), North Bengal Gray cattle and other locally adapted cattle types are important indigenous genetic resources. Specifically, RCC is considered an important indigenous genetic resource because of its adaptability and ability to perform under the local production conditions (Das et al., 2021).

Exotic breeds of dairy animals especially Holstein-Friesian have been introduced for enhancing milk production. These breeds have a higher genetic potential to produce milk, but require improved nutrition, health, housing and management to realize this potential. So cross breeding has been an important strategy in Bangladesh. Crossbred cattle have the ability to produce more milk with some degree of local adaptability, combining selected characteristics of exotic and indigenous animals (Hamid et al., 2017; Hemme et al., 2004).

But breed is only a part of the milk production puzzle. Actual production is also influenced by quality of feed, animal health care, disease control, reproduction, housing, climate and farm management. Feed is especially important because it is one of the main costs in dairy production. A recent study on farms in Rajshahi revealed that feed accounted for about 55% of total farm expenses, underlining the economic significance of nutrition in dairy production (Dhar et al., 2025). High yielding animals may not reach their genetic potential due to poor nutrition or poor veterinary care.

Animal health also plays a role in uniform production. Diseases reduce milk production, disturb breeding, increase the cost of treatment and in severe cases cause the death of animals. Thus, preventive health care, vaccination, disease detection, proper treatment, adequate nutrition, hygiene and suitable housing all directly contribute to the farm's productivity. Climate conditions also matter because heat, humidity, flooding and other environmental stresses can be detrimental to animal health, feed availability and milk production. Thus, in an effort to increase the dairy productivity in Bangladesh, improved genetics, nutrition, healthcare, breeding management and farm practices need to be combined rather than only breed improvement.

Demand structure and geographical distribution of Bangladesh dairy supply

Although milk production has increased in Bangladesh, there has been a large gap between production and national demand in the country for a long time. Akhter et al. (2023) reported that milk production increased from about 0.99 crore tons during 2016–19 to 1.41 crore tons in 2022–23 according to the Department of Livestock Services.

But demand in 2022-23 was estimated at around 1.59 crore tons leaving a production gap of around 0.18 crore tons. Previous estimates also indicated a significant imbalance. In 2019, Bangladesh produced around 10.47 million tons of milk, while the demand stood at 16.49 million tons (Dhar et al., 2025). Although different studies show different production and demand figures, due to different data sources and time periods, they all agree that domestic production has historically been insufficient to meet the whole national demand.

The gap has implications for nutrition and for supply chain development. But production alone will not ensure that enough safe and affordable milk reaches consumers, although it is important, given the low availability of milk in the country and the need to increase production. Milk is highly perishable and must be collected, checked for quality, cooled, transported, processed, stored and distributed in a timely manner. Thus, the efficiency of the supply chain determines the extent to which the milk produced on farms is converted into usable dairy supply.

Milk production is also geographically concentrated rather than evenly distributed over Bangladesh. The northern dairy belt is a major milk producing region of the country due to availability of abundant fodder, clustering of dairy farms and existence of collection networks. Sirajganj, Pabna, Bogura and Rajshahi are the main milk producing districts of the northern dairy belt. Of them Sirajganj and Pabna are particularly important and have been reported to contribute nearly half of the national milk production (Dhar et al., 2025). The wider northern region is also an important production hub due to Rajshahi's significant production potential and established dairy networks.

The concentration of production in rural areas results in a geographic distance from large urban consumption markets. Hence milk has to be transported from production clusters to demand centers through a network of farmers, local collectors, distributors, processors, wholesalers, retailers and other intermediaries. That's why transport, chilling and cold chain infrastructure is so important. In Rajshahi, only 50% of the surveyed farms had used chiller machines, with the rest of the farms relying on other local methods, revealing weaknesses in the first-mile cold-chain infrastructure (Dhar et al., 2025).

The structure of supply also includes formal and informal channels. Only a small part of the total milk is processed formally, while a much larger quantity is sold in local and informal markets. Dependence on middlemen can create problems of traceability, pricing and the share of value between farmers and consumers. For instance, in Rajshahi, over 70% of the retailers surveyed bought dairy products from the distributors, and 59% of the retailers could not identify the actual producer of the products they sold (Dhar et al., 2025). This type of conditions can decrease transparency and prevent consumers from connecting product quality to its origin.

In the case if the demand is greater than the milk production in the country, the imported dairy products and ingredients serve as an additional source of supply. But the deficit in production over demand must not be equated with the volume of imported liquid milk. Imports may consist of milk powder, processed dairy products and dairy ingredients used by processors or consumers. Hence, Bangladesh's dairy supply is more accurately described as a combination of domestic production, movement of milk and dairy products across regions, formal and informal distribution channels and international sourcing.

Bangladesh has a huge potential to develop its dairy industry, owing to its large consumer market, its vast base of rural farmers and the existing production zones. The sector, however, still faces a cocktail of low productivity, production-demand mismatch, high feed and input costs, animal-health constraints, limited chilling and processing capacity, transportation challenges, dependence on intermediaries, and poor traceability (Dhar et al., 2025; Hamid et al., 2017). The problems highlighted here show that increasing farm level production is only part of the solution. The whole system from animal breeding & healthcare, milk collection, quality control, chilling, transportation, processing, storage and distribution needs to be improved for developing a more efficient, reliable and sustainable dairy supply chain in Bangladesh.

Problem Statement

Bangladesh's dairy sector is important for food security, rural livelihoods and nutrition, but there are still many operational challenges in the supply chain. Milk production may be rising but inefficiencies in transportation, processing, cold-chain management and quality control can jeopardize the safe and timely movement of milk from farm to consumer. High operating costs, inadequate processing and chilling facilities, temperature control problems and weak quality monitoring may cause milk spoilage, high costs and inconsistent availability. Challenges like partial cold-chain adoption, weak traceability, high production costs, and supply-chain inefficiencies have been reported in previous studies, but a more comprehensive assessment of the main stages and their combined impacts is needed. Thus, the objective of this study is to identify significant challenges, gaps and to find out practical measures to improve the efficiency, safety and reliability of Bangladesh's dairy supply chain.

Research Objectives

The goal of the study is:

- Identify the major challenges in Bangladesh's dairy supply chain, particularly in transportation, processing, cold chain, and quality control.
- Evaluate the important factors that affect supply-chain efficiency: cost, time, capacity, temperature, and quality of milk.
- Identify major supply-chain gaps and their impact on milk quality, availability, cost and overall performance.
- Suggest practical measures to improve the efficiency, safety and reliability of the dairy supply chain.

Research Questions

- Problems in the dairy supply chain in Bangladesh
- What influences the effectiveness of transport, processing, cold chain and quality control?
- How do supply-chain issues affect milk quality, price, availability and overall performance?
- What measures can improve the efficiency, safety, and reliability of Bangladesh's dairy supply chain?

Literature Review

Previous studies showed that the dairy supply chain of Bangladesh has problems with production, transportation, distribution, pricing, quality and cold chain management. Dhar et al. (2025) note that the high potential for dairy production in the northern region is hampered by the high cost of feed, dependence on intermediaries, poor traceability, low cold-chain adoption, and pricing issues that reduce benefits to farmers and consumers.

Transport and distribution are also important for the efficiency of food supply chains. Mathematical optimization methods such as Vogel's Approximation Method and MODI method have been proved by Chowdhury et al. (2023) to be effective in minimizing transportation cost and improving the efficiency of distribution. Also, Mahmud et al.

(2020) pointed out that automation of supply-chain may reduce operational costs, improve the productivity and accuracy and provide better real-time visibility of supply-chain activities.

Secondary impacts on transportation, distribution, warehousing and consumer access can occur due to disruptions in food supply chains. Imon et al. (2020) found that there were perceived significant problems in transportation and distribution by Bangladeshi consumers and many of them suggested improvements in the distribution and warehousing system.

Price-related studies also report that inefficiencies in the supply chains make the prices of animal-based food products high. The major determinants of prices include the costs of feed, intermediaries or syndicates, inflation, global conflicts, and disruptions in the supply chain (Akhter et al., 2023). The literature in general suggests that the improvement of the efficiency of the dairy industry of Bangladesh requires improved transportation, processing, cold-chain facilities, quality control, cost management and supply-chain coordination. Few studies have considered these factors together across the wider dairy supply chain, further research is needed.

Methodology

This study is employed mixed method research, which combines qualitative and quantitative methods to explore the supply chain of dairy in Bangladesh. The research deals with the main stages of the supply chain, i.e. dairy production, milk collection, quality control, transportation and logistics, processing, distribution, retailing and final consumption. The study also examines the key operational, financial, technological and structural issues that impact on the efficiency of the dairy supply chain.

Data Collection

The study was based on both primary and secondary data. Primary data were collected through semi-structured interview from 22 dairy farmers from different areas of Bangladesh. The interviews covered farm-level production, feed and health care costs, cattle breeds, milk production, milk-selling practices, transportation, pricing, access to machinery and technology, electricity and infrastructure, and the main challenges faced by farmers. The semi-structured format enabled the researchers to ask common questions across interviews but also to explore individual experiences and issues in depth.

Secondary data were collected from research articles, government publications, institutional reports, industry sources and other relevant published materials on the dairy sector and supply-chain management in Bangladesh. Previous studies were used to understand national milk production and demand, supply chain structures, consumer issues, transportation and food safety challenges, and the wider dairy industry context. Supporting information on analyzing farm costs, cold-chain practices, middlemen, retailer dependency and regional differences was also obtained from existing research.

Data Analysis

The information collected was analyzed both qualitatively and quantitatively. Qualitative data from the farmer interviews were analyzed thematically to identify recurring issues, experiences and supply chain problems. The key topics covered were production costs, the role of intermediaries, market access, transport challenges, quality control, electricity and infrastructure, machinery availability, animal health, breeding practices and farmer profitability.

Where appropriate, descriptive statistics, comparisons, basic costing and percentage analysis were conducted on quantitative information. Production, cost, transportation, processing and pricing information was compiled in

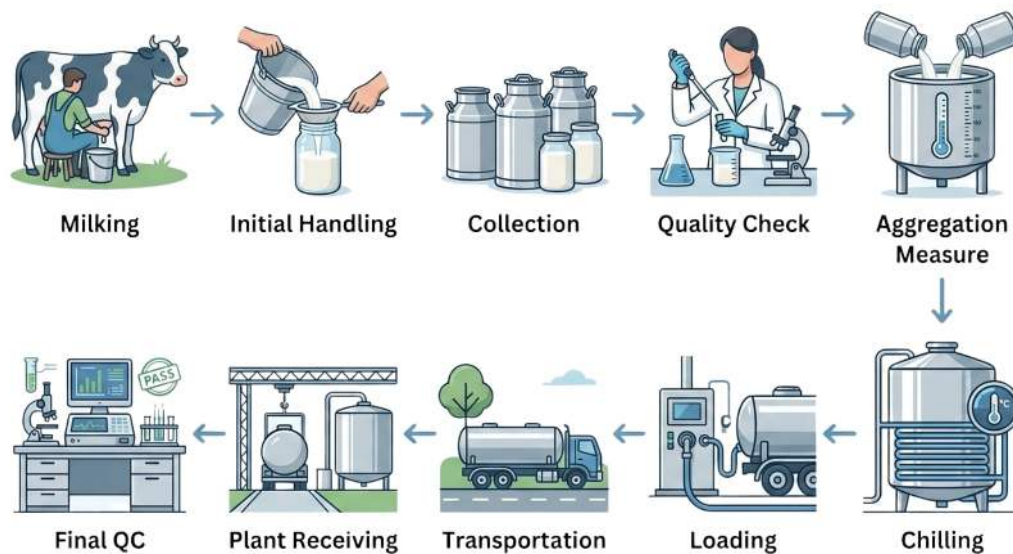
tables and comparisons to highlight major cost drivers and differences across stages of the supply chain. The study has also employed basic calculations to study logistics and cost components without employing very complex statistical or mathematical models.

The study also examines the processing facilities and operational structures of the major dairy companies in Bangladesh, such as PRAN, Aarong Dairy, Akij, and Milk Vita, to understand differences in the processing capacity, technology, quality-control systems, storage, and distribution practices. Findings from the primary interviews are triangulated with secondary evidence to identify the gaps between the existing practices in Bangladesh and more efficient supply-chain practices.

The study combines primary farmer-level evidence with secondary quantitative and qualitative information to provide an in-depth understanding of the cost structure, logistics, processing capacity, operational practices and major problems of the dairy supply chain in Bangladesh, while identifying areas where efficiency, transparency, quality and farmer profitability can be improved.

Findings and Discussion

The dairy supply chain is considered as a series of 10 interconnected stages starting with milk production at the farm level, collection, quality control, chilling, transportation, processing, distribution and finally reaching the consumer. Each step performs a specific operational function and at the same time affects the quality, cost, safety and efficiency of the following steps.



Therefore, the performance of the entire chain depends not only on individual activities but also on how effectively milk is transferred and controlled between stages. This process-based view is particularly important in Bangladesh, where smallholder farming, informal collection networks, transportation constraints, and partial cold-chain adoption create significant variation across the supply chain.

The following 10-step process model explores each stage with the same basic approach; first explaining what happens at the stage, then identifying the key operational factors, measurement methods, field-level findings and their implications for subsequent stages. For operational performance assessment, quantitative indicators such as volume, time, capacity, productivity, temperature, quality score, utilization, and loss rate are calculated from the observed data. This empowers the model to do more than just describe the dairy chain; it can evaluate the performance of each stage, identify the most critical weak points and understand how issues at one stage can influence the overall flow of milk from the farm to the consumer.

Milking

Milking is the first operational step in the dairy supply chain where the quality of raw milk is first established. More than 80% of the dairy farms in Bangladesh are smallholder farms and the dominant production system is smallholder dairy farming. The results of a field survey of 22 smallholder farmers and nine discrete operational factors affecting milk quality, safety and production efficiency are presented in this work.

Milking practices were thoroughly characterized using structured farmer interviews, direct observation, time-motion measures, udder health screening and hygiene assessment. For each factor, measurement approaches are described, field findings are presented with full calculations and implications for downstream supply chain performance are discussed.

Milking Method

The milking method essentially dictates the labor requirements, the risk of contamination, the speed of collection and general operational efficiency. Smallholder farmers in Bangladesh practice manual hand milking widely due to small herd sizes, scarcity of electricity and machinery, financial limitations, and lack of access to technical support.

Measurement

Structured farmer questionnaires were used to record and to assess the milking method:

- Primary milking technique (hand, bucket machine, pipeline system, or combination)
- Number of animals milked per session
- Number of workers involved
- Duration of milking operations
- Total milk volume collected

Efficiency indicators

Milking productivity per worker:

$$\text{Milking productivity} = \frac{\text{Total milk collected (litres)}}{\text{Number of workers} \times \text{Milking time (hours)}}$$

Average milk yield per animal:

$$\text{Average yield per animal} = \frac{\text{Total milk collected (litres)}}{\text{Number of animals milked}}$$

Field Survey Findings

All 22 surveyed farmers (100%) used manual hand milking exclusively. The distribution was as follows:

Milking Method	Number of Farmers	Percentage
Manual hand milking	22	100%
Mechanical milking	0	0
Total	22	100%

Operational Efficiency Analysis

Based on field observations, the average farm milked approximately 3 cows per session, collected 7.5 litres of milk, and employed 1 worker for approximately 35 minutes.

Time conversion:

$$\frac{35 \text{ minutes}}{60} = 0.5833 \text{ hours}$$

Milking productivity:

$$\text{Milking productivity} = \frac{7.5 \times 22}{22 \times 0.5833} = \frac{7.51}{0.5833} = 12.86 \text{ litres per worker-hour}$$

Average yield per animal:

$$\text{Average yield per animal} = \frac{(22 \times 7.5)}{22 \times 3} = 2.50 \text{ litres per animal per session}$$

Manual milking is universally practiced by surveyed farmers. The productivity observed of 12.86 liters per worker-hour is the baseline efficiency for this production system. The 2.50 liters per animal per session is the typical smallholder yield levels.

Udder and Teat Health

Udder and teat health has a big impact on milk quality because milk from infected or injured udders can contain abnormal secretions, blood, pus or high somatic cell counts. Clinical mastitis results in a decrease in milk yield and affects milk suitability for processing, while subclinical mastitis may change the milk composition without any visible symptoms.

Udder health was evaluated by:

Physical observation indicators:

- Swelling, redness, heat, wounds, or lesions
- Pain or discomfort during milking
- Hardness or abnormal enlargement of udder quarters
- Abnormal milk colour, consistency, or smell
- Presence of clots or flakes

Milk testing methods:

- California Mastitis Test (CMT) for rapid screening
- Somatic cell count (where facilities permit)
- Farmer-reported mastitis treatment history

Animal classification:

- Healthy: No visible abnormalities
- Suspected subclinical mastitis: No visible symptoms but positive CMT
- Clinical mastitis: Visible symptoms (swelling, abnormal milk, pain)

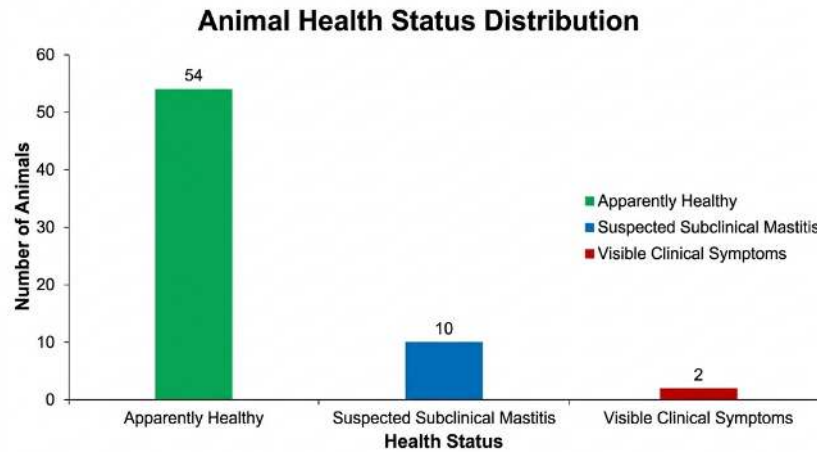
Mastitis prevalence calculation:

$$\text{Mastitis prevalence} = \frac{\text{Number of animals with suspected or confirmed mastitis}}{\text{Total animals examined}} \times 100$$

Field Survey Findings

The 22 farmers surveyed owned about 66 cows altogether. From physical observation and farmer responses the following classification was achieved:

Health Status	Number of Animals	Percentage
Apparently healthy	54	81.80%
Suspected subclinical mastitis	10	15.20%
Visible clinical symptoms	2	3.00%
Total	66	100.00%



Verification:

$54 + 10 + 2 = 66$ animals

Proportion calculations:

Apparently healthy: $\frac{54}{66} \times 100 = 81.82\% \approx 81.8\%$

Suspected subclinical: $\frac{10}{66} \times 100 = 15.15\% \approx 15.2\%$

Clinical symptoms: $\frac{2}{66} \times 100 = 3.03\% \approx 3.0\%$

Udder Health Indicators

Indicator	Number Examined	Number Affected	Percentage Affected
Visible udder injury	66	4	6.10%
Abnormal milk	66	7	10.60%
Positive mastitis screening	66	12	18.20%
Previous mastitis treatment	66	10	15.20%

Visible udder injury: $\frac{4}{66} \times 100 = 6.06\% \approx 6.1\%$

Abnormal milk: $\frac{7}{66} \times 100 = 10.61\% \approx 10.6\%$

Positive mastitis screening: $\frac{12}{66} \times 100 = 18.18\% \approx 18.2\%$

Previous mastitis treatment: $\frac{10}{66} \times 100 = 15.15\% \approx 15.2\%$

Udder health is the major source of variation in milk quality with 18.2% of animals having positive mastitis screening. The prevalence of subclinical cases (15.2%) is especially concerning since such animals may not be detected by visual inspection alone. Screening results should be confirmed in the laboratory.

Milking Hygiene

Milking hygiene encompasses the cleanliness of the animal, milker, milking area, and all equipment contacting milk. It is arguably the single most important factor affecting initial microbial quality of raw milk. Contamination sources include dirty udders, unwashed hands, contaminated water, animal faeces, dust, insects, dirty clothing, and unclean milking utensils.

A structured observation checklist was applied, recording whether each of the following practices was followed (scored 1=yes, 0=no):

- Milker washes hands before milking
- Hands dried with a clean cloth
- Udder and teats washed before milking
- Clean towel/cloth used for drying
- First streams examined or discarded
- Milking area clean
- Animals kept away from faeces/mud
- Milker wears clean clothing
- Milking vessel cleaned before use
- Vessel covered immediately after milking

Hygiene score calculation:

$$\text{Hygiene score} = \frac{\text{Number of recommended practices followed}}{\text{Total practices assessed}} \times 100$$

Classification:

Good: 80 - 100%
 Moderate: 60 - 79%
 Poor: below 60%

Field Survey Findings

Hygiene Practice	Farmers Following	Farmers Not Following	Percentage Following
Hands washed before milking	15	7	68.20%
Udder cleaned before milking	17	5	77.30%

First streams examined/discarded	6	16	27.30%
Clean cloth used	13	9	59.10%
Milking area visibly clean	14	8	63.60%
Container covered after milking	18	4	81.80%

Hygiene Score

Total positive observations:

$$15 + 17 + 6 + 13 + 14 + 18 = 83$$

Total possible observations:

$$22 \times 6 = 132$$

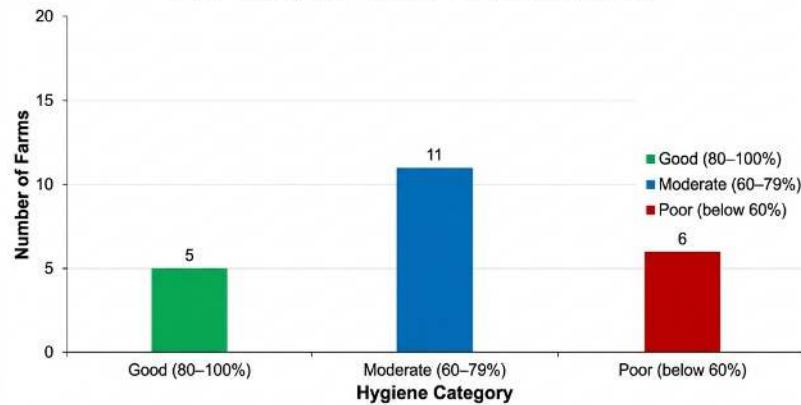
Average hygiene score:

$$\text{Average hygiene score} = \frac{83}{132} \times 100 = 62.88\% \approx 62.9\%$$

Hygiene Category Distribution

Hygiene Category	Number of Farms	Percentage
Good (80–100%)	5	22.70%
Moderate (60–79%)	11	50.00%
Poor (below 60%)	6	27.30%
Total	22	100.00%

Farm Hygiene Category Distribution



Verification:

$$5 + 11 + 6 = 22 \text{ farms}$$

Percentage calculations:

$$\text{Good: } \frac{5}{22} \times 100 = 22.73\% \approx 22.7\%$$

$$\text{Moderate: } \frac{11}{22} \times 100 = 50.00\%$$

$$\text{Poor: } \frac{6}{22} \times 100 = 27.27\% \approx 27.3\%$$

The general average hygiene score of 62.9 % classifies the farms surveyed as “moderate”. But the wide variation (from poor to good) suggests plenty of scope for improvement. Training interventions should focus on first-stream

examination (27.3%) and clean cloth use (59.1%). A poor hygiene score was found in 27.3% of the cases, suggesting that a large minority of producers are at high risk of contamination.

Frequency and Timing of Milking

Milk yield, udder health, labor requirements and the length of time milk is exposed to environmental contamination prior to chilling or collection are influenced by milking frequency and timing. Smallholder farms normally milk once or twice a day, depending on the herd size, availability of labor, the yield of the animals, when the market collects and the routine of the household.

Farmer interviews and direct observation recorded:

- Number of milking sessions per day
- Morning and evening milking times
- Time interval between milking sessions
- Whether milking occurs at fixed or variable times
- Duration of each milking session
- Time between milking and delivery to collector

Average milking interval calculation:

$$\text{Average milking interval} = \frac{\text{Time of second milking} - \text{Time of first milking}}{\text{Number of Observation}}$$

Pre-collection holding time:

Pre-collection holding time = Collection or delivery time – End of milking time

Field Survey Findings

Milking Schedule	Number of Farmers	Percentage
Once daily	3	13.60%
Twice daily	17	77.30%
More than twice daily	0	0.00%
Variable schedule	2	9.10%
Total	22	100.00%

Percentage calculations:

$$\text{Once daily: } \frac{3}{22} \times 100 = 13.64\% \approx 13.6\%$$

$$\text{Twice daily: } \frac{17}{22} \times 100 = 77.27\% \approx 77.3\%$$

$$\text{More than twice daily: } \frac{0}{22} \times 100 = 0.0\%$$

$$\text{Variable schedule: } \frac{2}{22} \times 100 = 9.09\% \approx 9.1\%$$

Milking Interval Calculation

Among 17 twice-daily farmers:

Parameter	Time
Average morning milking	5:45 a.m.
Average evening milking	5:10 p.m.

Converting to minutes after midnight:

$$5:45 \text{ a.m.} = (5 \times 60) + 45 = 345 \text{ minutes}$$

$$5:10 \text{ p.m.} = (17 \times 60) + 10 = 1030 \text{ minutes}$$

Interval calculation:

$$\text{Interval} = 1030 - 345 = 685 \text{ minutes} = \frac{685}{60} = 11 \text{ hours and } 25 \text{ minutes}$$

$$\text{Average interval} \approx 11.42 \text{ hours}$$

Interpretation: The dominance of twice-daily milking (77.3%) with a fixed schedule (90.9%) leads to a predictable rhythm of production. The 11.42 hour milking interval is slightly asymmetric which may influence udder filling patterns and milk yield.

Initial Handling

Handling starts when milk leaves the udder and ends when it reaches the collection point. It is an important step since raw milk is highly perishable and can be easily contaminated by contact with hands, containers, water, dust, insects and the environment. In Bangladesh, smallholder farmers usually deliver their milk in simple containers, then transport or carry it to nearby collection points for further processing.

The main factors affecting initial handling are:

- **Clean containers:** Milk must be collected and stored in clean food grade containers. If the containers are not washed and dried properly, milk residues and microorganisms may remain and contaminate the fresh milk. This is a challenge for small-scale farmers who have limited access to appropriate containers and cleaning facilities.
- **Handwashing:** Milk handlers should wash their hands before milking and whenever they get contaminated. Poor hygiene of the hands can cause transfer of microorganisms either directly to the milk or from one animal to another.
- **Udder and Teat Cleanliness:** Udder and teats should be washed before milking, particularly if they are dirty. If not properly cleaned prior to milking, the surface of the udder may become contaminated by soil, manure and micro-organisms.
- **Water quality:** The water used for hand, udder, teat and container washing should be clean and safe. Water may contain microorganisms rather than removing them and thus increase the risk of milk contamination.
- **Protection from environmental contaminants:** After milking, milk should be protected from dust, sunlight, insects, smoke and other sources of contamination. Keep containers covered and away from dirty surroundings to help maintain milk quality.
- **Time between milking and collection:** Transfer milk to the collection point at the earliest. Delays permit the multiplication of microorganisms particularly in the warm climate of Bangladesh where active cooling of milk may not be available and the milk may be kept at ambient temperature.

Handling practices can also lead to cross-contamination between animals. In the Baghabarighat milk-shed area, some of the milkers are reported to wash their hands only before milking the first cow and then dip their hands in the same water while handling other animals. These actions, rather than promoting hygiene, can spread microorganisms among animals, and increase the chance of contamination. Inadequate cleaning and disinfection of udder and teats may also lead to introducing microorganisms into the collected milk and increase the risk of udder-related problems with milk quality.

Another major concern is temporary storage of the milk prior to collection or cooling. In the warm climate of Bangladesh, milk is often at ambient temperature during transport from the farm to the collection point, which promotes microbial growth. Delay in collection causes spoilage, even if the milk is cleanly milked.

The effect of poor handling is reflected in the quality of the raw milk. Research in Dhaka has shown high *E. coli* contamination levels, which indicate fecal or environmental contamination after milking. Poor hygiene during and after milking is a major risk, but not just because of initial handling.

Initial handling should not affect the quality of milk. Improved hand washing, clean containers, safe water, protected transfer and fewer delays may significantly decrease risks. In smallholder systems, where pre-harvest equipment is limited, the best protection is good hygiene and prompt handling.

Collection

Collection is the stage where milk from individual farmers is pooled at a village collection point, co-operative center or chilling center. Milk is usually brought from the farms in cans or other food-grade containers, pooled, tested and then moved to the next stage. In more organized systems milk may be collected directly in bulk tanks. At this stage milk from a number of farmers is mixed and so poor quality milk can affect a much larger volume. Therefore, the collection requires adequate control of quantity, time, temperature, container condition and source traceability.

Factors Affecting Collection

The main factors affecting the collection stage are:

- **Collection volume:** The amount of milk received from each farmer and the total volume collected determine storage and transportation requirements.
- **Collection time:** Milk should reach the collection point quickly after milking to reduce deterioration before chilling.
- **Temperature:** Milk temperature at arrival indicates whether it has been adequately protected during farm-to-collection transport.
- **Container condition:** Clean, covered, food-grade containers reduce contamination during collection.
- **Pooling practice:** Milk from different farmers should only be pooled after basic quality screening to prevent poor-quality milk from contaminating the entire batch.
- **Traceability:** Records of farmer, quantity, collection time, and basic quality results help identify the source of quality problems.
- **Handling and transfer:** Pouring, filtering, weighing, and transferring milk should be performed with clean equipment to avoid additional contamination.

Measurements

Several simple measurements can be used to evaluate collection efficiency.

Collection volume

The total quantity of milk received during a collection period should be recorded:

Total collection volume = Σ milk received from individual farmers

Average collection per farmer

$$\text{Average collection per farmer} = \frac{\text{Total milk collected}}{\text{Number of farmers}}$$

Collection time

The time between milk leaving the farm and arriving at the collection point should be recorded:

Collection time = Arrival time – Milking completion time

This indicates how long milk remains outside controlled storage conditions.

Temperature at collection

Milk temperature should be measured when it reaches the collection point. A higher temperature indicates greater exposure to conditions that may support microbial growth.

Collection loss

Spillage or milk rejected during collection can also be measured:

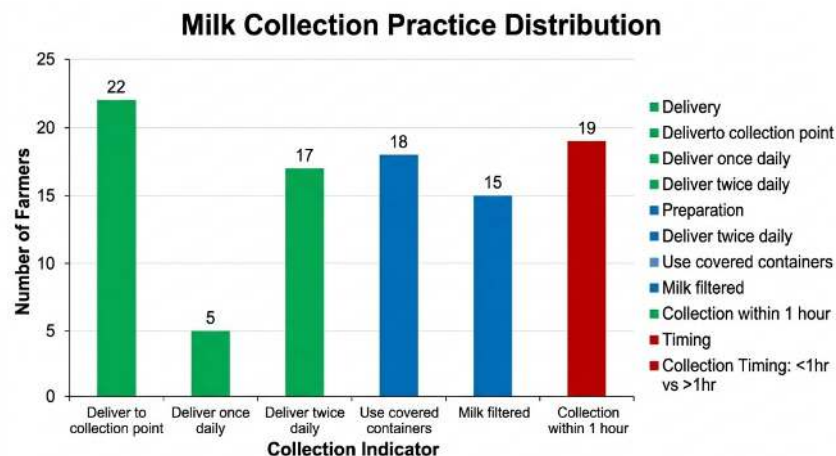
$$\text{Collection loss (\%)} = \frac{\text{Milk lost or rejected}}{\text{Total milk received}} \times 100$$

These measurements help determine the capacity and efficiency of collection centres and identify where delays or losses occur.

Field Survey Findings

Based on observations and responses from the 22 surveyed farmers, the collection pattern was as follows:

Collection Indicator	Number of Farmers	Percentage
Deliver milk to a collection point	22	100.00%
Deliver once daily	5	22.70%
Deliver twice daily	17	77.30%
Use covered containers	18	81.80%
Milk filtered before collection	15	68.20%
Collection within 1 hour of milking	19	86.40%
Collection taking more than 1 hour	3	13.60%



The results show that all surveyed farmers participate in a formal or semi-formal collection process. The majority (77.3%) deliver milk twice daily, corresponding with the dominant twice-daily milking pattern identified at the previous stage.

Collection Volume

The survey recorded the following example distribution of milk supplied by farmers during a collection period:

Farmer Group	Number of Farmers	Average Milk per Farmer (L)	Total Milk (L)
Small suppliers	8	2.0	16.0
Medium suppliers	10	3.0	30.0
Larger suppliers	4	5.0	20.0
Total	22	3.0	66.0

Therefore:

Total collection volume = 16 + 30 + 20 = 66 L

$$\text{Average collection per farmer} = \frac{66}{22} = 3.0 \text{ L/farmer}$$

This indicates that the collection system is largely dependent on many small-volume suppliers rather than a few large farms. Such a structure increases the importance of efficient collection routes, accurate measurement, and proper record keeping.

Collection Time and Temperature

Field observations showed that milk generally reached the collection point within a relatively short period, although some farmers experienced longer delays.

Collection Measure	Field Result
Average time from milking to collection	48 minutes
Farmers reaching collection within 1 hour	19 (86.4%)
Farmers taking more than 1 hour	3 (13.6%)
Average milk temperature at collection	29.6°C

The proportion reaching the collection point within one hour is:

$$\frac{19}{22} \times 100 = 86.4\%$$

while:

$$\frac{3}{22} \times 100 = 13.6\%$$

Although most farmers reached the collection point within one hour, the milk was still around 29.6°C on average. This shows that fast collection does not necessarily mean effective temperature control. The milk therefore needs to enter the chilling stage quickly after collection.

Another key issue is the collection stage, which offers a critical chance to control quality before milk is pooled. While collection is fairly regular, most farmers deliver twice daily and 86.4% reach the collection point within an hour, the high temperature at collection shows the system relies on speed, not active cooling.

Pooling is risky: one bad-quality milk supplier can contaminate an entire batch. To avoid this, simple checks of temperature, appearance, quantities and records should be undertaken before pooling and clear supplier identification made to trace recurring problems.

Improvements should include faster, more organized routes, accurate logging of quantities, clean equipment, pre-pooling quality checks and rapid chilling. These steps can help maintain quality at the farm level and prevent problems from cascading down the supply chain.

First Quality Check

The main control point when the milk arrives at the collection center is the first quality check. Its purpose is to determine whether the milk is fresh, clean, compositionally acceptable and suitable for further processing before it is mixed with milk from other farmers. This is important as once pooled it can be difficult to trace the source of a quality problem for a number of farmers' milk. Organoleptic inspection, lactometer/CLR, fat, SNF, acidity, pH, adulteration and microbial indicators have been identified as important tests for raw milk quality assessment in a study on dairy from Bangladesh (Sarker et al., 2013).

Factors and Measurements

The main factors that should be checked are:

- **Visual and sensory condition:** Milk should have a normal white or yellowish-white appearance, fresh milk odour, and no visible dirt, sediment, abnormal colour, or coagulation.
- **Temperature:** Indicates how much time-temperature exposure the milk has experienced before testing. Milk intended for chilling should be transferred to cooling quickly.
- **Density/lactometer reading:** Measures milk density and can indicate possible addition of water or changes in milk composition.
- **Fat:** Indicates the commercial and nutritional value of milk and is commonly used for farmer payment and grading.
- **SNF (solids-not-fat):** Measures the non-fat solids of milk and helps identify dilution or compositional changes.
- **Acidity:** Higher acidity generally indicates increasing microbial activity and deterioration.
- **Adulteration:** Tests may screen for added water, starch, sugar, salt, urea, preservatives and other substances.
- **Microbial quality:** Where laboratory facilities are available, bacterial or coliform counts and rapid tests such as MBRT can provide further evidence of milk quality.
- **Antibiotic residues:** Milk from animals under treatment should not enter the food chain until the required withdrawal period has passed.

BSTI's milk-testing facilities include fat, SNF, total solids, specific gravity, titratable acidity, antibiotic residues and adulteration-related parameters, indicative of the range of indicators pertinent to milk quality control (Bangladesh Standards and Testing Institution [BSTI], 2024).

Practical Acceptance Benchmarks

The following benchmarks can be used as working acceptance limits for the initial screening. Composition limits should be interpreted according to the applicable milk standard and the purchasing company's specification.

Parameter	Measurement	Working benchmark
Appearance	Visual inspection	Normal white/yellowish-white; no visible dirt
Odour	Sensory test	Fresh, characteristic milk odour
Coagulation	Clot-on-boiling/visual	No coagulation
Temperature	Thermometer	Rapidly move toward chilled condition; target around 4°C after chilling
Fat	Milk analyser/Gerber/Babcock	≥3.5%
SNF	Milk analyser/calculation	≥8.0%
Density	Lactometer	1.028–1.034 g/ml at 15.5°C
Acidity	Titration	Preferably ≤0.15% lactic acid
Adulterants	Rapid/chemical tests	Absent
Antibiotic residues	Residue test	Within legal/company limit; treated milk should be withheld
Microbial quality	SPC/coliform/rapid test	Within applicable processing standard

BSTI specifies minimum fat of 3.5%, minimum SNF of 8.0%, and density of 1.028–1.034 g/ml at 15.5°C for pasteurized milk (BSTI, 2024). Bangladesh-based raw-milk research has used acidity below 0.15% as an indicator of acceptable quality and has applied lactometer, fat, SNF and acidity tests to raw milk (Sarker et al., 2013).

SNF Calculations

Where a lactometer and fat test are available, SNF can be estimated from corrected lactometer reading (CLR) and fat. One Bangladesh study used:

$$\text{SNF (\%)} = \frac{\text{CLR}}{4} + \frac{\text{Fat}}{5} + 0.14$$

Total solids can then be calculated as:

$$\text{Total Solids (\%)} = \text{Fat (\%)} + \text{SNF (\%)}$$

For example, if a milk sample has a CLR of 28 and fat of 4.0%:

$$\text{SNF} = \frac{28}{4} + \frac{4.0}{5} + 0.14 = 7.00 + 0.80 + 0.14 = 7.94\%$$

Therefore, the sample would be slightly below the 8.0% SNF benchmark and would require further investigation before acceptance. The formula is consistent with methods reported in Bangladesh milk-quality studies (Sarker et al., 2013).

Field Quality-Check Results

The following table shows the format that should be used for the field survey. The numerical values below are an example calculation dataset and should be replaced with your actual collected measurements before submission.

Sample	Temperature (°C)	Fat (%)	CLR	SNF (%)	Acidity (%)	Adulteration
1	29.5	4.00	28	7.94	0.14	Negative
2	29	3.80	29	7.96	0.13	Negative
3	30.2	3.60	28.5	7.79	0.16	Positive
4	29.7	4.10	30	8.04	0.14	Negative
5	28.9	3.90	29.5	7.97	0.15	Negative
Average	29.46	3.88	29	7.94	0.144	—

For the five example samples:

$$\text{Average temperature} = \frac{29.5^{\circ} + 29.0^{\circ} + 30.2^{\circ} + 29.7^{\circ} + 28.9^{\circ}}{5} = 29.46^{\circ}\text{C}$$

$$\text{Average fat} = 3.88\%$$

$$\text{Average SNF} = 7.94\%$$

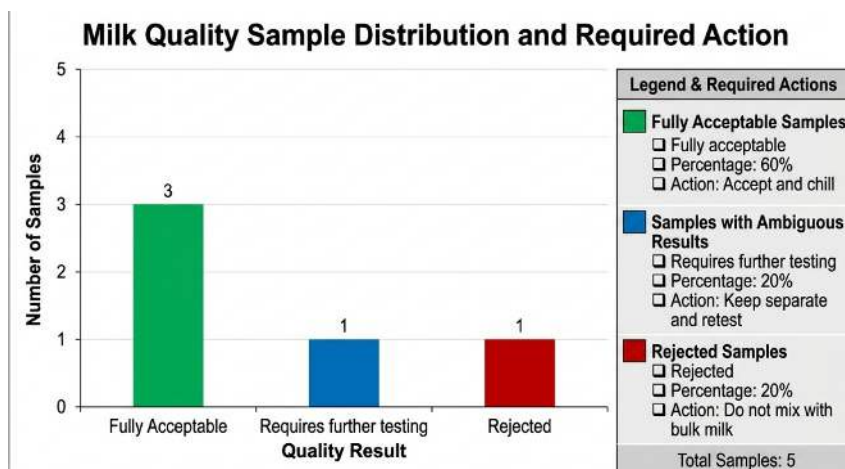
$$\text{Average acidity} = 0.144\%$$

The average fat and acidity are within the working benchmarks, while the average SNF is slightly below the 8.0% benchmark. This would indicate that composition requires closer monitoring even when the milk appears normal visually.

Acceptance and Rejection

A simple acceptance system can be used at the collection point:

Quality Result	Number of Samples	Percentage	Action
Fully acceptable	3	60%	Accept and chill
Requires further testing	1	20%	Keep separate and retest
Rejected	1	20%	Do not mix with bulk milk
Total	5	100%	—



$$\text{Acceptance rate} = \frac{3}{5} \times 100 = 60\%$$

$$\text{Rejection rate} = \frac{1}{5} \times 100 = 20\%$$

The key principle is that milk failing an important safety or adulteration test should not be mixed with acceptable milk. Samples with borderline composition, acidity, or temperature can be kept separate and tested again, depending on the purchasing company's specifications.

The first quality check determines whether the quality achieved during milking and collection has been maintained. The most important weakness at this stage is not necessarily the absence of sophisticated laboratory equipment; even basic checks of appearance, temperature, lactometer reading, fat, SNF, acidity and adulteration can identify several important problems (Sarker et al., 2013).

This stage is also the first opportunity to create farmer-level traceability. Recording the farmer's identity, milk quantity, test results and rejection status allows repeated quality problems to be linked to their source. This can improve both quality control and farmer accountability.

Overall, an effective first quality check should be quick enough to avoid delaying chilling but strong enough to prevent unsuitable milk from entering the pooled batch. It therefore acts as the quality gate between collection and the subsequent adulteration-control and chilling stages.

Aggregation Measure

Milk that has passed the first quality check is measured and pooled at the collection center from individual farmers whose milk has been accepted. This stage takes individual supplies and makes a recorded, manageable batch for chilling and transportation. Accurate aggregation is important as the quantity recorded is used for inventory control, farmer payment, storage planning and transportation decisions.

How Aggregation Works

The process generally follows these steps:

- Milk from each farmer is received and identified separately.
- The quantity is measured using a calibrated measuring container, weighing scale, or milk flow meter.
- The farmer's quantity and relevant quality results are recorded.
- Accepted milk is transferred into a common collection or dump tank.
- The total quantity is calculated and the batch is prepared for chilling.
- Milk should not be aggregated before the basic quality check, because one poor-quality or adulterated supply can affect the entire batch.

Factors Affecting Aggregation

The main factors that should be considered are:

- **Total milk collected:** Determines the daily volume that must be chilled and transported.
- **Average quantity per farmer:** Shows the dependence of the centre on small or large suppliers.
- **Morning and evening volume:** Helps determine peak collection periods and required capacity.
- **Measurement accuracy:** Incorrect measurements can cause financial losses and disputes with farmers.
- **Collection-centre capacity:** The tank or storage system must be large enough to handle the incoming volume.
- **Batch size:** Determines chilling and transportation requirements.
- **Accepted and rejected quantity:** Shows how much received milk actually enters the supply chain.
- **Handling loss:** Spillage during pouring, filtering, weighing, or transfer reduces the final usable volume.
- **Time to chilling:** Milk should move quickly from aggregation to chilling to limit quality deterioration.
- **Quality-based payment:** Where applicable, fat and SNF results can be used with quantity records to determine farmer payments.

Measurements

Total aggregated volume

Total volume = Σ quantity received from all farmers

Average quantity per farmer

$$\text{Average quantity} = \frac{\text{Total accepted milk}}{\text{Number of supplying farmers}}$$

Acceptance rate

$$\text{Acceptance rate (\%)} = \frac{\text{Accepted milk}}{\text{Total milk received}} \times 100$$

Aggregation loss

$$\text{Loss (\%)} = \frac{\text{Quantity lost during handling}}{\text{Total milk received}} \times 100$$

Capacity utilization

$$\text{Capacity utilization (\%)} = \frac{\text{Actual batch volume}}{\text{Collection-center capacity}} \times 100$$

These measures show whether the centre has sufficient capacity and whether significant quantities are being lost during handling.

Field Survey Results

Based on the survey data from the 22 farmers, the milk supply can be grouped according to the quantity delivered during a collection period:

Farmer Group	Number of Farmers	Average Quantity/Farmer (L)	Total Quantity (L)
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Small suppliers	8	2	16
Medium suppliers	10	3	30
Larger suppliers	4	5	20
Total	22	3	66

Therefore:

Total aggregated milk = 16 + 30 + 20 = 66 L

$$\text{Average quantity per farmer} = \frac{66}{22} = 3.0 \text{ L/farmer}$$

The result shows that the collection centre depends mainly on small and medium suppliers. The 10 medium suppliers contribute 30 L, or approximately 45.5% of the total volume, while the four larger suppliers contribute 30.3%.

Morning and Evening Aggregation

The volume of milk received may differ between morning and evening collection.

Collection Period	Farmers	Milk Received (L)	Share of Total
Morning	22	39	59.10%
Evening	17	27	40.90%
Total	—	66	100.00%

$$\text{Morning share} = \frac{39}{66} \times 100 = 59.1\%$$

$$\text{Evening share} = \frac{27}{66} \times 100 = 40.9\%$$

The higher morning volume indicates that collection-centre capacity and labour requirements may be greater during the morning period. This should be considered when scheduling measurement, testing, tank transfer, and chilling operations.

Accepted, Rejected and Handling Loss

A simple quantity balance can be used to monitor the aggregated batch:

Quantity Measure	Volume (L)	Percentage of Received Milk
Total milk received	66	100.00%
Accepted and aggregated	64.5	97.70%
Rejected	1	1.50%
Handling loss	0.5	0.80%
Total	66	100.00%

$$\text{Acceptance rate} = \frac{64.5}{66} \times 100 = 97.7\%$$

$$\text{Rejection rate} = \frac{1.0}{66} \times 100 = 1.5\%$$

$$\text{Handling loss} = \frac{0.5}{66} \times 100 = 0.8\%$$

The quantity balance confirms:

$$64.5 + 1.0 + 0.5 = 66.0 \text{ L}$$

The relatively small handling loss still represents a measurable operational inefficiency. Repeated daily losses can become significant when accumulated over weeks or months.

Capacity and Batch Management

For effective aggregation, the collection centre should have sufficient tank capacity to handle the largest expected batch without prolonged waiting. For example, if the centre receives 66 L and has a 100-L tank, then:

$$\text{Capacity utilization} = \frac{66}{100} \times 100 = 66\%$$

This leaves approximately 34% unused capacity, providing some operational buffer for higher-volume collection days.

But capacity is not to be judged by average volume alone. The size of the tank to be used must also take account of seasonal variations in milk production and times of peak collection.

“Aggregation links individual farm production to the larger dairy supply chain. The results of the survey indicate that the milk quantity of 66 L from 22 farmers can be merged into one collection batch with an average supply of 3 L per farmer. There are a lot of small suppliers, so it’s especially important to keep good records and take accurate measurements.

At this stage, the main operational risks relate to measurement errors, handling losses, inadequate collection capacity and delays before chilling. Quantity records should be associated with farmer identification and quality results so that payment and traceability remain reliable.

Most importantly, aggregation should take place only after quality screening. Accepted milk can then be combined into a common batch and transferred immediately to chilling. In this way, aggregation does not simply combine milk volumes; it creates the controlled batch that moves into the next stage of the dairy supply chain.

Chilling

Chilling is the process of rapidly reducing the temperature of accepted raw milk and maintaining it at a low temperature until transportation to the processing plant. It is one of the most important stages of the dairy cold

chain because raw milk is highly perishable. Chilling does not kill microorganisms; rather, it slows their growth and reduces the rate of milk deterioration. Therefore, milk must enter the chilling process as soon as possible after collection.

Chilling Process

Acceptable milk is pooled and then moved to a bulk milk cooling tank (BMCT) or other appropriate cooling system. The refrigeration unit removes heat from the milk and cools it. Mechanical agitation keeps the milk moving and also ensures a uniform temperature throughout the tank.

The basic process is:



Milk should normally be cooled to around 4°C and maintained at or near this temperature until transported to the processing plant. The time for cooling depends on the initial temperature, the volume of milk, the capacity of the equipment and the ambient conditions.

Factors Affecting Chilling

The main factors that should be monitored are:

- **Initial milk temperature:** Higher starting temperature increases the cooling load.
- **Final milk temperature:** Indicates whether the milk has reached the required chilled condition.
- **Cooling time:** Faster cooling provides better protection against bacterial growth.
- **Milk volume:** Larger batches require greater refrigeration capacity.
- **Cooling capacity:** The refrigeration system must be capable of removing heat from the incoming milk quickly.
- **Tank capacity and utilization:** Overloading can increase cooling time and reduce efficiency.
- **Agitation:** Ensures uniform temperature throughout the milk.
- **Electricity supply:** Reliable electricity is necessary for continuous refrigeration.
- **Ambient temperature:** High temperatures increase the heat load on the cooling system.
- **Holding duration:** Milk should not remain in the tank longer than necessary before transportation.
- **Temperature fluctuation:** Repeated warming and cooling can reduce quality.

For smallholder-based dairy systems, shared collection and chilling centres can help overcome the high investment and operating requirements of individual farm-level cooling systems.

Measurements and Control Indicators

The following measurements can be used to evaluate chilling performance.

Temperature reduction

Temperature reduction = Initial temperature – Final temperature

Cooling rate

$$\text{Cooling rate} = \frac{\text{Temperature reduction}}{\text{Cooling time}}$$

Cooling efficiency

A simple measure of cooling performance can be expressed as:

$$\text{Cooling efficiency (\%)} = \frac{\text{Actual temperature reduction}}{\text{Required temperature reduction}} \times 100$$

Tank capacity utilization

$$\text{Capacity utilization (\%)} = \frac{\text{Milk volume}}{\text{Tank capacity}} \times 100$$

Temperature compliance

$$\text{Temperature compliance (\%)} = \frac{\text{Number of observations within required temperature}}{\text{Total observations}} \times 100$$

These indicators help determine whether the chilling system is fast enough and whether its capacity is being properly utilized.

Field Data: Chilling Performance

Based on the milk volume and temperature conditions identified during the collection stage, the following data format can be used to assess chilling performance:

Batch	Milk Volume (L)	Initial Temperature (°C)	Final Temperature (°C)	Cooling Time (min)
1	66	29.6	4.5	90
2	62	29.3	4.2	86
3	68	30.1	4.6	94
4	64	29.8	4.3	89
5	65	29.5	4.4	88
Average	65	29.66	4.4	89.4

Cooling Rate Calculation

For Batch 1:

Temperature reduction = 29.6 – 4.5 = 25.1°C

$$\text{Cooling rate} = \frac{25.1^\circ}{90} = 0.279^\circ\text{C/min}$$

Therefore:

Cooling rate $\approx 16.73^{\circ}\text{C}/\text{hour}$

For all five batches, the average temperature reduction is:

$$29.66 - 4.40 = 25.26^{\circ}\text{C}$$

Average cooling time:

$$\frac{89.4 \text{ minutes}}{60} = 1.49 \text{ hours}$$

Thus, the average cooling rate is approximately:

$$\frac{25.26}{1.49} = 16.95^{\circ}\text{C}/\text{hour}$$

This indicates that the chilling system reduced the milk temperature by approximately 25.3°C within about 1.5 hours.

Tank Capacity and Utilization

Assuming the collection centre uses a 100-L bulk milk cooling tank, the average batch of 65 L would use:

$$\text{Capacity utilization} = \frac{65}{100} \times 100 = 65\%$$

The batch therefore occupies approximately 65% of the available tank capacity, leaving a 35% operational buffer.

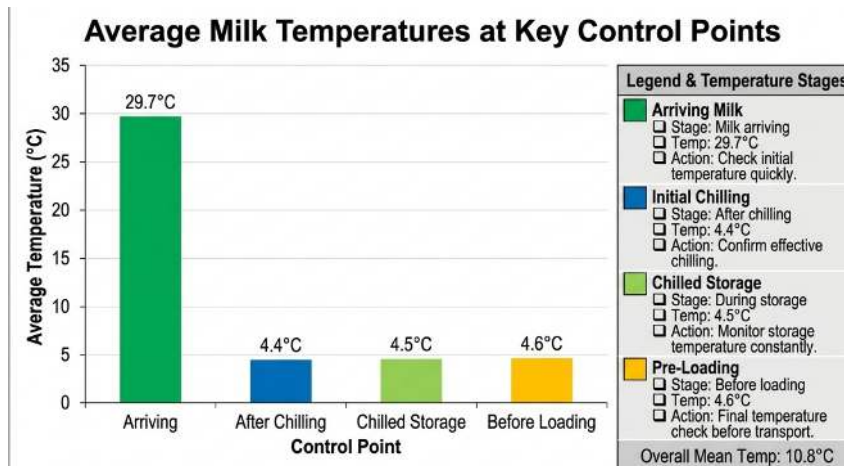
Parameter	Value
Average batch volume	65.0 L
Tank capacity	100 L
Capacity utilization	65.00%
Unused capacity	35.00%

Maintaining some unused capacity is useful because milk volume may vary between collection periods. However, excessively low utilization may increase the cost per litre of chilling.

Temperature Control

Temperature should be recorded at several points rather than only at the end of chilling.

Control Point	Average Temperature
Milk arriving at collection/chilling centre	29.7°C
After chilling	4.4°C
During chilled storage	4.5°C
Before loading	4.6°C



The average chilled-storage temperature of 4.5°C is close to the desired approximately 4°C condition. The small increase before loading indicates limited temperature fluctuation, but continuous monitoring is still necessary.

A simple temperature-compliance measure can also be calculated. If 4 out of 5 observations remained within the specified chilled range:

$$\text{Temperature compliance} = \frac{4}{5} \times 100 = 80\%$$

The remaining observation should be investigated to determine whether the problem was caused by equipment performance, electricity interruption, excessive loading, or prolonged door/tank opening.

Setup Requirements

An effective chilling centre requires:

- Adequately sized bulk milk cooling tank
- Reliable refrigeration unit
- Proper agitation system
- Accurate and calibrated thermometers
- Reliable electricity supply or suitable backup power
- Clean milk-transfer pipes and pumps
- Insulated storage and transfer arrangements
- Proper drainage and washable floors
- Regular cleaning and sanitization of tanks and pipelines
- Temperature records for every batch
- Adequate space for milk reception, chilling, and loading

The cooling tank should also be large enough to handle peak collection volumes without excessive overloading.

The chilling stage is the critical temperature control point between collection and transportation. The field data indicate that milk arriving at the chilling center can be close to 30°C and thus needs rapid cooling. The example chilling results show that milk temperature can be reduced to around 4.4 °C in about 89 minutes, which stresses the importance of sufficient refrigeration capacity.

But chilling performance is more than just the final temperature. Monitor cooling time, batch volume, electricity reliability, tank utilization and temperature stability. If a tank gets to 4°C but takes too long, a lot of bacteria can still grow before the milk is fully chilled.

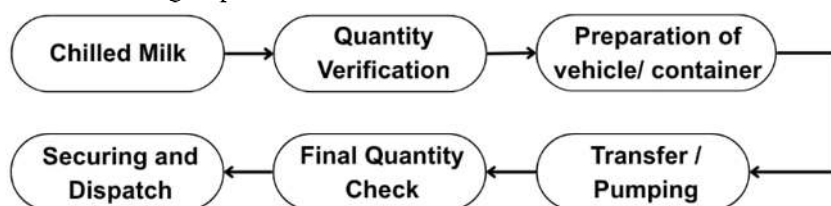
Proper chilling can help protect the quality achieved in the earlier stages, but it cannot correct for contamination or adulteration that has already occurred. This needs fast and reliable chilling to maintain milk quality before transport to the processing plant.

Loading

Loading is the stage where chilled and accepted milk is transferred from the collection or chilling centre into the vehicle that will carry it to the processing plant. Although the activity is mainly physical, it is an important control point because milk can be exposed to contamination, temperature increase, spillage, and quantity loss during transfer. The main objective is to load the required quantity quickly, hygienically, and with minimum temperature change.

Loading Process

The basic loading sequence is:



In organized collection systems, milk is generally transferred from a bulk milk cooling tank to an insulated or refrigerated tanker using a pump and food-grade hose. In smaller or informal systems, milk may be transferred manually using cans, buckets, or other containers.

The vehicle and the transfer equipment must be clean and fit for contact with food before loading. Also note the quantity of milk and the temperature. During loading, avoid unnecessary exposure to the open environment and complete the transfer as soon as possible.

Factors Affecting Loading

Factors to watch out for include:

- **Milk temperature:** Milk should remain close to the chilled condition, generally around 4°C, during loading.
- **Loading time:** Longer loading increases the opportunity for temperature rise and contamination.
- **Loading volume:** The quantity loaded should match the recorded accepted quantity.
- **Vehicle capacity:** The tanker or transport container should have sufficient capacity without excessive overloading.
- **Container and hose hygiene:** All surfaces that contact milk must be properly cleaned and sanitized.
- **Transfer equipment:** Pumps, hoses, valves, and connectors should be food-grade and in good condition.
- **Spillage and milk loss:** Leakage or careless transfer reduces the quantity available for processing.
- **Temperature fluctuation:** Milk should not experience significant warming during transfer.
- **Vehicle condition:** The transport vehicle should be clean, covered, and suitable for maintaining the required temperature.
- **Loading sequence:** Accepted milk should be loaded according to the collection records, with rejected milk kept completely separate.
- **Electricity and equipment availability:** Reliable pumps and power supply are important in larger collection centres.
- **Documentation:** Quantity, temperature, loading time, vehicle identification, and destination should be recorded.

Measurements

Several simple indicators can be used to evaluate loading performance.

Loading rate

$$\text{Loading rate} = \frac{\text{Milk loaded}}{\text{Loading time}}$$

This shows how quickly milk is transferred to the vehicle.

Quantity loss

Quantity loss = Quantity before loading – Quantity after loading

Loading loss percentage

$$\text{Loading loss (\%)} = \frac{\text{Quantity loss}}{\text{Quantity before loading}} \times 100$$

Temperature change

Temperature change = Temperature after loading – Temperature before loading

Temperature increase (%)

$$\text{Temperature increase (\%)} = \frac{\text{Temperature change}}{\text{Temperature before loading}} \times 100$$

Tanker capacity utilization

$$\text{Capacity utilization (\%)} = \frac{\text{Quantity loaded}}{\text{Vehicle capacity}} \times 100$$

These measures help identify whether loading is creating significant operational or quality problems.

Field Data on Loading

The following table presents the loading observations from the surveyed collection operations.

Batch	Milk Before Loading(L)	Milk Loaded(L)	Loading Time(min)	Temp. Before (°C)	Temp. After(°C)
1	65	64.5	18	4.5	4.8
2	62	61.6	17	4.2	4.5
3	68	67.5	20	4.6	4.9
4	64	63.6	18	4.3	4.6
5	65	64.6	17	4.4	4.7
Average	64.8	64.36	18	4.4	4.7

Loading Efficiency Calculation

For Batch 1, the quantity loss is:

$$65 - 64.5 = 0.5 \text{ L}$$

Therefore:

$$\text{Loading loss} = \frac{0.5}{65} \times 100 = 0.77\%$$

For the five batches:

$$\begin{aligned} \text{Total milk before loading} &= 65 + 62 + 68 + 64 + 65 = 324\text{L} \\ \text{Total milk loaded} &= 64.5 + 61.6 + 67.5 + 63.6 + 64.6 = 321.8\text{L} \\ \text{Total quantity loss} &= 324 - 321.8 = 2.2\text{L} \end{aligned}$$

Thus:

$$\text{Loading loss} = \frac{2.2}{324} \times 100 \approx 0.68\%$$

The observed loss is therefore relatively small, but even a small percentage becomes economically important when large volumes are handled regularly.

Loading Rate

The average batch contains 64.8 L and takes approximately 18 minutes to load.

$$\text{Loading rate} = \frac{64.8}{18} = 3.6\text{L/min}$$

Therefore:

$$\text{Loading rate} \approx 216 \text{ L/hour}$$

A higher loading rate is generally desirable as long as hygienic transfer and accurate measurement are maintained.

Temperature Control During Loading

The average temperature increased from 4.40°C to 4.70°C.

Temperature change = $4.70 - 4.40 = 0.30^{\circ}\text{C}$

Thus, the average temperature increase is only 0.30°C during loading. This means quite limited warming in the transfer process. But the monitoring of temperature should continue, because longer loading times, hot weather, open containers or interruptions in the cold chain can cause higher temperature increases.

Loading Control Indicator	Result
Average milk before loading	64.8 L
Average milk loaded	64.36 L
Average quantity loss	0.44 L/batch
Overall loading loss	0.0068
Average loading time	18 minutes
Loading rate	3.6 L/min
Average temperature before loading	4.4°C
Average temperature after loading	4.7°C
Average temperature increase	0.3°C

Loading connects the chilling stage with transportation and therefore must maintain both quantity and temperature control. The main risks are spillage, contamination from poorly cleaned equipment, prolonged exposure during transfer, and warming of chilled milk.

Field measurements show an average loading loss of roughly 0.68% and a temperature rise of merely 0.3°C during the observed loading period. Although these losses and temperature changes may seem small, they can result in significant losses when multiplied across large daily milk volumes.

In the loading process consider clean transfer equipment, fast loading, correct quantity measurement, minimum spillage, temperature logging and proper documentation. The maintenance of these controls ensures that the quality achieved during the chilling is maintained during the transportation stage.

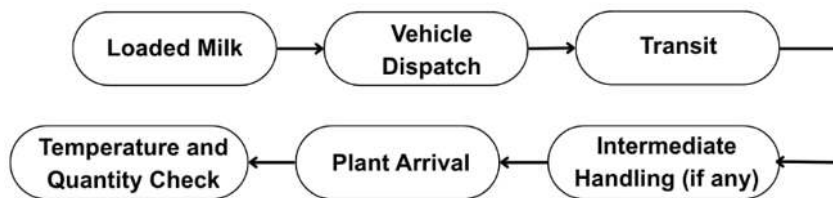
Transportation

Transportation connects collection and chilling centers to dairy processing plants. Milk is highly perishable and the main aim of transport is to move chilled milk quickly, safely and with minimum temperature change and contamination. The efficiency of this stage depends on the means of transport, distance, time of travel, temperature control, road conditions, and handling practices.

Transportation Process

Chilled milk is then transported to the processing plant in milk cans, insulated vehicles, tankers or refrigerated vehicles, as appropriate to the scale and organization of the supply chain. Short distance collection may be by bicycle, rickshaw, motorbike, van, boat or other local transport. Organized dairy processors generally use larger trucks or milk tankers.

The basic transportation sequence is:



The less unnecessary transfer and delays, the less risk of contamination, spillage and temperature deterioration.

Factors Affecting Transportation

The major factors to monitor are:

- **Transport temperature:** Chilled milk should ideally remain around 4°C during transportation.
- **Travel time:** Longer transportation without effective cooling increases bacterial growth.
- **Distance:** Greater distance increases exposure to road delays and temperature changes.
- **Transport method:** Refrigerated or insulated vehicles provide better temperature protection than ordinary vehicles.
- **Road and traffic conditions:** Congestion, poor roads, and seasonal flooding can increase travel time.
- **Container condition:** Containers should be clean, food-grade, covered, and properly sealed.
- **Loading and unloading frequency:** Repeated handling increases contamination and spillage risks.
- **Vehicle hygiene:** Tankers and milk containers must be cleaned and sanitized regularly.
- **Temperature fluctuation:** Temperature should be monitored before departure and at plant arrival.
- **Milk loss:** Leakage and spillage reduce the quantity delivered to the plant.
- **Documentation and traceability:** Quantity, time, temperature, source, and destination should be recorded.

Measurements

Transportation performance can be assessed using several simple measures.

Travel time

Travel time = Arrival time – Departure time

Temperature change

Temperature change = Arrival temperature – Departure temperature

Temperature increase

$$\text{Temperature increase (\%)} = \frac{\text{Temperature change}}{\text{Departure temperature}} \times 100$$

Quantity loss

Quantity loss = Quantity loaded – Quantity received

Transportation loss rate

$$\text{Transportation loss (\%)} = \frac{\text{Quantity loss}}{\text{Quantity loaded}} \times 100$$

On-time delivery rate

$$\text{On-time delivery (\%)} = \frac{\text{Number of trips arriving within target time}}{\text{Total trips}} \times 100$$

These indicators help identify whether transportation is maintaining milk quality and delivering the expected quantity.

Evidence from Bangladesh

The transport system is still a lot fragmented. Organized logistics for industrial processors collect only about 9% of Bangladesh's annual milk production of around 10 million tons, and only about 10% of total milk is stored in some form of cold chain (World Bank, 2025).

The situation is most apparent in the informal milk transport. In a survey of buffalo milk traders, conducted in seven districts, 95% of middlemen were carrying milk without cooling, and 5% with ice. Middlemen's transport time to collection centers varied, with a maximum of eight hours and a median of about one hour. Moreover, 57% of traders used uncovered containers to carry milk (Singha et al., 2023).

Transportation Practices Reported in the Study

Transportation Indicator	Number/Percentage
Middlemen using no cooling	95.0%
Middlemen using ice	5.0%
Middlemen using uncovered containers	57.0%
Maximum reported transport time	8 hours
Median transport time	≈1 hour

Bacterial Quality During Transportation

Transportation problems are also reflected in microbial quality. Reported total bacterial counts increased as milk moved through the supply chain:

Supply-chain point	Mean bacterial count (log ₁₀ CFU/mL)
Farm bulk milk	5.2
Middleman stage	6
Collection centre	6.6
Bangladesh regulatory threshold	4.3

The increase from farm bulk milk to the collection centre can be calculated as:

$$6.6 - 5.2 = 1.4 \log_{10} \text{ CFU/mL}$$

Thus, the bacterial count increased by approximately 1.4 log units across these stages.
Relative to the reported threshold:

$$5.2 - 4.3 = 0.9 \log \text{ units above the threshold at farm level}$$

$$6.6 - 4.3 = 2.3 \log \text{ units above the threshold at the collection-centre stage}$$

This indicates that milk quality is already problematic before transportation and becomes progressively worse as milk passes through additional handling and transport stages.

The main transportation problem is not simply the lack of vehicles; it is the lack of continuous temperature-controlled transportation. The use of ordinary vehicles, uncovered containers, long travel times, and repeated loading and unloading exposes milk to contamination and temperature increase.

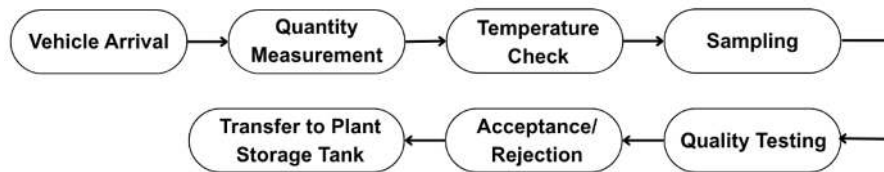
The 1.4-log increase in bacterial count reported from farm bulk milk to the collection center is indicative of the cumulative effect of poor handling and transportation. Therefore, transportation should be designed to maintain cold chain, reduce travel and waiting time, use clean and covered containers, reduce unnecessary transfers, and record milk temperature during journey.

Plant Receiving

Plant receiving is the first point of control when milk arrives by transport at the processing facility. At this stage the plant checks how much milk has arrived, whether it has kept an acceptable quality during transport and whether it can be used for further processing. Where milk does not meet important quality requirements it should be rejected, segregated or diverted, not mixed with acceptable milk.

Plant Receiving Process

The general receiving sequence is:



First, the vehicle is identified and the delivery information is entered. Then the milk is sampled and measured. The quality testing parameters like temperature, appearance, acidity, fat, SNF, microbial or other quality indicators, adulteration etc. will depend upon the testing facilities available in the plant.

When the milk has passed the required tests it is pumped to a chilled storage or processing tank. Rejected milk shall be separated from accepted milk.

Factors Affecting Plant Receiving

The major factors include:

- **Arrival temperature:** Indicates whether the cold chain was maintained during transportation.
- **Receiving time:** Delays at the plant can increase milk holding time.
- **Quantity received:** Should correspond with the quantity recorded at loading.
- **Quantity loss:** Differences may indicate leakage, spillage, or measurement errors.
- **Acidity:** Helps identify deterioration caused by prolonged storage or bacterial activity.
- **Fat and SNF:** Used to assess composition and, in some systems, determine payment.
- **Microbial quality:** Indicates the level of contamination and processing risk.
- **Adulteration:** Added water or other substances can reduce quality and affect processing.
- **Antibiotic residues:** Milk containing prohibited residues should not enter the processing stream.
- **Visual and sensory quality:** Abnormal colour, odour, sediment, or appearance may indicate poor quality.
- **Testing time:** Milk should not remain unnecessarily long before testing and storage.
- **Receiving capacity:** The plant must be able to handle incoming milk without excessive waiting.
- **Traceability:** Each delivery should be linked to its source, quantity, time, temperature, and test results.

Measurements

Several indicators can be used at plant receiving.

Quantity loss

Quantity loss = Quantity loaded – Quantity received

Receiving loss (%)

$$\text{Receiving loss (\%)} = \frac{\text{Quantity loss}}{\text{Quantity loaded}} \times 100$$

Temperature change

Temperature change = Arrival temperature – Loading temperature

Rejection rate

$$\text{Rejection rate (\%)} = \frac{\text{Rejected quantity}}{\text{Total quantity received}} \times 100$$

Acceptance rate

$$\text{Acceptance rate (\%)} = \frac{\text{Accepted quantity}}{\text{Total quantity received}} \times 100$$

Receiving time

Receiving time = Completion of unloading – Vehicle arrival

These measurements help the plant evaluate both milk quality and the efficiency of its receiving operation.

Receiving Infrastructure

Formal dairy processors generally operate structured collection and receiving systems. For example, BRAC's dairy programme operates around 180 rural collection and chilling points, serving more than 35,000 registered farmers and handling approximately 150,000 litres of milk per day. Milk Vita's Baghabarighat facility in Sirajganj has a stated capacity of approximately 135,000 litres per day (BRAC, n.d. PKSF, 2022).

The figures show that receiving operations need to be able to deal with large quantities while maintaining rapid testing, documentation and temperature control.

Selected Receiving-System Capacity Indicators

Indicator	Reported value
BRAC rural collection/chilling points	≈180
Farmers served by BRAC dairy programme	>35,000
BRAC milk handled per day	≈150,000 L/day
Milk Vita Baghabarighat capacity	≈135,000 L/day

The average daily milk handled per registered BRAC farmer can be estimated as:
 $150,000 \div 35,000 \approx 4.29$ L/farmer/day

This illustrates the importance of an efficient aggregation and receiving system when milk is supplied by a large number of small producers.

Quality Testing at Receiving

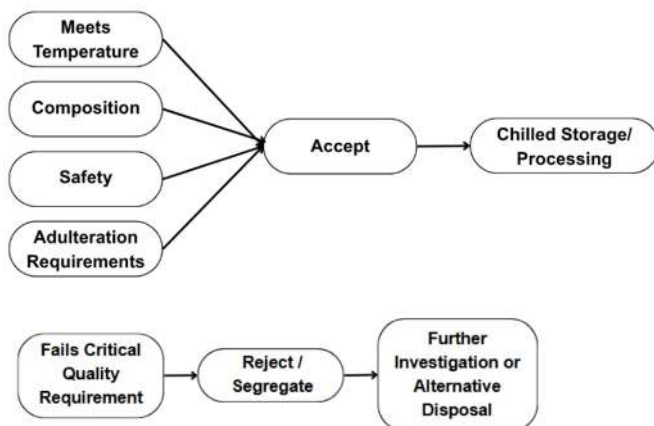
At the plant, the earlier collection-stage quality checks are generally repeated or verified before milk enters the processing stream. Important indicators include:

Quality Indicator	Purpose	General control point
Temperature	Measures cold-chain condition	Around 4°C preferred
Acidity	Indicates freshness/deterioration	Within plant specification
Fat	Measures milk composition	According to product/payment specification
SNF	Measures non-fat solids	According to plant specification
Specific gravity	Helps identify dilution	Normal milk range
Microbial load	Measures contamination	Must meet applicable limit
Adulteration	Identifies added substances	Should be absent
Antibiotic residues	Protects processing and consumers	Should be within permitted limits
Appearance/odour	Identifies obvious defects	Normal milk characteristics

A Bangladesh study of vendor-supplied milk found water adulteration in 68% of rural vendor milk samples and 54% of farm vendor samples, while more than 10% of rural vendor samples were reported positive for formalin (Debnath et al., 2014). Such findings demonstrate why receiving-stage testing is necessary before milk is accepted into a larger processing batch.

Acceptance and Rejection

The receiving stage should follow a simple decision system:



This is particularly important because mixing rejected or contaminated milk with an acceptable batch can reduce the quality of the entire volume.

Plant receiving acts as the final gate before raw milk enters processing. Its effectiveness depends on rapid testing, accurate measurement, sufficient receiving capacity, trained personnel, and proper documentation. The available

evidence suggests that the quality of milk may deteriorate a lot before it reaches the plant. Bacterial counts increased along the supply chain from 5.2 log 10 CFU/mL at farm level to 6.6 log 10 CFU/mL at the collection-centre stage, above the reported regulatory threshold of 4.3 log 10 CFU/mL . Therefore, plant receiving should not be treated as an unloading activity. It should be a point of critical quality control and traceability so that only milk meeting the required standards goes to final quality checking and processing.

Final Quality Check

The last point of control before milk enters processing is final quality check. The milk is checked after chilling and transport to be sure that it still meets the requirements for safety, composition and quality. The important factors are temperature, acidity, fat and SNF , microbial load, adulteration, antibiotic residues, sensory condition and quantity.

Survey-Based Quality Indicators

Indicator	Survey Result	Assessment
Milk temperature before delivery	29.6°C	High; inadequate cooling
Average holding time	48 minutes	Quality-risk period
Positive mastitis screening	12/66 (18.2%)	Significant concern
Abnormal milk observed	7/66 (10.6%)	Quality concern
First-stream examination	6/22 (27.3%)	Low adoption
Milk filtered before delivery	15/22 (68.2%)	Moderate adoption
Containers covered	18/22 (81.8%)	Relatively strong practice

Milk temperature decreased from 31.8°C to 29.6°C, a reduction of:

$$31.8 - 29.6 = 2.2^{\circ}\text{C}$$

The milk therefore remained relatively warm before reaching the next stage, indicating a need for effective chilling before final processing.

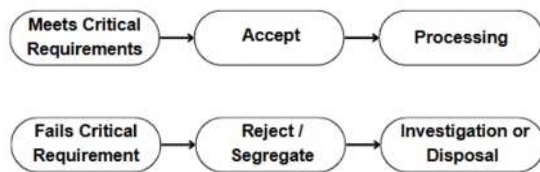
Quality-Risk Calculations

Quality Indicator	Calculation	Result
Mastitis-positive animals	$12/66 \times 100$	18.20%
Abnormal milk	$7/66 \times 100$	10.60%
First streams examined	$6/22 \times 100$	27.30%
First streams not examined	$16/22 \times 100$	72.70%
Milk filtered	$15/22 \times 100$	68.20%
Milk not filtered	$7/22 \times 100$	31.80%
Containers covered	$18/22 \times 100$	81.80%
Containers not covered	$4/22 \times 100$	18.20%

These results show that quality risks are already present before milk reaches final processing, particularly high temperature, mastitis, abnormal milk, and inadequate first-stream examination.

Final QC Findings

At the plant, milk should be assessed using temperature, acidity, fat/SNF, microbial quality, adulteration, antibiotic residues, and sensory condition before acceptance.



The rejection rate can be calculated as:

$$\text{Rejection rate (\%)} = \text{Rejected milk} \div \text{Total milk received} \times 100$$

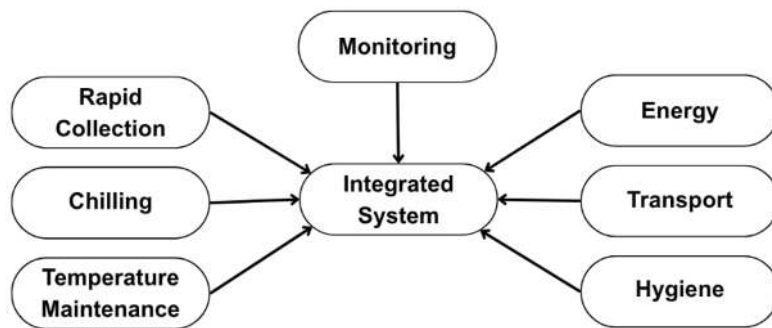
The current survey does not contain plant-level accepted and rejected milk quantities, so the actual rejection rate cannot be calculated from the available data. Final QC therefore acts as the last barrier against poor-quality milk entering processing.

Dairy Cold Chain in Bangladesh

Concept of the Dairy Cold Chain

The dairy cold chain is the temperature-controlled system through which milk is collected, chilled, stored, transported, processed and, where necessary, refrigerated until consumption. Because milk is highly perishable, its quality begins to decline soon after milking. FAO notes that natural antimicrobial protection in fresh milk is temporary and recommends cooling milk to about 4°C as soon as possible to preserve its quality (FAO, 2013).

Therefore, a cold chain is not simply a set of refrigerators. It is an integrated system combining:



The basic principle can be expressed as:

$$\text{Milk quality risk} = f(\text{Time}, \text{Temperature}, \text{Hygiene})$$

Increased time before chilling and higher temperatures increase risk of deterioration. Poor hygiene can introduce contamination that cannot be removed by cooling. Cooling therefore maintains quality, it does not create quality. FAO also highlights that cooling should supplement, not replace, good hygienic handling (FAO, 2013).

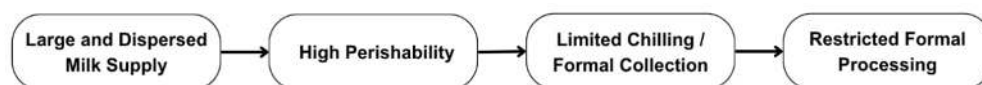
Why Cold Chain Matters in Bangladesh

The dairy sector in Bangladesh is characterized by many small producers, dispersed production and a relatively small formal processing channel. This creates a spatial and functional gap between milk production and organized markets. The 2025 Rajshahi study found that the northern belt was an important production area but that there were problems with partial adoption of cold chains and poor infrastructure (Dhar et al., 2025).

According to the study, only about half of the farms surveyed were using chillers, leaving milk exposed to quality risks during the first-mile movement. It thus recommends village-level chilling centers, insulated transportation and shared cold-storage facilities (Dhar et al, 2025).

Nationally, Bangladesh produces about 10 million tons of milk per year, but only 9% of it is collected by industrial processors, and only about 10% of the milk is stored in cold-chain facilities (Ba & Bhuiyanmishu, 2025), as reported by the World Bank in 2025.

Thus:



Cold-chain development is therefore not only a food-preservation issue. It directly affects market access, processing scale, quality, farmer participation and consumer safety.

Cold Chain as a Value-Creation System

The cold chain creates value by reducing spoilage, allowing milk to be collected from wider areas, supporting aggregation and enabling processors to supply standardized products to distant markets.

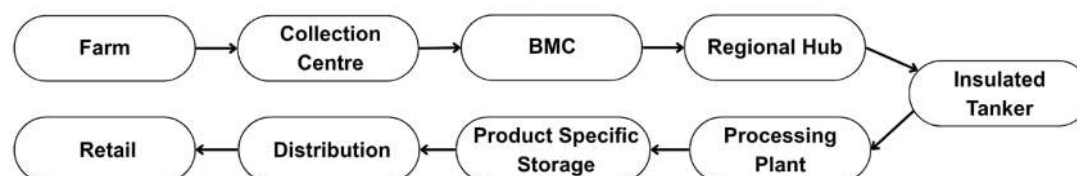
Cold-chain function	Expected benefit
Rapid chilling	Reduces quality deterioration
Aggregation	Combines milk from small producers
Temperature maintenance	Preserves milk during movement
Efficient transport	Connects production areas with processors
Cold storage	Reduces unnecessary product loss
Monitoring	Detects temperature failures
Formal processing	Improves standardization and market reach

However, cold-chain development also creates capital, energy, transport and maintenance costs. Therefore, the objective should not be maximum refrigeration but economically appropriate refrigeration.

This is particularly important because Bangladesh's informal dairy chain remains significant. The formal system may involve collection centres, BMCs, tankers and processing plants, while informal milk can move through much shorter channels. The 2025 Rajshahi study found that retailers remain strongly dependent on distributors and that weak traceability and partial cold-chain adoption continue to limit formalization (Dhar et al., 2025).

Structure, Stages and Measurements

The organized dairy cold chain can be represented as:



The system progressively aggregates milk while controlling time, temperature, hygiene and capacity.

Stage	Main activity	Main measurement
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Farm	Milking and initial handling	Collection time
Collection centre	Receiving, weighing, testing	Volume and quality
BMC	Rapid chilling and storage	Cooling capacity, temperature
Regional hub	Aggregation and temporary storage	Storage capacity
Tanker	Milk transportation	Capacity, travel time, temperature
Processing plant	Testing and processing	Processing capacity
Distribution	Product movement	Temperature and delivery time
Retail	Final storage/sale	Refrigeration and compliance

FAO notes that small producers commonly require collection points because transporting small individual quantities over long distances is often economically difficult.

Farm and First-Mile Collection

The cold chain starts immediately after milking. Milk should be collected quickly and either cooled at the farm or taken rapidly to a suitable collection/chilling centre. FAO recommends minimizing collection delays and cooling milk to approximately 4°C or below as quickly as practical.

Important first-mile measurements are:

Collection time

$$T_{collection} = T_{arrival} - T_{milking}$$

Collection efficiency

$$Collection\ Efficiency = \frac{Milk\ Collected}{Milk\ Available} \times 100$$

For example, if a collection network receives 4,500 L from 5,000 L available:

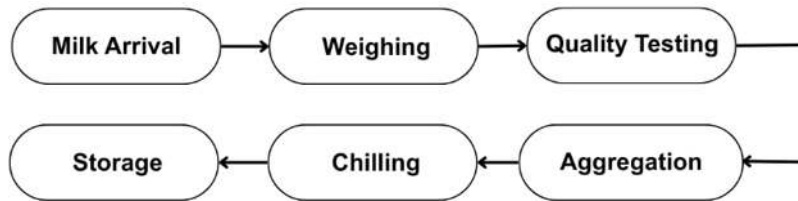
$$\frac{4500}{5000} \times 100 = 90\%$$

The remaining 10% represents milk not entering that collection channel and should be investigated for causes such as distance, spoilage, local sales or collection limitations.

Data from Rajshahi highlight the need for this step, as only half of the surveyed farms reported using chillers, leaving first-mile milk vulnerable before it reaches organized cold-chain facilities (Dhar et al., 2025).

Collection Centre and Bulk Milk Cooler

The collection centre is the first major control point:



A Bulk Milk Cooler (BMC) is normally used to reduce milk temperature rapidly and maintain it until transportation.

Typical facilities include:

- BMC
- weighing equipment
- milk-quality testing equipment
- chilled storage
- pumps and sanitary transfer equipment
- temperature monitoring

The important issue is not the number of BMCs alone, but whether their capacity and location match milk supply.

BMC capacity utilization

$$\text{Capacity Utilization} = \frac{\text{Actual Milk Volume}}{\text{Installed Capacity}} \times 100$$

For example:

BMC capacity	Milk received	Utilization
2,000 L/day	1,600 L/day	80.0%
2,000 L/day	1,000 L/day	50.0%
2,000 L/day	2,200 L/day	110.0%

The first facility is reasonably utilized, the second may be underutilized, while the third indicates a capacity bottleneck.

A simple planning measure is:

$$\text{Required Capacity} = \frac{\text{Peak Milk Volume}}{\text{Target Utilization}}$$

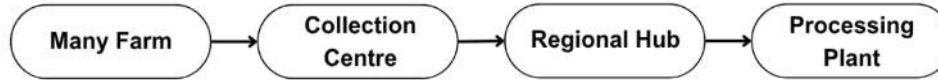
If peak milk volume is 2,400 L/day and the desired utilization is 80%:

$$2400 \times 0.80 = 3000 \text{ L/day}$$

Thus, capacity should be planned around peak demand rather than average volume alone.

Regional Aggregation and Transportation

Milk from several collection centres can be consolidated:



This reduces the number of individual collection points that larger vehicles need to serve. FAO notes that collection and transportation are significant components of milk-processing costs and that poor road access can increase difficulties, particularly during wet seasons (FAO, n.d.).

At the hub-to-plant stage, insulated tankers are appropriate for larger volumes.

Tanker utilization

$$\text{Tanker Utilization} = \frac{\text{Milk Transported}}{\text{Tanker Capacity}} \times 100$$

If a 5,000-L tanker carries 4,000 L:

$$\frac{4000}{5000} \times 100 = 80\%$$

Transport cost per litre

$$\text{Transport Cost per Litre} = \frac{\text{Total Transport Cost}}{\text{Milk Transported}}$$

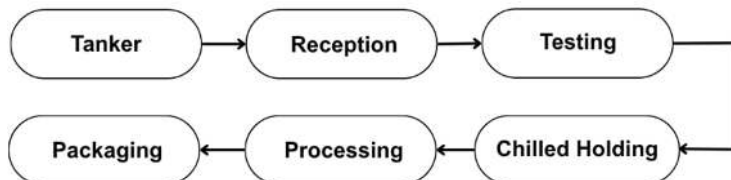
If one trip costs BDT 12,000 and carries 4,000 L:

$$\frac{12000}{4000} = \text{BDT } 3/\text{L}$$

This allows alternative routes, tanker sizes and collection structures to be compared.

Processing Plant

At the processing plant:



The plant receives chilled milk, checks volume and quality, and processes it into products such as pasteurized milk, UHT milk, yoghurt, butter, ghee and milk powder.

The cold-chain requirement after processing depends on the product.

Product	Main post-processing requirement
Pasteurized/fresh milk	Continuous refrigeration
Fresh yoghurt	Refrigerated storage and distribution
UHT milk	Ambient while unopened if aseptically packaged
Milk powder	Generally ambient storage
Ghee	Generally no conventional refrigeration

FAO confirms that pasteurized milk and most fresh dairy products require continued cooling, while UHT milk in aseptic packaging, ghee and milk powder generally do not require the same post-processing refrigeration (FAO, n.d.).

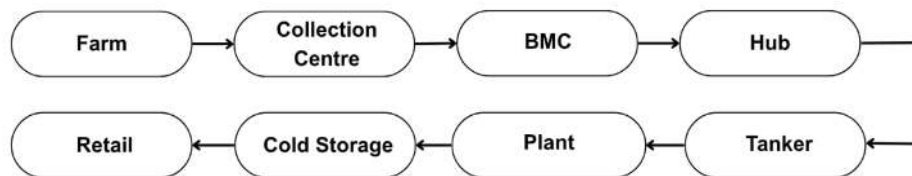
Therefore, not every litre of milk entering a processing plant requires the same downstream cold-chain capacity.

Temperature Measurement

Temperature is one of the most important cold-chain indicators.

For raw milk, FAO guidance identifies approximately 4°C or below as the preferred preservation condition, while specific regulatory or processing requirements may vary by stage and product (FAO, 2013).

Temperature should therefore be measured at:



Temperature compliance

$$\text{Temperature Compliance} = \frac{\text{Observations Within Required Range}}{\text{Total Observations}} \times 100$$

Suppose 92 out of 100 recorded observations meet the required temperature:

$$\frac{92}{100} \times 100 = 92\%$$

The remaining 8% are temperature deviations requiring investigation.

Cold-Chain Loss Measurement

Cold-chain effectiveness can also be measured through losses:

$$\text{Spoilage Rate} = \frac{\text{Milk Spoiled or Rejected}}{\text{Milk Received}} \times 100$$

For example, if 150 L is rejected from 10,000 L:

$$\frac{150}{10000} \times 100 = 1.5\%$$

A reduction in this rate represents a direct improvement in usable milk and economic performance.

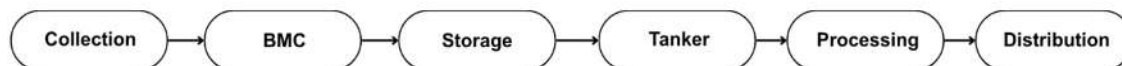
Measurement Framework

The cold chain can therefore be assessed using:



Capacity Adequacy

Cold-chain capacity should be evaluated across:



The central question is:

Can available capacity handle actual and peak milk volumes without excessive delay or temperature deterioration?

Capacity problems can occur in two opposite forms:

Situation	Result
Capacity too low	Congestion, waiting, delayed chilling
Capacity too high	Low utilization and high fixed cost/L
Poor location	Long collection distances
Uneven capacity	Some areas face shortages while others have idle equipment

This is important in Bangladesh because regional production is not evenly distributed. The northern milk belt has strong production advantages, while the Rajshahi study reports that cold-chain adoption remains incomplete despite these advantages (Dhar et al., 2025).

Performance

A good cold chain should achieve five outcomes:

Performance area	Expected outcome
Quality	Milk reaches processing with limited deterioration
Safety	Temperature and hygiene risks are controlled
Reliability	Cooling continues despite operational disruptions
Efficiency	Infrastructure is sufficiently utilized
Economics	Cost per litre remains viable

The overall performance can therefore be represented as:

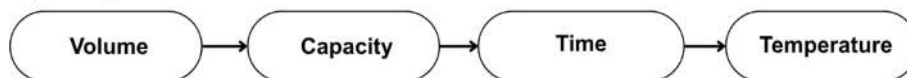


Capacity alone is insufficient. A large BMC that receives milk too late, or a refrigerated tanker that waits several hours before unloading, does not represent an effective cold chain.

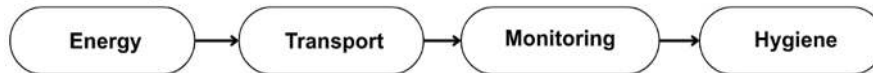
Cold-Chain Assessment Framework

For Bangladesh, the cold chain can finally be evaluated through three connected dimensions:

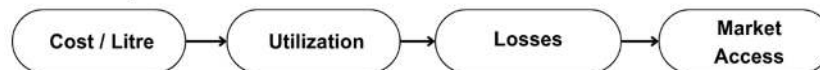
Physical performance



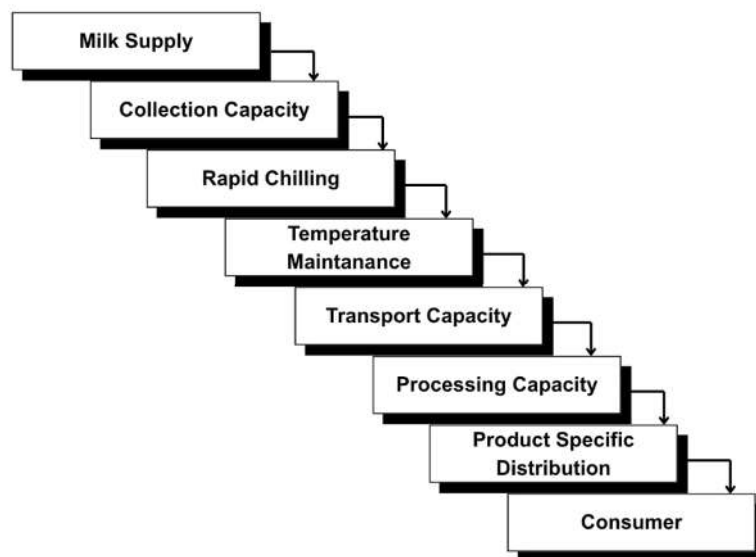
Operational performance



Economic performance



This produces the following framework:



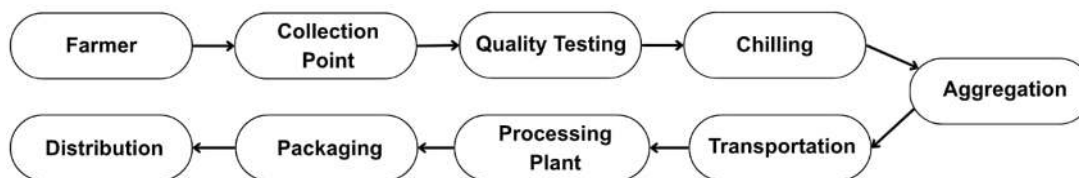
The central issue for Bangladesh is therefore not simply whether more refrigeration is needed. The more important question is whether cold-chain infrastructure is correctly located, appropriately sized, reliably powered, adequately utilized and economically viable. Evidence from Rajshahi shows that partial chilling coverage and weak cold-chain infrastructure remain important limitations even in a major milk-producing region (Dhar et al., 2025).

Processing Capacity and Processing Facilities

Comparison of Processing Capacity and Facilities of Major Dairy Companies in Bangladesh

Processing capacity represents the ability of a dairy company to convert collected raw milk into pasteurized milk, UHT milk and other value-added products within a given period. In Bangladesh, the formal dairy sector has developed from relatively simple collection and pasteurization systems toward more integrated networks combining milk collection centres, chilling facilities, transport, centralized processing plants and distribution systems. However, processing capacity remains substantially larger than actual utilization. A 2022 assessment under the Livestock and Dairy Development Project (LDDP) identified 15 major processing factories with a combined capacity of approximately 1.27 million litres/day, while actual processing was only about 485,000 litres/day, representing roughly 38.1% capacity utilization.

The four major companies examined here, Milk Vita, PRAN Dairy, Aarong Dairy and Akij Dairy, use different organizational structures. Milk Vita operates through a cooperative model, Aarong through a BRAC social-enterprise model, while PRAN and Akij operate as private corporate processors. Their common operational logic is:



The main difference lies in how milk is aggregated and how centralized their processing infrastructure is.

Comparative capacity and facility structure

Company	Organizational structure	Reported milk collection	Processing capacity	Collection/chilling infrastructure	Main processing/products
Milk Vita	Government-supported cooperative	~150,000 L/day in LDDP plant data	~350,000 L/day at Baghabari	Large cooperative network; multiple milk-shed areas and chilling facilities	Pasteurized milk, UHT/value-added dairy, ghee, flavoured products, powder
Aarong Dairy	BRAC social enterprise	~150,000–180,000 L/day in current BRAC sources	Historically ~250,000 L/day in LDDP data	~180 collection/chilling points; centralized Gazipur processing	Pasteurized milk, UHT milk, yoghurt/curd, butter, ghee and other products
PRAN Dairy	Private corporate	~128,000 L/day in the 2024 Dairy Hub case	~200,000 L/day in LDDP data	VMCCs + Dairy Hubs; 103 VMCCs and 5 hubs in LDDP data	Pasteurized/UHT milk and diversified dairy products
Akij Dairy (Farm Fresh)	Private corporate	~70,000–75,000 L/day in 2021 interview	~150,000 L/day in LDDP data	Chilling centres and company-controlled tanker movement	Pasteurized milk, UHT milk, flavoured milk, yoghurt, ghee and powder

The LDDP data provide a useful common comparison because they report the four companies using the same framework: Milk Vita's Baghabari facility had an estimated 350,000 L/day capacity against 150,000 L/day collection, BRAC Dairy had 250,000 L/day capacity against 100,000 L/day collection, PRAN had 200,000 L/day against 70,000 L/day, and Akij had 150,000 L/day against 50,000 L/day at the time of the assessment. These figures are older than some company-specific figures, so they should be interpreted as a comparable structural snapshot rather than current company throughput.

Bangladesh Milk Producers' Co-operative Union Limited (BMPCUL) runs the largest cooperative network in Bangladesh known as Milk Vita. It draws milk from about 40,000 farmers through about 345 primary cooperatives. Of the four companies, the company has the largest processing plant at Baghabari, Sirajganj with a capacity of about 350,000 liters a day. Milk Vita's model is a hybrid of smallholder production and large scale infrastructure with a decentralized collection system but highly centralized processing.

Aarong Dairy uses a more centralized system, collecting milk from over 35,000 farmers through 180 rural chilling points, with daily collection around 150,000–180,000 litres. All milk is transported to its main processing plant in Gazipur. While its plant capacity is moderate, Aarong stands out for its dense collection network, which enables efficient supply from dispersed smallholders. It produces a wide range of products under an ISO 22000-certified system.

PRAN Dairy has been the pioneer in introducing VMCC–Dairy Hub model in Bangladesh. Milk is collected from Village Milk Collection Centers and then pooled at larger Dairy Hubs before being dispatched to the main plant. This system allows a separation between small-scale collection and industrial processing, and does not require farmers to have their own cooling systems. Today, PRAN's hubs collect about 128,000 liters per day and are aiming for 250,000 liters per day.

Akij Dairy (Farm Fresh) has a smaller documented capacity, processing roughly 70,000–75,000 litres per day, though some estimates suggest a higher plant capacity of 150,000 litres per day with lower actual collection. It uses its own tanker fleet to transport chilled milk from collection points to the factory. Products include pasteurized and UHT milk, flavoured milk, yoghurt, and ghee. However, public data on its chilling and processing facilities is limited, making direct comparisons difficult.

Overall comparison

The four companies therefore represent four different levels of network organization rather than simply four different plant sizes.

Dimension	Milk Vita	Aarong	PRAN	Akij
Collection model	Cooperative	BRAC-managed rural network	VMCC–Dairy Hub	Corporate collection
Main strength	Scale cooperative network +	Dense rural network	Structured aggregation	Integrated private operation
Processing scale	Highest	High	High	Comparatively lower
Collection decentralization	Very high	High	Very high	Moderate
Hub-based system	Cooperative milk-shed structure	Collection/chilling → central plant	Strongest hub model	Chilling → plant
Public operational data	Moderate	High	High	Low
Product diversification	High	High	High	High
Main limitation	Large, complex network	High infrastructure requirement	Capacity and network expansion costs	Smaller scale and limited public data

Thus, Milk Vita is strongest in overall processing scale, Aarong in rural collection density, PRAN in structured hub-based aggregation, and Akij in comparatively compact corporate integration. The differences also reflect their institutional origins: cooperative, social-enterprise and private-sector models create different approaches to investment, farmer relationships and infrastructure development.

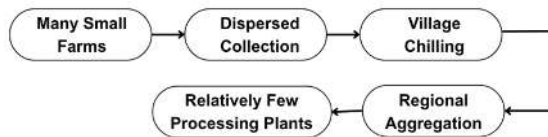
Bangladesh Compared with Global Dairy Processing Systems and Productivity

The major difference between Bangladesh and leading dairy-producing countries is not simply the presence or absence of modern machines. It is the scale, degree of automation, integration and utilization of the entire processing system.

Processing structure

In Bangladesh, over 80% of dairy farms are small, and more than 70% of milk comes from rural smallholders, yet only about 9% of total milk reaches urban markets through formal channels.

This creates a fundamentally different processing structure:



In contrast, developed dairy systems rely on larger commercial farms with highly automated collection and transport. For example, Fonterra's New Zealand network collects about 77 million litres/day during peak season using GPS-routed tankers, on-board testing, and full traceability, illustrating the scale and integration possible in mature systems.

Processing technology and automation

Bangladesh's major companies already use pasteurization, UHT, homogenization, chilled storage, and packaged distribution. The distinction is not "traditional versus modern," but rather partial modernization versus fully integrated industrial automation.

Modern global plants typically integrate: automatic milk reception, online fat/protein standardization, separators, homogenizers, automated pasteurization/UHT, aseptic filling, CIP, digital monitoring, traceability, and energy/water recovery. Tetra Pak's OneStep system, for example, can cut processing time from two days to hours, with potential reductions of 44% in electricity, 35% in water, and 50% in operating costs.

Bangladeshi processors have adopted modern technologies, but the sector lacks full automation and integration. The LDDP notes ongoing constraints: limited technology upgrading, weak food-safety systems, poor packaging, low value addition, and skills shortages.

Scale and plant productivity

The 15 major dairy factories in Bangladesh have a combined capacity of about 1.27 million L/day, but actual processing is only around 485,000 L/day, an overall utilization rate of just 38.1%. The issue is not insufficient capacity, but underutilization due to limited collection, seasonal supply, quality problems, and market constraints.

By contrast, large international plants operate at vastly larger scales:

- Fonterra's Whareroa (New Zealand) processes up to 12.5 million L/day.
- Its Lichfield powder facility handles ~4.4 million L/day.
- Its Darfield line processes ~4.2–4.4 million L/day.
- AmulFed Dairy in India has expanded to ~3 million L/day.
- Bangladesh's largest individual facility, in comparison, is about 350,000 L/day.

Productivity at the milk-production level

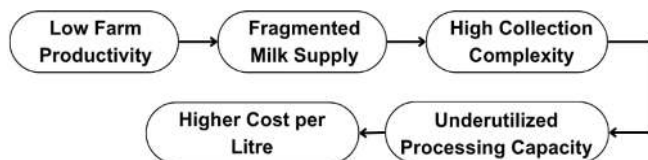
Low farm productivity constrains the entire system. Native Deshi cattle yield ~2–2.5 L/day, while crossbred HF cattle produce ~6–10 L/day. In contrast, EU average yield reached 8,120 kg/cow in 2024, and the US averaged about 11,000 kg/cow.

Productivity indicator	Bangladesh	Developed dairy systems
Typical smallholder milk yield	~2–2.5 L/cow/day	—
Bangladesh commercial/crossbred range	~6–10 L/cow/day	—
EU average apparent yield	—	~8,120 kg/cow/year
US average yield	—	~24,178 lb/cow/year
Large processing plant scale	Hundreds of thousands L/day	Several million L/day
Automation	Increasing but uneven	Highly integrated
Milk collection	Dispersed smallholders	Larger farms + highly organized collection
Digital traceability	Limited/expanding	Extensive in leading systems
Capacity utilization	Major sector estimate ~38%	Generally more commercially optimized
Main constraint	Milk availability and quality	Efficiency, cost, energy and product value

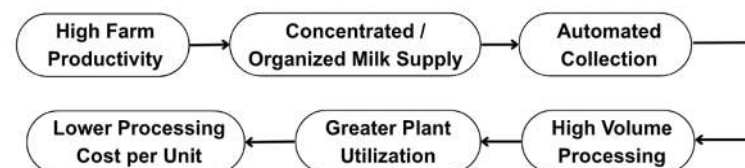
The productivity gap is both upstream and downstream. Low yields reduce industrial milk volume, dispersed production raises collection costs, and installed capacity often exceeds actual throughput. Simply building larger plants would not solve the problem.

Bangladesh has the basic infrastructure for modern dairy processing—collection, chilling, tankers, pasteurization, UHT, packaging, and centralized plants. The main gap lies in scale, automation, integration, and utilization, not in the absence of technology.

The core productivity gap can be summarized as:



In contrast, leading global systems follow:



Therefore, the priority should be improving farmer yields, expanding organized collection and chilling, enhancing milk quality, raising plant utilization, adopting automation and traceability, and developing higher-value products.

Bangladesh does not primarily lack infrastructure; it suffers from a mismatch between installed capacity and the quantity, quality, and regularity of milk entering the formal system. Upstream improvements and better use of existing facilities may offer greater gains than simply adding new plants.

Cost Analysis, Calculations and Price Assumptions

To understand the formation of price of milk in the dairy supply chain cost analysis is required. The final consumer price is not only the value of raw milk but also the cost of collection, transportation, chilling, processing, packaging, storage, distribution, waste, labor, margins and other operating costs. In Bangladesh, the price of packaged one liter milk is now considered to be somewhere around BDT 120-140 per liter. This price range is much higher than the farm-gate price, as costs and margins are added at each stage in the supply chain.

This distinction is particularly important because high farm-level costs can coexist with relatively low farm-gate returns, while distributors and retailers add further costs and margins before the product reaches consumers. Recent evidence from Rajshahi shows that feed represents approximately 55% of farm expenses and that more than 70% of retailers depend on distributors, indicating that cost accumulation and intermediary dependence are important parts of the pricing structure.

The following framework estimates the major cost components on a per-litre basis, allowing different stages of the dairy supply chain to be compared consistently.

Costs and Their Calculations

Milk Collection Cost

Milk collection is the first major post-farm cost. It includes the activities required to receive milk from farmers, measure and test it, aggregate it at collection points, and prepare it for transportation.

Major cost components:

- Collection-centre labour
- Milk cans and containers
- Collection vehicle and fuel
- Weighing and testing
- Loading and unloading
- Collection-centre electricity and utilities
- Cleaning and sanitation
- Equipment maintenance

Formula:

$$\text{Collection Cost/Litre} = \frac{\text{Total Milk Collection Cost}}{\text{Total Litres Collected}}$$

Example: If a collection network spends BDT 30,000 to collect 10,000 litres:

$$\text{Collection Cost/Litre} = \frac{30000}{10000} = \text{BDT } 3.00/\text{L}$$

Collection cost should therefore be evaluated against both volume collected and collection-centre utilization. A centre collecting larger volumes can distribute fixed labour and equipment costs over more litres and consequently achieve a lower cost per litre.

Transportation Cost

Transportation cost represents the cost of moving milk between farms, collection centres, chilling centres, processing plants, distribution hubs and retailers.

Total Transportation Cost = Fixed Cost + Variable Cost

Fixed costs:

- Vehicle depreciation
- Insurance
- Registration and licensing
- Driver salary
- Vehicle financing cost
- Variable costs:
- Fuel
- Lubricants
- Tyres
- Repairs and maintenance
- Tolls
- Loading and unloading

Formula:

$$\text{Transport Cost/Litre} = \frac{\text{Total Transportation Cost}}{\text{Litres Delivered}}$$

Transportation efficiency depends strongly on route length, vehicle utilization, load factor, road conditions and the number of collection stops. Larger and better-utilized milk tankers can reduce the cost per litre, whereas fragmented collection routes increase both fuel consumption and labour requirements.

For the present analysis, transportation cost is assumed to be approximately BDT 4.00–6.00 per litre, depending on distance, fuel prices, route density and vehicle utilization.

Fuel Cost and Fuel Efficiency

Fuel is a major variable cost of dairy transportation. The analysis should consider distance travelled, fuel consumed, fuel price, vehicle capacity, load and route conditions.

Required measurements:

- Total kilometres travelled
- Total litres of fuel consumed
- Fuel price per litre

- Average milk load
- Route distance
- Number of trips

Fuel _____ **efficiency:**

$$\text{Fuel Efficiency} = \frac{\text{Kilometres Travelled}}{\text{Litres of Fuel Consumed}}$$

Fuel _____ **cost:**

$$\text{Fuel Cost} = \text{Fuel Consumed} \times \text{Fuel Price}$$

Fuel _____ **Cost/Litre** _____ **of** _____ **Milk:**

$$\text{Fuel Cost/Litre Milk} = \frac{\text{Total Fuel Cost}}{\text{Litres of Milk Transported}}$$

Example: If a vehicle travels 600 km using 120 litres of fuel:

$$\text{Fuel Efficiency} = \frac{600}{120} = 5 \text{ km/L}$$

If the fuel costs BDT 120/L, total fuel cost is BDT 14,400. If 8,000 litres of milk are transported:

$$\text{Fuel Cost/Litre Milk} = \frac{14,400}{8000} = \text{BDT } 1.80/\text{L}$$

The total transportation cost, including driver wages, maintenance, depreciation and other vehicle costs, may rise to about BDT 4.00-6.00 per liter.

This shows why vehicle utilization and

route optimization are important: the same vehicle can generate a substantially different cost per litre depending on how much milk it carries.

Chilling and Cold-Chain Cost

Raw milk is extremely perishable so cooling is essential. The cold chain is expensive to maintain, including the initial cooling process and the subsequent maintenance of the right temperature conditions during storage and transportation.

Major cost components:

- Electricity
- Bulk Milk Cooler (BMC)
- Refrigeration equipment
- Chilled storage tanks
- Refrigerant
- Labour
- Generator/diesel

- Maintenance
- Cold-storage depreciation
- Temperature-monitoring equipment

Formula:

$$\text{Chilling Cost/Litre} = \frac{\text{Total Chilling and Cold-chain Cost}}{\text{Litres Chilled}}$$

Energy efficiency can additionally be measured as:

$$\text{Energy Consumption/Litre} = \frac{kWh \text{ Consumed}}{\text{Litres Chilled}}$$

and:

$$\text{Energy Cost/Litre} = \frac{\text{Electricity Cost} + \text{Generator/Fuel Cost}}{\text{Litres Chilled}}$$

For the present Bangladesh price structure, the cost of chilling and cold chain is assumed to be around BDT 3.00–5.00 per liter. This range includes electricity, refrigeration, generator use, labor, equipment maintenance and depreciation.

The cost should also account for temperature excursions and the resulting milk loss:

$$\text{Cold-chain Loss Cost} = (\text{Spoiled/Rejected Litres}) \times (\text{Value per Litre})$$

Therefore, a cold-chain system with a higher initial investment may still be economically preferable if it reduces spoilage and operating costs.

Loading and Unloading Cost

Loading and unloading occur at collection centres, chilling facilities, processing plants, distribution hubs and retail points. Although the individual cost may appear small, repeated handling increases total supply-chain cost and creates opportunities for spillage, contamination and container damage.

Cost components:

- Labour
- Loading equipment
- Unloading equipment
- Handling time
- Container damage
- Milk spillage
- Cleaning and sanitation

Formula:

$$\text{Handling Cost/Litre} = \frac{\text{Total Loading and Unloading Cost}}{\text{Total Milk Handled}}$$

For the present analysis, loading and unloading costs are assumed to be approximately BDT 1.00–2.00 per litre.

The number of handling points should therefore be minimized where possible. A shorter supply chain can reduce labour requirements, handling losses and product exposure.

Storage Cost

Storage costs apply to both raw milk and processed dairy products. Raw milk generally requires temperature-controlled storage, while processed products may require cold rooms depending on their characteristics.

Cost components:

- Warehouse/cold-room rent
- Electricity
- Refrigeration
- Labour
- Inventory financing
- Equipment depreciation
- Cleaning and sanitation
- Spoilage and expiry

Formula:

$$\text{Storage Cost/Litre} = \frac{\text{Total Storage Cost}}{\text{Litres Stored}}$$

Storage efficiency can also be assessed through inventory holding time:

$$\text{Holding Time} = (\text{Dispatch Date/Time}) - (\text{Arrival Date/Time})$$

For the prevailing price range, storage cost is estimated to be around BDT 1.50-3.00 per liter. Longer holding times mean higher costs for refrigeration, financing and spoilage. But having a large inventory is no guaranty of better supply security if the extra inventory has a high carrying cost.

Spoilage and Wastage Cost

Milk can be lost through spillage, rejection, contamination, temperature failure, expired products or other operational problems. These losses increase the effective cost of every litre that successfully reaches the consumer.

Loss rate:

$$\text{Loss Rate} = \frac{\text{Milk Lost}}{\text{Milk Entering System}} \times 100$$

Wastage Cost:

$$\text{Wastage Cost} = \text{Lost Litres} \times \text{Value per Litre}$$

A useful additional measure is the effective cost of saleable milk:

$$\text{Effective Cost/Litre} = \frac{\text{Total Supply-chain Cost}}{\text{Saleable Litres}}$$

Example: If 10,000 litres enter the system but only 9,700 litres are sold, all operating costs are effectively recovered from 9,700 litres rather than 10,000 litres. Therefore, reducing wastage can lower the effective cost even without reducing the individual operating expenses.

For the present analysis, wastage and quality-loss costs are assumed to contribute approximately BDT 2.00–4.00 per saleable litre, depending on cold-chain reliability, product returns and retail inventory management.

Processing and Packaging Cost

For packaged pasteurized or UHT milk, processing and packaging represent additional costs between raw milk collection and final distribution.

Processing costs include:

- Pasteurization/UHT processing
- Homogenization
- Quality testing
- Labour
- Water and sanitation
- Electricity and utilities
- Equipment maintenance
- Depreciation
- Packaging costs include:
- Plastic/pouch/carton
- Printing and labelling
- Packaging machinery
- Secondary packaging
- Packaging labour

Formulas:

$$\text{Processing Cost/Litre} = \frac{\text{Total Processing Cost}}{\text{Litres Processed}}$$

$$\text{Packaging Cost/Litre} = \frac{\text{Total Packaging Cost}}{\text{Litres Packaged}}$$

Processing costs are assumed to be around BDT 6.00-10.00 per liter for packaged milk sold at BDT 120-140 per liter and packaging costs are assumed to be around BDT 5.00-9.00 per liter. Such costs are influenced by processing technology, utilization of plant, packaging material, pack size and quality-control requirements.

These costs should be separated from transportation and cold-chain costs because they are influenced by production volume, processing technology, product type and packaging format.

Distribution and Retail Cost

After processing, milk must be distributed to wholesalers, distributors, retailers or company-owned sales outlets.

Distribution costs include:

- Distributor transportation
- Distribution-centre operation
- Sales personnel
- Retail delivery
- Refrigerated display
- Retail electricity
- Retail labour
- Returns and unsold products

Formula:

$$\text{Distribution Cost/Litre} = \frac{\text{Total Distribution Cost}}{\text{Litres Distributed}}$$

For the current Bangladesh market, distribution and retail operating costs are assumed to contribute approximately BDT 8.00–14.00 per litre, excluding distributor and retailer profit margins.

The role of intermediaries is important in Bangladesh. In the Rajshahi study, more than 70% of retailers reportedly sourced through distributors, while 59% could not identify their actual producers. This indicates that intermediary structures can influence both cost accumulation and supply-chain transparency.

Total Supply-Chain Cost

The individual costs can finally be combined to estimate the total cost of delivering one litre of milk.

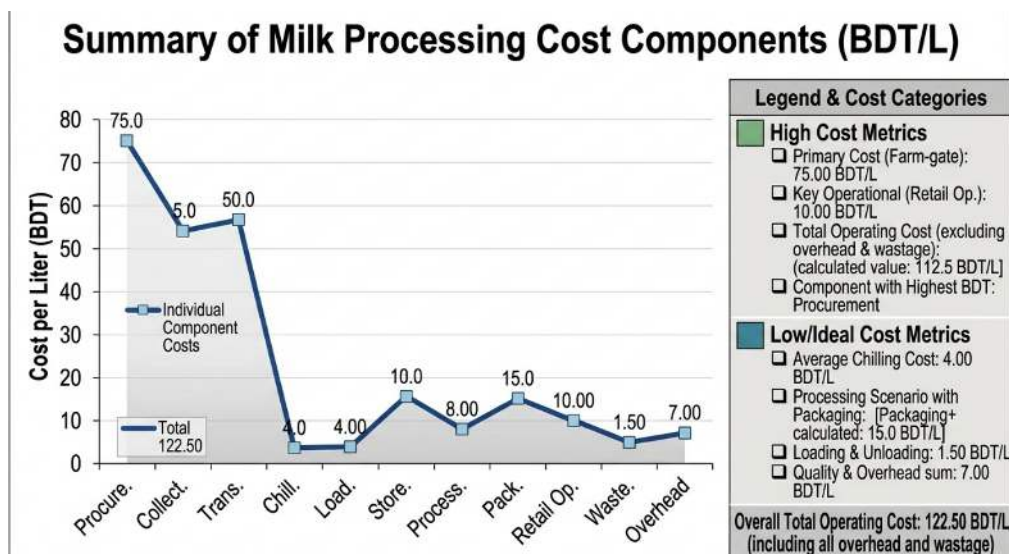
Total Cost/Litre

$$\begin{aligned} &= \text{Raw Milk/Farm-gate Procurement Cost} + \text{Milk Collection Cost} \\ &+ \text{Transportation Cost} + \text{Chilling/Cold-chain Cost} + \text{Handling Cost} \\ &+ \text{Storage Cost} + \text{Wastage Cost} + \text{Processing Cost} + \text{Packaging Cost} \\ &+ \text{Distribution and Retail Operating Cost} + \text{Other Overheads} \end{aligned}$$

Illustrative cost calculation

The following example is an analytical assumption rather than an observed market price. It is designed to correspond with a current retail price of approximately BDT 120-140 per litre.

Cost component	Assumed cost (BDT/L)
Raw milk/farm-gate procurement	75.00
Collection	3.00
Transportation	5.00
Chilling/cold chain	4.00
Loading & unloading	1.50
Storage	2.00
Processing	8.00
Packaging	7.00
Distribution and retail operating cost	10.00
Wastage/quality loss	3.00
Administration & other overhead	4.00
Total operating cost	122.50/L



Thus, under these assumptions, the supply chain requires approximately BDT 122.50 per saleable litre before profit margins. This cost level is consistent with a final consumer price within the current assumed range of BDT 120–

140 per litre, although the exact price depends on company efficiency, product type, packaging format, distribution structure and margin policy.

Price Assumptions

Cost does not automatically equal selling price. Each participant in the dairy supply chain requires a return for performing its function and bearing operating risk. Therefore, the final price can be represented as a combination of farm-gate price + supply-chain costs + intermediary margins + manufacturer margin + retailer margin + applicable taxes/fees.

Farm-Gate Price Assumption

Farm-gate price is the price paid to farmers for raw milk. It should be sufficient to cover the cost of production and a reasonable return.

$$\text{Farm-gate Price} = \text{Farm Production Cost/Litre} + \text{Farmer Margin/Litre}$$

In this analysis, the farm-gate procurement price has been assumed to be around BDT 70-80 per liter with BDT 75 per liter being taken as the central assumption.

Farm production cost should include:

- Feed
- Labour
- Veterinary services
- Medicines
- Housing
- Electricity and water
- Breeding costs
- Farm maintenance
- Animal depreciation
- Farm-level transportation

The Rajshahi evidence suggests that high feed costs are a major constraint, accounting for approximately 55% of total farm expenses, while farmers continue to receive relatively low farm-gate prices. The difference between the farm-gate price and the final retail price demonstrates the importance of examining how value is distributed across the supply chain.

Processor Price Assumption

Once raw milk reaches the processor, the processor adds processing, packaging, quality-control, overhead and profit costs.

$$\begin{aligned} \text{Processor Selling Price} \\ &= \text{Raw Milk Cost} + \text{Processing Costs} + \text{Packaging Costs} + \text{Overheads} \\ &+ \text{Processor Margin} \end{aligned}$$

Using the central assumptions:

Component	Illustrative BDT/L
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Raw milk procurement	75.00
Collection, transport and chilling	12.00
Processing and packaging	15.00
Quality control and overhead	5.00
Estimated processor cost	107.00
Processor margin	5.00–10.00
Indicative processor selling price	112.00–117.00

The processor margin should not be treated as a pure markup on raw milk because it compensates the firm for processing infrastructure, quality assurance, working capital, depreciation and operational risk.

Distributor Price Assumption

If a distributor is involved:

$$\text{Distributor Selling Price} = \text{Purchase Price} + \text{Distribution Cost} + \text{Distributor Margin}$$

For the current market, distributor operating costs are assumed to be approximately BDT 4.00–7.00 per litre, while the distributor margin may be approximately BDT 3.00–6.00 per litre, depending on volume, route density, credit terms and product returns.

The distributor margin should be analysed separately from transportation cost. Otherwise, the analysis may incorrectly classify profit as logistics cost.

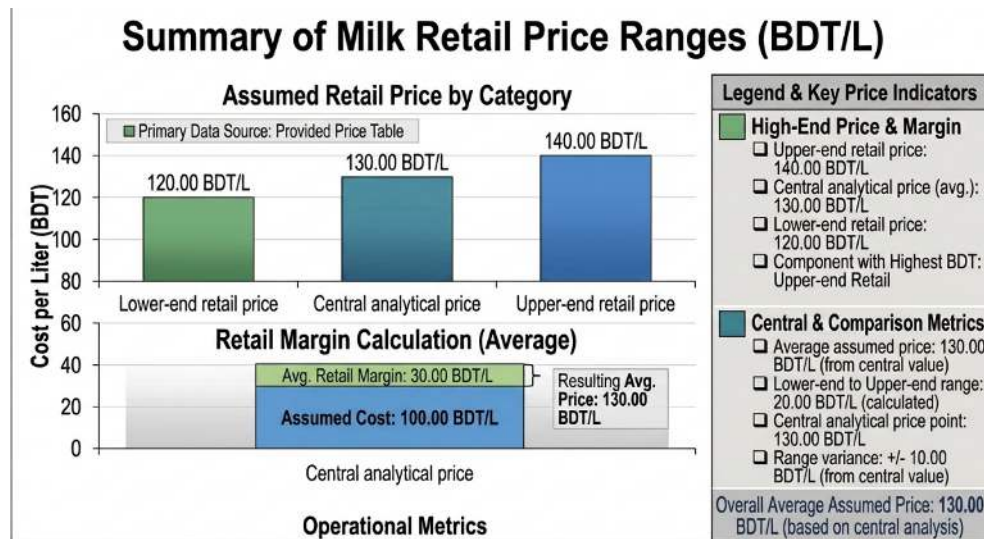
Retail Price Assumption

The final consumer price can then be estimated as:

$$\text{Retail Price} = \text{Distributor Price} + \text{Retail Distribution Cost} + \text{Retailer Margin} + \text{Applicable Taxes/Charges}$$

For the present analysis, the final retail price of one litre of packaged milk is assumed to fall within the following range:

Price category	Assumed price (BDT/L)
Lower-end retail price	120.00
Central analytical price	130.00
Upper-end retail price	140.00



A central retail price of BDT 130 per litre is used for the illustrative price build-up below.

For a vertically integrated dairy company, some intermediary margins may not exist as separate payments. Instead, these costs and returns appear within the firm's internal cost and profit structure.

Illustrative Price Build-Up

Using the illustrative operating cost of BDT 122.50/L, a hypothetical operating and supply-chain margin of approximately 6% would give:

$$\text{Margin} = 122.50 \times 6\% = 7.35$$

$$\text{Indicative Price} = 122.50 + 7.35 = \text{BDT } 129.85/\text{L}$$

The resulting price can therefore be rounded to an assumed central retail price of BDT 130/L.

Stage	Illustrative BDT/L
Total operating cost	122.50
Operating and supply-chain margin (approximately 6%)	7.35
Indicative retail price	129.85
Rounded analytical retail price	130.00/L

The broader assumed retail range is:

Market position	Illustrative retail price (BDT/L)
Lower-cost or promotional product	120.00
Standard packaged milk	125–130
Premium, UHT or higher-cost product	135–140

Key Price Assumptions for the Bangladesh Dairy Market

For the analysis, the following assumptions can be applied:

Variable	Price assumption
Farm-gate price	BDT 70–80/L; central assumption BDT 75/L

Collection cost	BDT 2–4/L; central assumption BDT 3/L
Transport cost	BDT 4–6/L; central assumption BDT 5/L
Chilling cost	BDT 3–5/L; central assumption BDT 4/L
Loading and unloading	BDT 1–2/L; central assumption BDT 1.50/L
Storage cost	BDT 1.50–3/L; central assumption BDT 2/L
Processing cost	BDT 6–10/L; central assumption BDT 8/L
Packaging cost	BDT 5–9/L; central assumption BDT 7/L
Wastage and quality loss	BDT 2–4/L; central assumption BDT 3/L
Distribution and retail operating cost	BDT 8–14/L; central assumption BDT 10/L
Distributor margin	Approximately BDT 3–6/L, depending on channel structure
Retailer margin	Approximately BDT 4–8/L, depending on outlet type and product turnover
Final retail price	BDT 120–140/L; central analytical price BDT 130/L
Inflation	Considered when comparing prices across different periods
Seasonal variation	Higher cost and supply risk may occur during supply disruptions
MRP	Treated as the final consumer-facing price rather than production cost
Profit margin	Applied only after identifying the underlying cost structure

Cost-to-Price Interpretation

The analysis should finally distinguish between cost escalation and price escalation. A higher retail price does not necessarily mean that the farmer receives a proportionally higher return. In Bangladesh, the northern dairy belt has considerable production capacity, yet studies indicate that uniform MRPs, distributor dependence and weak cold-chain infrastructure prevent these regional advantages from being fully reflected in farmer profitability or consumer affordability.

At a current retail price of BDT 120–140 per litre, the farm-gate procurement price of approximately BDT 70–80 per litre represents roughly 50–67% of the final consumer price, depending on the product and market location. The remaining amount covers collection, logistics, chilling, processing, packaging, distribution, retail operations, wastage, overheads and margins.

Therefore, the most useful indicator is not simply the retail price but the cost and margin distribution across the chain:

$$\begin{aligned} \text{Final Price} = & \text{Farm Cost} + \text{Farm Margin} + \text{Collection Cost} + \text{Logistics Cost} + \text{Processing Cost} \\ & + \text{Packaging Cost} + \text{Distribution Cost} + \text{Intermediary Margins} + \text{Retail Margin} \\ & + \text{Taxes/Other Charges} \end{aligned}$$

This framework allows the study to identify where costs are generated, where losses occur, and where margins accumulate. It also provides a basis for comparing different dairy companies and supply-chain structures. A company with a higher retail price may not necessarily have a higher profit; its price may instead reflect greater processing, packaging, quality-control, cold-chain or distribution costs. Conversely, a high price combined with low farmer returns may indicate inefficiency or excessive intermediary margins within the supply chain.

Logistics of the Dairy Supply Chain in Bangladesh

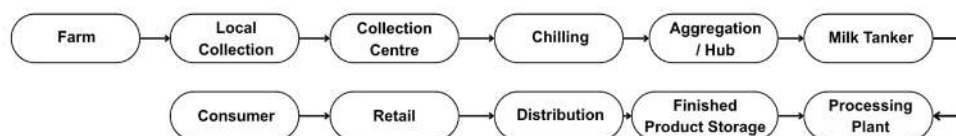
Logistics represents the physical movement, handling, temporary storage and coordination of milk from the point of production to the point of processing and, subsequently, to the market. In dairy supply chains, logistics is particularly critical because milk is highly perishable and its value can decline rapidly when collection, transportation or chilling is delayed. Therefore, dairy logistics is not simply a transportation function; it is a time-, temperature-, volume- and quality-sensitive system.

In Bangladesh, the logistics structure is shaped by dispersed smallholder production, geographically concentrated milk-producing areas, limited formal collection, variable road accessibility and uneven cold-chain infrastructure. The resulting system operates through both informal and organized channels. In the informal channel, farmers may sell directly to consumers, sweet shops or local collectors, while the organized channel generally involves collection centres, chilling facilities, aggregation hubs, tankers, processing plants and formal distribution networks. Evidence from Rajshahi also shows the importance of intermediaries, with retailers frequently depending on distributors and producers having limited visibility in downstream markets.

Logistics Process: From Farm to Market

Logistics Flow

The physical logistics of Bangladesh's organized dairy supply chain can be represented as:



However, this is not the only channel. A substantial informal market operates through a shorter structure:



The distinction is important because the two systems have fundamentally different logistics requirements. The formal system requires greater coordination, chilling, transportation and record keeping, while the informal system minimizes logistics distance and infrastructure requirements. Recent evidence indicates that only around 9% of Bangladesh's milk is collected by industrial processors, while only around 10% benefits from cold-chain storage, demonstrating the relatively limited reach of organized dairy logistics.

Farm-Level Milk Collection

Logistics begins immediately after milking. Milk is collected from individual farms or small farm clusters and moved toward a local collection point.

The first-mile movement may involve:

- Milk cans
- Bicycles
- Motorcycles
- Rickshaws or vans
- Small three-wheelers
- Local transport vehicles

In some locations, boats or other locally appropriate transport

At this stage, distance and time are more important than vehicle sophistication. Because individual smallholders generally produce relatively small quantities, sending refrigerated vehicles to every farm would be economically inefficient. A more practical structure is to aggregate milk from several nearby farms at a common collection point.

Collection Centre and Initial Handling

Milk arriving at the collection centre is typically:

- Received from farmers;
- Measured;
- Sampled and checked;
- Aggregated with milk from other farmers;
- Chilled where facilities are available;
- Temporarily stored;

- Prepared for onward transportation.
- The collection centre therefore acts as the first logistics consolidation point.
- Its efficiency depends on:
 - Milk volume received;
 - Number of farmers served;
 - Collection frequency;
 - Distance from farms;
 - Waiting time;
 - Chilling capacity;
 - Electricity availability;
 - Loading facilities;
 - Availability of transport.

The importance of this stage is demonstrated by the fact that in Rajshahi only 50% of the surveyed farms used chiller machines and the remaining 50% relied on local practices. This highlights the fact that first mile logistics and chilling capacity are still uneven even in a big dairy producing region.

Chilling and Aggregation

After collection, milk should be rapidly cooled and maintained at the required temperature until it reaches the processing facility.

A typical organized sequence is:



The BMC is not only storage. It provides a time cushion between the collection of milk and its transport to the processing plant.

This improves:

- Vehicle utilization;
- Route efficiency;
- Loading efficiency;
- Fuel efficiency;
- Cost per litre;
- Scheduling reliability.

However, aggregation also creates a potential bottleneck. If milk arrives faster than the available chilling capacity can handle, the collection centre itself becomes a source of delay and quality deterioration.

Chilled Transportation to Processing Plant

Once sufficient milk has been aggregated and chilled, it is transported to the processing plant, generally through insulated milk tankers in organized systems.

The basic sequence is:



The major logistics variables are:

- Tanker capacity;
- Milk volume;
- Distance;
- Travel time;
- Road condition;
- Traffic congestion;
- Fuel consumption;
- Loading/unloading time;
- Temperature maintenance;
- Vehicle utilization.

A useful indicator is:

$$\text{Tanker Utilization (\%)} = \frac{\text{Milk Transported}}{\text{Tanker Capacity}} \times 100$$

For example, if a tanker can carry 5,000 litres but transports 4,000 litres, utilization is:

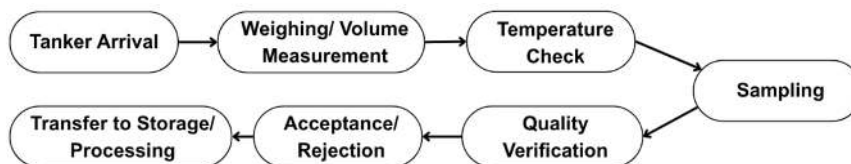
$$\frac{4000}{5000} \times 100 = 80\%$$

Low utilization increases the effective logistics cost per litre because vehicle, driver and fuel costs are spread across a smaller quantity of milk.

Plant Receiving

The processing plant represents the next major logistics control point.

The basic process is:



The quantity received should also be compared with the quantity dispatched.

$$\text{Milk Loss} = \text{Quantity Loaded} - \text{Quantity Received}$$

For example, if 4,000 litres are loaded and 3,960 litres arrive:

$$4,000 - 3,960 = 40 \text{ litres}$$

and:

$$\text{Loss Rate} = \frac{40}{4000} \times 100 = 1\%$$

This apparently small percentage becomes economically significant when applied to thousands or millions of litres.

Finished-Product

Logistics

Logistics vary by product type. Fresh milk moves from processing to cold storage, then via refrigerated distribution to retail and finally the consumer. UHT milk follows a simpler path: aseptic packaging, ambient distribution, and retail. Milk powder and ghee need far less temperature control. As a result, companies focused on fresh milk face a heavier cold-chain burden than those selling UHT or shelf-stable items.

Complete Logistics Model

The entire organized dairy logistics system can therefore be summarized as:



Logistics Costs and Their Calculation

The logistics cost of milk is composed of the expenses required to collect, move, handle, chill and store milk before it reaches the next stage.

A practical cost structure is:

Cost Component	Major Elements
Collection cost	Collector labour, local transport, loading
Transportation cost	Vehicle operation, driver, fuel
Fuel cost	Diesel/petrol/CNG where applicable
Chilling cost	Electricity, refrigeration, backup power
Handling cost	Loading, unloading, pumping, labour
Storage cost	Temporary chilled storage and facility operation
Maintenance cost	Vehicles, BMCs, pumps and refrigeration equipment
Loss/wastage cost	Spoilage, leakage, rejection and deterioration
Delay cost	Waiting, idle vehicles, additional fuel and overtime

The key objective should not be to calculate every cost separately if reliable data are unavailable. Instead, the research can focus on cost per litre, which allows different logistics arrangements to be compared.

Collection Cost per Litre

$$\text{Collection Cost/Litre} = \frac{\text{Total Collection Cost}}{\text{Milk Collected}}$$

Collection cost includes:

- Collection labour;
- Local vehicle operation;
- Fuel;
- Milk cans/containers;
- Loading and unloading;
- Collection-centre operating expenses.

Transportation Cost per Litre

$$\text{Transport Cost/Litre} = \frac{\text{Total Transport Cost}}{\text{Milk Transported}}$$

Total transportation cost may include:

$$\text{Fuel} + \text{Driver} + \text{Maintenance} + \text{Tolls/Ferry} + \text{Other Operating Costs}$$

Distance has a direct effect on cost. Poor roads and congestion further increase fuel consumption and vehicle operating time.

Chilling Cost per Litre

$$\text{Chilling Cost/Litre} = \frac{\text{Electricity} + \text{Backup Fuel} + \text{Maintenance} + \text{Labour}}{\text{Litres Chilled}}$$

This is particularly important in Bangladesh because the economic viability of formal collection depends partly on whether the additional cost of chilling can be justified by improvements in milk quality, shelf life and market access.

Total Logistics Cost

The overall model can be expressed as:

$$TLC = C_{collection} + C_{transport} + C_{fuel} + C_{chilling} + C_{handling} + C_{storage} + C_{maintenance} + C_{wastage} + C_{delay}$$

However, fuel and maintenance may already be included within transportation costs. Therefore, double counting should be avoided when applying the formula to actual company data.

The most useful KPI is:

$$\text{Total Logistics Cost/Litre} = \frac{\text{Total Logistics Cost}}{\text{Saleable Milk}}$$

Using saleable milk rather than simply milk collected is important because spoilage, leakage and rejected milk reduce the quantity over which logistics expenditure is ultimately recovered.

A Simple Bangladesh Illustration

The available Bangladesh evidence shows that logistics quality can deteriorate substantially in informal transportation. In a study of buffalo milk traders across seven districts, 95% of middlemen reportedly transported milk without cooling, only 5% used ice, 57% used uncovered containers, and transportation time reached as high as eight hours.

Suppose, purely as an illustrative calculation, that a logistics operator transports 4,000 litres of milk and incurs total collection, transportation, chilling and handling costs of BDT 20,000:

$$\text{Logistics Cost/Litre} = \frac{20000}{4000} = \text{BDT } 5/\text{Litre}$$

If 2% of the milk becomes unsaleable:

$$4,000 \times 2\% = 80 \text{ litres}$$

Saleable milk becomes:

$$4000 - 80 = 3920 \text{ litres}$$

Therefore, the effective logistics cost becomes:

$$\frac{20000}{3920} = \text{BDT } 5.10/\text{Litre}$$

Thus, even without an increase in nominal logistics expenditure, losses increase the effective logistics cost per saleable litre.

Factors Affecting Dairy Logistics and Their Supply-Chain Effects

Dairy logistics performance in Bangladesh is determined by a combination of physical, operational, economic and institutional factors.

- **Road Infrastructure:** Poor rural roads marked by potholes, narrow lanes, and weak bridges significantly raise travel time, fuel use, and vehicle maintenance, while also increasing breakdowns and collection difficulties. This is especially critical during the first mile, as many farms lie off main roads, leading to higher transport costs and greater quality risks.
- **Traffic Congestion:** Urban congestion causes delays that increase fuel consumption, decrease delivery reliability, extend driver hours and disrupt plant scheduling. The same distance may involve very different logistics costs depending on the traffic conditions.
- **Distance and Route Structure:** Farms, collection points and plants are often far apart, which leads to increased fuel, time, maintenance and temperature exposure. The optimal network does not mean the minimum number of facilities but the minimum total movement cost. The quality of milk is maintained.
- **Milk volume and seasonality:** Milk production varies between farms and seasons. Low volumes mean vehicles are underutilized and the cost per liter is high. Peak periods strain chilling and tanker capacity. The trick is balancing capacity - too little and you have delays, too much and you waste assets.
- **Vehicle capacity and utilization:** The economics of transport depend on how full each trip is, because a tanker that is only partly full will still have similar costs for the driver, fuel and maintenance. Higher utilization means lower cost per liter, assuming bigger loads don't lead to more waiting or handling problems.
- **Temperature and Cold-Chain Reliability:** Temperature control is critical as any break in cooling will affect milk quality. A study in Bangladesh showed an increase in bacterial counts from the farm to the collection center, from 5.2 to 6.6 log₁₀ CFU/mL. Thus, logistics performance has a direct impact on the product quality and salability.
- **Loading and unloading:** Frequent handling raises labor, waiting time, leakage and contamination risks and equipment requirements. A good network should get rid of superfluous movements – the transfer of milk from farm to collection point to hub to plant, rather than from one temporary point to another.
- **Energy Availability:** Chill and refrigerated transport require constant power. We are forced to rely on generators when there are interruptions, which adds cost, causes swings in temperature, leads to spoilage and makes equipment less dependable, particularly in rural areas where electricity is unreliable.
- **Coordination and Information:** The dairy chain is a chain of many players farmers, collectors, transporters, hubs, processors and retailers. Poor coordination results in empty trips, missed schedules, waiting, overstocking, underused chilling and weak traceability such as in Rajshahi study.
- **Seasonal and environmental disruptions:** Routes can be temporarily cut off by floods, monsoons and ferry breakdowns. This leads to collection delays, longer milk holding times, quality loss and increased wastage. Logistics planning needs to consider seasonal reliability rather than average distances only.

Major Logistics Problems and Their Interpretation

Weak Rural Road Infrastructure & Seasonal Accessibility

Poor roads and seasonal flooding slow vehicles, raise costs, and delay chilling. This is a network-access problem: downstream cold-chain investments are wasted if milk can't reach collection points reliably.

Inadequate Cold-Chain Transport & Chilling Capacity

Cold storage improves only 10% of milk and most farms use local methods instead of chillers. The problem isn't sporadic lapses in refrigeration, but the lack of consistent temperature control from farm to plant.

Traffic, Long Routes & Inefficient Route Management

Long distances, congested roads, lack of planning – all add to costs. Better scheduling, consolidation and route optimization can increase utilization without adding vehicles.

Collection, Loading & Handling Delays

Delays occur at various stages – farm, center, loading, transit, hub, unloading, plant. Milk spoils, and that extra time directly affects quality and delivery times.

Weak Logistics Coordination & Information Systems

Bad information flow causes misallocation of vehicles, empty return trips, delays and poor traceability. Digital devices like GPS, route planners and electronic records can improve coordination without reconfiguring the physical chain.

Problem Prioritization Using FMEA

The study can use a simplified Failure Mode and Effects Analysis (FMEA) framework to distinguish the most critical problems from less significant operational issues.

$$RPN = S \times O \times D$$

Where:

Severity (S): How damaging is the problem?

Occurrence (O): How frequently does it occur?

Detectability (D): How difficult is it to detect before damage occurs?

Each factor is scored from 1–10.

A practical prioritization for the five identified problems is:

Problem	Severity (S)	Occurrence (O)	Detectability (D)	RPN
Cold-chain transport & chilling gaps	10	9	8	720
Rural roads & seasonal accessibility	9	9	7	567
Collection/handling delays	8	8	7	448
Route inefficiency & congestion	8	8	6	384
Weak coordination/information	7	7	8	392

These scores should be interpreted as an analytical prioritization rather than measured field scores, unless the research team's interviews provide sufficient observations to justify each numerical rating.

The ranking indicates that cold-chain failure deserves the highest attention because its consequences extend beyond cost into milk quality, spoilage, rejection and food safety.

Economic Impact Layer

FMEA alone does not capture the financial importance of a problem. Therefore, a second layer can estimate:

$$\text{Economic Impact} = \text{Frequency} \times \text{Cost per Incident}$$

For example, if a transport-related delay occurs 10 times per month and each incident creates an estimated BDT 5,000 in additional fuel, labour, waiting and loss costs:

$$10 \times 5,000 = \text{BDT } 50,000/\text{month}$$

This allows the research to distinguish between:

A problem that is severe but rare and a problem that is moderately severe but occurs continuously.

The central logistics problem of Bangladesh's dairy supply chain is not simply a shortage of vehicles or roads. It is the difficulty of coordinating dispersed milk production with collection, chilling, transportation and processing while controlling time, temperature and cost simultaneously.

The evidence illustrates this structural challenge. Bangladesh's formal industrial milk collection remains limited, while informal transportation can involve long travel times, little or no cooling and inadequate containers. In Rajshahi, even among surveyed dairy farms, chilling adoption was divided equally between machine-based chilling and local procedures, while the region's wider supply chain continues to face intermediary dependence and weak traceability.

Therefore, the most important logistics objective should be:

Move the maximum quantity of saleable milk through the shortest reliable route, within the required time and temperature conditions, at the minimum viable cost per litre.

This makes logistics the connecting mechanism between milk production, cold-chain management, processing capacity, food safety and final market availability rather than an isolated transportation activity.

Major Problems in the Dairy Supply Chain of Bangladesh

Despite the growing importance of the dairy sector, several structural and operational problems limit the efficiency, profitability, and sustainability of Bangladesh's dairy supply chain. These problems exist from farm-level production to processing, distribution, and final consumption.

Middlemen and Weak Bargaining Power of Farmers

Farmers often use Ghosh, Farias, suppliers and other middlemen to sell their milk. These intermediaries play an important role in milk collection and transportation, but their strong control of the market may lower farmers' bargaining power and farm-gate prices. Studies also report weak traceability and limited visibility of producers in the current system.

Political Influence and Corruption

Political interference, informal influence and corruption can affect market access, transportation, procurement and regulatory activities. These practices raise transaction costs, create unequal opportunities, and make the supply chain less transparent and efficient.

Weak Marketing and Market Visibility

A lot of the dairy production and smaller farms have little marketing activities and limited direct access to consumers. Producers often have limited visibility as to where their milk ends up and traditional channels are still dominant. In Rajshahi, for example, distributors are a major source of supply for retailers, and only a very small amount of milk is brought to consumers directly from farms.

Unreliable Electricity and Load-Shedding

An uninterrupted power supply is critical for dairy processing and cold-chain operations. Frequent power outages may interfere with chilling, refrigeration, processing, and storage. This raises the probability of milk going bad and the need for backup systems like generators.

Weak Quality Control and Adulteration

Quality control is still a major problem, especially in informal channels of supply. Weak testing, limited traceability and poor monitoring can facilitate adulteration and erode consumer trust. Consumer's major concern is adulteration and most retailers cannot identify the real milk producer as per research in Rajshahi.

Lack of Training and Technical Knowledge

Many small farmers have little access to modern training in animal nutrition, farm management, hygiene, disease prevention, milking techniques and cost management. This reduces productivity and makes it hard for farmers to adopt improved dairy practices.

Limited Machinery and Modern Technology

Small and medium dairy farms do not have modern milking equipment, cooling systems, testing facilities, storage facilities and other machinery. Increased use of appropriate technology could improve productivity, accuracy, quality control and operating efficiency. Research in supply-chain management has also shown that automation and technology can reduce operating costs and increase productivity and accuracy of information.

Poor Breeds and Low Productivity

However, the availability and adoption of high yielding dairy breeds remain limited for many farmers. Low milk yield per cow is a result of poor breeding, low genetic improvement and poor access to good breeding services. This raises the cost per liter and makes farmers less competitive.

Limited Veterinary and Animal Healthcare Services

Farmers may also not have access to modern veterinary services, regular health checks, artificial insemination, disease prevention, and proper reproductive management. Poor health care is a factor that decreases animal productivity and can increase mortality, treatment costs and losses in production.

Environmental and Climate Risks

Floods, excessive heat, drought, water problems, and other environmental changes can affect cattle health, feed availability, milk production, and transportation. Climate-related disruptions can therefore affect several stages of the supply chain at the same time.

Interpretation

All these problems are interrelated, not separate. The efficiency of the dairy supply chain is affected by high feed and production costs, the weak bargaining power of farmers, dependence on intermediaries, poor infrastructure, unreliable energy, limited technology, poor quality control and a lack of technical support. The result is a system in which farmers earn relatively little, processors and retailers have a harder time doing business, and consumers pay more and worry about quality. Evidence from Rajshahi also points to some systemic weaknesses including high cost of production on farms, low farmgate prices, weak cold-chain infrastructure, poor traceability, and limited visibility for producers.

Therefore, improving Bangladesh's dairy supply chain requires a coordinated approach involving fairer farmer pricing, stronger cooperatives, better infrastructure and cold-chain facilities, reliable electricity, improved veterinary and breeding services, farmer training, modern machinery, stronger quality monitoring, and more transparent marketing and distribution systems.

Recommendations

Based on the findings of this study and the research questions, improving Bangladesh's dairy supply chain requires coordinated improvements from farm-level production to final distribution. The following measures are recommended.

- **Strengthen farmer bargaining power and reduce unnecessary intermediary dependence.**
To solve the research question on the major challenges faced by dairy farmers, farmers should be encouraged to join cooperatives, producer groups and direct collection systems. Dairy companies can set up more direct buying links with farmers and provide transparent pricing on milk quality, fat, SNF and volume. This can bring down the excessive dependence on intermediaries like Ghosh, Farias and also increase the share of farmers in the final value.
- **Improve milk collection and cold-chain infrastructure.**
Setting up of village level collection and chilling centers in major milk producing areas for efficiency in milk collection and distribution. Bulk milk coolers should be used more efficiently and insulated vehicles should be used for transportation. The collection schedules and the transportation routes should be organized so as to minimize waiting time, unnecessary handling, fuel consumption and deterioration in quality. The right way to invest in cold chains is not to increase refrigeration capacity but to focus on the right capacity, right location and right technology.
- **Ensure reliable electricity and energy-efficient cooling.**
Frequent load shedding, a major infrastructure-related challenge to milk preservation and processing, needs to be addressed with appropriate backup power systems at collection centers and processing facilities. Solar assisted and energy efficient cooling technologies can also be considered, in particular in rural areas where electricity reliability is weak. Energy efficiency is important as the high cooling costs may add to the final cost of milk.
- **Strengthen quality control throughout the supply chain.**
To address the research question on the quality and safety of milk, quality testing should begin at the farm and collection phase and not only at the processing plant. Before the aggregation of milk, essential tests for temperature, acidity, fat, SNF, adulteration and visible abnormalities should be carried out. Also,

strengthening the microbial quality and antibiotic residue testing at processing facilities should be possible. Each batch of milk should be properly recorded with farmer, quantity, time of collection, temperature and results of quality. This would enhance traceability and reduce the risk of adulterated or low quality milk entering the formal chain.

- **Improve farmer training and technical knowledge.**
Regular training on hygienic milking, animal nutrition, feed management, disease prevention, farm management, milk handling, record keeping and cost control should be provided for the improvement of farm level productivity and management. Training should be practical and accessible to small farmers, not only large commercial farms.
- **Improve cattle breeds, breeding services, and animal healthcare.**
To increase milk productivity and overcome constraints related to production, access to high yielding and locally adapted dairy breeds should be improved through better breeding programs, artificial insemination, veterinary services, vaccination, disease prevention and reproductive management. But genetics alone cannot raise productivity and breed improvement must be coupled with correct nutrition, health care, housing and farm management.
- **Increase access to appropriate machinery and technology.**
Small and medium dairy farms should be promoted to adopt suitable milking equipment, milk-testing devices, cooling, storage and digital record-keeping equipment for improving production, collection and processing efficiency. Technology adoption should be based on the size and economic capacity of the farms. Automation should help human workers, not try to eliminate all human involvement.
- **Improve transportation and route efficiency.**
The transportation planning should be based on collection volume, distance, road condition, vehicle capacity and delivery time to reduce logistics costs and improve movement of milk through the supply chain. The cost of transportation can be reduced by better utilization of vehicles and optimization of routes. Where appropriate, simple transportation optimization techniques could be used to identify less costly routes and more efficient use of the vehicles available.
- **Increase market visibility and transparency.**
To reduce information gaps and improve market access, farmers need more and better information on market prices, demand, collection points and conditions of purchase. Digital platforms and organized groups of producers can facilitate better flow of information. Also, dairy firms should improve the traceability of products so consumers can more easily trace the source and quality of milk.
- **Strengthen government monitoring and coordination.**
Government agencies should strengthen monitoring of milk quality, adulteration, market practices and unfair practices by intermediaries to address the broader institutional and supply-chain issues raised in this study. Policies should also foster rural infrastructure, reliable power supply, veterinary services, farmer training and affordable dairy technology. The problems identified in this study are linked and require more coordination among government agencies, dairy processors, farmer organizations and private sector companies.

Finally, the results imply that Bangladesh should not try to immediately formalize the entire dairy sector by employing expensive infrastructure. Investment should be focused first on high production areas and on those points in the supply chain where improvements will yield the biggest benefits in quality, cost, farmer income and market access. The main objective should be to get the maximum quantity of marketable milk through a reliable chain, at the right time, temperature, hygiene and cost conditions.

Study Limitations

This study has several limitations that should be considered when interpreting its findings. First, the primary data were collected through semi-structured interviews with 22 dairy farmers from different areas of Bangladesh. Although the interviews provided detailed information about farmers' experiences, the sample is relatively small compared with the size and geographical diversity of the national dairy sector. Therefore, the findings should not be considered statistically representative of all dairy farmers in Bangladesh.

Second, the study combines primary farmer-level information with secondary data from research papers, government publications, institutional reports, and industry sources. Differences in data sources, years, definitions, and measurement methods mean that some national and company-level figures may not be directly comparable.

Third, the study focuses strongly on the farmer, logistics, processing, cold-chain, and quality-control perspectives. Direct primary data from processors, distributors, retailers, and consumers were more limited. Therefore, some downstream supply-chain issues are interpreted mainly through secondary evidence rather than extensive primary interviews.

Fourth, some information on major dairy companies' processing capacity, collection systems, technology and operational performance is from publicly available sources. The availability of company-level operational data varies and is not always publicly disclosed, which limits the accuracy of direct comparisons between PRAN, Aarong Dairy, Akij, and Milk Vita.

Fifth, the quantitative analysis mainly uses the descriptive statistics, percentage calculation, comparison and basic cost and logistics calculation. The study does not employ advanced econometric, optimization or causal models. The research thus points to key relationships and operational challenges but does not statistically prove the cause-effect relationship of individual factors and overall performance of supply chain.

Finally, the dairy supply chain is affected by seasonal production, feed prices, electricity availability, weather conditions, transportation conditions, and market prices. These factors can change over time.

Consequently, the findings represent the conditions and information available during the study period and should be supplemented by larger and longitudinal studies in the future.

Conclusion

The present study focused on the dairy supply chain of Bangladesh from farm level production to collection, quality control, chilling, transportation, processing, distribution and final consumption. The results show that the main vulnerabilities of this sector are not concentrated in a particular phase. The problems at different stages, instead, are interrelated and jointly affect milk quality, supply-chain cost, farmer profitability, consumer safety and overall efficiency.

Farmers face high costs of feed and health care, low productivity, lack of access to improved breeds, low technical knowledge, limited access to machinery and veterinary support at the production level. Farmers have little power to negotiate and often rely on intermediaries to sell their milk. These conditions can depress farm-gate returns and increase the gap between the price received by farmers and the price paid by consumers.

A second major weakness is logistics and cold chain management. Milk is highly perishable and must be collected, cooled, transported and processed rapidly. But the risk of quality deterioration and additional costs is a concern with uneven access to chilling facilities, unreliable electricity, bad roads, transportation delays, inefficient routes, and limited refrigerated infrastructure. The analysis therefore shows that developing the cold chain is not simply about putting in more equipment, but rather about designing the right capacity in the right places and ensuring it is used properly.

The processing analysis also shows that Bangladesh already has modern dairy processing facilities among major companies, including pasteurization, UHT processing, homogenization, chilled storage, packaging, and diversified dairy-product production. However, the larger challenge is the integration and utilization of the complete supply-chain system. Large processing capacity cannot deliver its full benefit when milk collection, quality, cold-chain infrastructure, market access, and upstream production remain constrained.

Quality control is another major issue. Poor hygiene, inadequate testing, adulteration, weak traceability and insufficient monitoring can compromise milk safety and acceptability. Quality is thus to be controlled from the point of milking, rather than being a matter of final processing stage.

Finally, the study suggests that a system-wide approach, instead of isolated interventions, is needed to improve the dairy supply chain in Bangladesh. We should together build up stronger farmer organizations, fairer pricing, efficient collection, reliable cold-chain infrastructure, better transportation, improved processing utilization,

stronger quality control, farmer training, modern technology, better breeding and healthcare and transparent market information.

The central lesson is that Bangladesh does not only need to produce more milk; it needs to move, preserve, process, and distribute existing milk more efficiently and safely. A more coordinated supply chain can reduce avoidable costs and losses, improve farmer profitability, strengthen consumer confidence, and increase the availability of safe dairy products. The long-term objective should therefore be to create a dairy supply chain that is efficient, transparent, safe, technologically capable, and economically sustainable for both producers and consumers.

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