

Research Article

Unveiling the Chilled Meat and Milk Demand: Exploring Behavioral Hurdles in Embracing Cold Chain Solutions within Bangladesh's Livestock Sector

Sheikh Mohammad Fakhurul Islam^{1,*} , Sarker Mohammad Rajiur Rahman¹ ,
Siddika Bhuiyanmishu² 

¹International Resource Group Development Services Ltd (IRGDSL)-World Bank Project on Cool Chain Solution for Livestock Value Chain in Bangladesh, Dhaka, Bangladesh

²World Bank, Washington, United States of America

Abstract

This study examines the behavioral barriers to adopting cold chain solutions in Bangladesh's livestock value chains. It aims to identify challenges related to frozen livestock product consumption and cold chain investment, while suggesting potential solutions. Using primary data from Key Informant Interviews (KIIs) and secondary sources, the study finds that cultural, economic, and socio-political factors contribute to negative perceptions of chilled and frozen milk and meat, particularly among lower-income groups who prefer fresh products due to perceived nutritional value. Urbanization, however, is driving demand for chilled and frozen options among middle- to high-income consumers. Consumer decisions are influenced by factors such as nutritional value, taste, price, availability, hygiene, packaging, and branding. Traditional practices, which prioritize immediate sales, deter butchers from investing in cold chain solutions. However, some butchers are open to adopting modern technologies if supported by government and financing. Traditional sweet meat producers primarily use milk to make sweets, yogurt, and fermented products, highlighting the need for support to modernize their businesses with cooling facilities. Challenges in the informal livestock sector, such as poor hygiene and limited cooling facilities, restrict the market for chilled and frozen food products. In contrast, the formal sector, including supermarkets and processing plants, has showcased successful cold chain models. To address these issues, the study recommends investing in energy-efficient refrigeration, improving inventory management practices, and implementing awareness campaigns. Collaborative efforts among the government, financial institutions, and industry stakeholders—along with policy reforms, financial incentives, and capacity-building initiatives—are essential for creating an enabling environment for cold chain infrastructure. Ultimately, addressing these barriers can enhance food safety, reduce waste, and increase the sustainability of Bangladesh's meat and milk industries.

Keywords

Chilled Livestock Products, Consumer Behavior, Influencing Factors, Investment

*Corresponding author: smfakhruli@gmail.com (Sheikh Mohammad Fakhurul Islam)

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1. Introduction

The agricultural sector in Bangladesh, which includes crops, forestry, fisheries, and livestock, plays a vital role in the nation's economy. It significantly contributes to GDP and employs nearly 40% of the labor force. Additionally, it provides essential raw materials for agro-based industries, establishing agriculture as one of the core drivers of Bangladesh's economic growth. Over the past few decades, Bangladesh's agriculture has made remarkable progress in both production and diversification, shifting toward high-value crops and non-crop activities. This structural transformation has enabled the country to achieve self-sufficiency in food grain production. However, despite these advancements, the country has yet to meet its animal protein production targets.

Within the broader agricultural sector, the livestock sub-sector has expanded significantly relative to crops, fisheries, and forestry. The contribution of livestock to agricultural income rose from 7.6% in 1973–74 to 19.9% in 2020, and it now employs approximately 14% of the workforce, accounting for around one-third of all agricultural jobs [22]. This growth has been driven by increasing income levels, population growth, and rapid urbanization, all of which are contributing to higher demand for livestock products. Consequently, Bangladesh has achieved self-sufficiency in meat and egg production and has made notable progress in milk production. However, while food security for livestock products has improved, food safety remains a major challenge. It poses risks to public health and limits the expansion of Bangladesh's livestock product market both domestically and internationally. Studies by [23, 18] highlight significant food safety risks in Bangladesh.

Freezing and cooling technologies are among the most effective long-term preservation methods, ensuring high-quality, safe, and nutritious foods with extended shelf lives. For small producers in developing countries like Bangladesh, these technologies also offer a way to add value to their products in competitive markets [11]. In the livestock value chain, cooling practices are essential for maintaining product quality and supporting sustainable business models. As climate change increases temperatures, the demand for cooling solutions will rise. However, these devices require substantial energy and can leak refrigerants, contributing to global warming and exacerbating environmental challenges. Addressing these issues with affordable, efficient, and sustainable cold chain solutions is critical to unlocking the full potential of Bangladesh's livestock sector. The current lack of a robust cold chain infrastructure in Bangladesh presents a major constraint, leading to reduced economic growth, limited market connections between rural producers and urban consumers, restricted product diversification, decreased access to nutrient-dense animal foods, increased food waste, and food safety risks.

Bangladesh's emerging cold chain and refrigeration sectors offer promising opportunities for preserving perishable foods, such as milk and meat products. However, smallholder live-

stock producers, who form the backbone of the livestock value chain, face several barriers, including limited market access, inadequate transportation and storage, insufficient capital, and a lack of cold chain infrastructure. To improve efficiency in the informal sector, the development of Farmer Producer Organizations (FPOs) or similar collaborative models could be key. These organizations would help smallholders access cooling technologies, leading to increased efficiency and reduced post-harvest losses. Additionally, establishing an effective transportation network with integrated cold chain systems is crucial for reducing spoilage and preserving the nutritional value and freshness of milk and meat as they move from farms to consumers.

Existing policies and government initiatives, including tax incentives, subsidies, and partnerships with international organizations, aim to boost investment in cold storage facilities and strengthen infrastructure and logistics for maintaining the quality and safety of perishable products. These efforts are supported by regulatory bodies such as the Department of Livestock Services (DLS) and the Local Government Division, which are responsible for establishing slaughterhouse standards and inspection systems [19]. Addressing the predominantly informal nature of Bangladesh's milk and meat market, where consumers are accustomed to purchasing raw products, will require a shift toward safer, chilled alternatives. A recent UNIDO study identified the lack of cooling practices at various stages of the milk and meat value chains as a major contributor to unsafe food. Therefore, addressing these challenges and integrating cold chain solutions into livestock value chains is crucial for realizing Bangladesh's vision of development by the year 2041.

This study aims to identify the behavioral barriers consumers face regarding cold chain adoption within Bangladesh's livestock value chains. It seeks to pinpoint obstacles to the consumption of chilled and frozen livestock products, examine challenges to investing in cold chain infrastructure, and propose practical solutions to support the sector's adoption of cold chain practices. Addressing these challenges will help Bangladesh strengthen food safety standards, improve the quality and sustainability of its livestock products, and drive economic growth within the sector.

2. Methodology

This study employed a mixed-method approach, utilizing both primary and secondary data sources to gain a comprehensive understanding of the barriers to cold chain adoption within Bangladesh's livestock value chains. Primary data collection involved Key Informant Interviews (KIIs) with carefully selected stakeholders across three primary value chains:

Beef Meat Value Chain – Including beef fattening farmers, butcher shop owners, and representatives from formal meat

markets and private chain stores.

Poultry Meat Value Chain – Covering broiler farmers, Sonali chicken farmers, live bird market (wet market) vendors, and further processors.

Milk Value Chain – Involving dairy cattle farmers, chilling centers, milk collectors, and sweetmeat shop owners.

Additionally, interviews were conducted with professional experts and consumers within each value chain to provide further insights.

To ensure data quality, tailored checklists were developed for each stakeholder group. These checklists were refined with feedback from World Bank (WB) officials, followed by expert consultations and field tests to validate their effectiveness. Field visits and Key Informant Interviews (KIIs) were conducted in key districts of Bangladesh, including Dhaka, Manikganj, Gazipur, Sirajganj, Rangpur, and Chattogram, between February 28 to March 20, 2024. These districts were chosen for their strategic importance in livestock production and distribution. In each district, one market was purposively selected to gather insights, ensuring a focused and representative understanding of the livestock value chain in these critical regions. The selection criteria for respondents participating in the Key Informant Interviews (KIIs) were designed to encompass five distinct categories of stakeholders within the livestock value chain. These categories include: (1) Milk and Meat Consumers, (2) Livestock Producers, (3) Officials from the Department of Livestock Services, (4) Private Sector Market Actors and (6) Cooling Equipment Providers. The distribution of respondents was carefully structured to ensure diverse and representative insights from each category. The breakdown is as follows: (1) Consumers: 25 respondents, (2) Livestock Producers: 20 respondents, (3) DLS Officials: 3 respondents, (4) Private Sector Market Actors: 20 respondents and (5) Cooling Equipment Providers: 5 respondents.

In addition to primary data, secondary data sources were reviewed to contextualize the findings within existing literature and provide a well-rounded analysis. Qualitative analysis was primarily used to identify and understand the behavioral barriers to cold chain adoption in Bangladesh's livestock value chains, enabling a nuanced exploration of the cultural, economic, and logistical challenges faced by various stakeholders.

3. Results and Discussion

3.1. Understanding Consumption Patterns at the Household Level

According to [27], their study on food intake frequency in Dhaka city revealed notable consumption patterns across different income groups. Pulses and vegetables were the most frequently consumed protein-rich foods, with households consuming them an average of 20 and 18 days per month, respectively. Animal protein-rich foods like eggs, small fish,

and liquid milk followed this trend, suggesting a preference for plant-based proteins. The study also highlighted a significant income-based disparity in consumption, with middle- and high-income households consuming protein-rich items more frequently than lower-income households. As income levels rise, the frequency of consumption of eggs, liquid milk, and chicken also increases, indicating a clear correlation between income and dietary preferences [21]. In a current field study at Protein House, a leading broiler shop in Rangpur City, approximately 9% of dressed chicken was sold daily, reflecting a growing demand for chilled dressed broiler meat. This demand reduces processing time for cutting the chicken into smaller portions, catering to the busy schedules of medical students and other consumers. Customers also value the option to select specific cuts of meat, providing a customized culinary experience tailored to individual preference.

The data from the current field study in Dhaka and Chattogram cities reveals notable consumption trends relative to income levels. In Dhaka, a family of seven members in the upper-middle-income bracket consumes 15 kg of chicken, 5 kg of beef, and 45 liters of milk monthly, primarily sourcing meat from local wet markets. In Chattogram, a middle-income family of six members consumes 10 kg of chicken, 5 kg of beef, and 30 liters of milk, procuring meat similarly from nearby wet markets but opting for home-delivered fresh milk. In contrast, a high-income or upper-middle-income family of four members in Chattogram shows higher consumption, with 20 kg of chicken, 6 kg of beef, and 30 liters of milk, sourced from supermarkets.

This data underscores a positive correlation between income levels and meat consumption, particularly chicken. It also highlights the impact of access to different sources of meat and milk—such as wet markets, supermarkets, or home delivery services—reflecting varying levels of affordability and convenience. These findings illustrate not only the economic factors influencing consumption but also the role of accessibility and lifestyle preferences in shaping food choices. According to [21], 41% of households purchase from mobile door-to-door vendors, while middle- and high-income households primarily buy from supermarkets.

3.2. Rising Demand for Chilled/Frozen Meat and Milk: A Shift in Consumer Preferences

Bangladesh has made significant progress in meat production, achieving self-sufficiency as per government reports. Over the past decade, meat production has increased by 4.65 times, reaching 9.27 million metric tons in FY 2021-2022, with per capita availability rising to 147.84 grams per day. However, the majority of meat—both red and white—is still sold in raw, fresh forms. According to a 2021 report by KOK, an average butcher in Dhaka sells about 8,525 kilograms of beef annually, with over 97% of it sold fresh on the day of slaughter. In contrast, formal chain stores are increasingly offering chilled meat products that meet quality standards. For

instance, Bengal Meat's outlet in Dhanmondi reported in Key Informant Interviews (KIIs) that daily frozen meat sales include 40-50 kg of chicken, 3-4 kg of mutton, 45 kg of beef, and 8-10 kg of processed meat products. The outlet manager noted a 10% annual growth in frozen meat demand over the past five years, attributing this increase to consumer perceptions of better quality and hygiene. Weekly sales of chilled/frozen meat across 80 outlets average approximately 7.3 tons (Figure 1). Similarly, Shwapno, another major retailer, has also seen a steady rise in frozen meat demand.

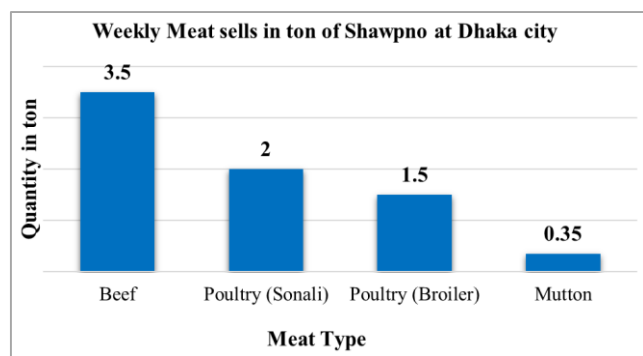


Figure 1. Average weekly sales of chilled/frozen meat in 80 outlets of SHWAPNO at Dhaka city (Source: KII with SHWAPNO).

The poultry sector has seen significant growth in formal slaughtering and processing. Ferdous [8] reported that nine companies with established slaughterhouses process approximately 50,000 birds daily. Large supermarkets in Dhaka and smaller ones in Chattogram sell around 4,000 kg and 73 kg of dressed poultry meat per day, respectively, which accounts for less than 1% of Bangladesh's total daily poultry production (DLS), [6]. This trend reflects a modest but emerging shift towards chilled and processed poultry options in urban areas.

Demand for milk has steadily increased, reaching 15.66 million metric tons in FY 2021-2022, while domestic production stood at 13.07 million metric tons, a significant rise from FY 2010-2011. The milk market in Bangladesh comprises both traditional raw milk and commercial chilled and processed products. Traditional raw milk, which accounts for about 80% of total production, is typically sold directly by dairy farmers or through intermediaries such as Farias (petty traders) and Ghosh (milkmen). In the commercial sector, which makes up roughly 20% of the market, consumers can purchase pasteurized milk, UHT milk, yogurt, powdered milk, and other dairy products. Despite the growth of the commercial sector, traditional sales channels still dominate, with small-scale processors collecting milk from farmers and transporting it to chilling centers.

In addition, local milk processors, such as sweetmeat shops, have begun incorporating cooling devices to ensure product quality for items like labang (fermented milk), yogurt, cheese, and other sweets. This mixed approach to milk marketing

reflects the dynamic evolution of Bangladesh's dairy industry, which balances traditional consumer preferences with a growing demand for modern, commercialized products. Small-scale processors and local vendors remain vital to the supply chain, especially in rural areas, while larger processors cater to urban consumers with ready-to-use chilled and frozen options. There are ample opportunities for further growth and development.

The growing demand for chilled livestock products reflects a broader shift in consumer preferences in Bangladesh, driven by rising incomes, urbanization, and increased awareness of food safety and hygiene. This shift is fostering the gradual adoption of frozen and processed foods. The chilled meat and dairy sectors offer significant opportunities for growth, with traditional practices continuing to coexist alongside modern, commercial marketing strategies. This evolving market landscape highlights the potential for expanding cold chain infrastructure, which could improve product quality, reduce food waste, and better serve the needs of Bangladesh's diverse consumer base.

3.3. Consumer Perceptions of Chilled and Frozen Milk and Meat

Field investigations in Bangladesh have revealed that consumer perceptions of chilled and frozen milk and meat are influenced by various cultural, economic, and socio-political factors. Concerns about quality degradation during freezing, potential health risks from contamination, and a strong preference for fresh products—shaped by local culinary traditions—contribute to widespread skepticism. Additionally, suspicions about preservatives, cultural and religious opposition to processed foods, and the perception of chilled and frozen products as premium-priced further reinforce these reservations. Several studies [9-11] support these findings, highlighting that consumer perceptions are often shaped by factors such as health, food safety, quality, nutritional value, product origin, taste, and trust in public institutions. Moreover, the demand for ready-to-eat and semi-ready meals has risen, particularly among working women who face time constraints in cooking [25].

Field observations indicate that, after purchasing milk or meat, most consumers either cook these items immediately or store them partially in home refrigerators. In Bangladesh, raw milk is typically boiled right after purchase. This preference for fresh over frozen products is consistent across income groups, although attitudes vary. For example, lower- and middle-income groups often believe that fresh milk and meat are more nutritious than frozen or chilled alternatives, perceiving fresh milk as creamier and thicker after boiling compared to frozen or pasteurized milk. In contrast, higher-income consumers tend to view chilled or frozen milk and meat as equally, if not more, nutritious.

Scientific research supports the idea that frozen foods retain their nutrients well due to preservation techniques. Studies have

shown that freezing, by slowing chemical reactions and microbial growth, is one of the most effective methods for long-term food preservation [13, 4]. While taste preferences still favor fresh over frozen meat, participants in this study acknowledged that the nutritional value of frozen and fresh products is similar. Research by several authors [26, 17, 29 1] further confirms that frozen foods can sometimes retain higher nutrient levels than fresh ones. This suggests that, while taste preferences may lean toward fresh products, consumers can still obtain comparable nutritional benefits from frozen items.

Hygiene and cleanliness in the cooling process are crucial factors for consumers, particularly among upper-middle and high-income groups. These consumers expressed a strong willingness to pay a premium for chilled or frozen products that meet stringent hygiene standards. Market associations play a vital role in upholding hygiene, maintaining facilities for washing, cleaning, and sanitation to ensure a safe environment for workers and consumers. Although cold storage facilities and structured slaughtering utilities are often lacking, occasional awareness campaigns—supported by initiatives like the Global Alliance for Improved Nutrition (GAIN)—focus on promoting personal hygiene among staff and emphasizing the importance of cleanliness in maintaining food safety. However, there is still a gap in providing regular health checkups for market workers, which, if implemented, could further improve hygiene practices.

In terms of market dynamics, respondents across various regions have reported a noticeable increase in demand for chilled meat and milk over the past decade, driven primarily by changing urban lifestyles. As urban areas become more fast-paced, people are increasingly opting for frozen products and ready-to-eat meals over fresh, raw ingredients. This shift is further fueled by rising disposable incomes and evolving dietary preferences, especially among the middle-income demographic, who frequently choose chilled meat and milk products for convenience. The growing demand for frozen and chilled foods reflects socio-economic shifts and the adaptation of food supply chains to meet the needs of a rapidly urbanizing population.

Therefore, consumer perceptions of chilled and frozen milk and meat in Bangladesh are shaped by a mix of cultural attitudes, health considerations, and economic factors. While traditional preferences for fresh products persist, particularly among lower-income groups, the demand for chilled and frozen products is increasing in urban areas as people prioritize convenience and food safety. This evolving market presents significant growth opportunities, especially if cold chain infrastructure can be further developed to address consumer concerns and improve the accessibility of high-quality chilled and frozen foods.

3.4. Producers' Perceptions on Cold Chain Investment

Producers in Bangladesh have mixed views on investing in

cold chain infrastructure, mainly due to the significant challenges and uncertainties associated with its implementation and maintenance. Several key concerns hinder their willingness to adopt cold chain technologies:

1) **High Upfront Costs:** Establishing cold chain infrastructure requires substantial initial investment in refrigerated storage facilities, specialized transportation vehicles, and processing equipment. For many small and medium-sized producers, these costs are prohibitively high, discouraging them from adopting cold chain technology.

2) **Ongoing Operational Expenses:** In addition to the initial investment, producers face high operational costs, including electricity, equipment maintenance, and training personnel to operate cold chain facilities. These continuous expenses add to the financial burden, making cold chain investments less appealing.

3) **Uncertain Returns on Investment:** Producers perceive a high level of uncertainty regarding returns on investment due to market demand fluctuations, competition, and potential regulatory changes. These unpredictable factors create a challenging environment, making it difficult for producers to confidently invest in cold chain infrastructure with the expectation of profitability.

4) **Limited Access to Sustainable Business Models:** While innovative financing options, such as "cooling as a service" or "pay-as-you-go" models, have been adopted in some countries to make cold chain adoption more feasible, these options are not yet available in Bangladesh. Without such models, producers have limited ways to offset the high upfront costs associated with cold chain investments.

5) **Infrastructure Challenges:** Unreliable electricity supply and inadequate transportation networks in Bangladesh further deter investment in cold chain infrastructure. These infrastructure deficiencies complicate the maintenance of consistent temperature controls, which are crucial for an effective cold chain system.

6) **Need for Policy Support:** Producers stress the need for favorable policy reforms to encourage cold chain adoption. Incentives such as tax breaks, subsidies, and tariff adjustments could help reduce the financial barriers to entry for producers interested in cold chain investments.

7) **Lack of Technical Expertise:** A significant barrier is the limited availability of technical expertise in designing, operating, and maintaining efficient cold chain systems. Without sufficient knowledge and training, producers feel ill-equipped to manage the complexities of cold chain infrastructure effectively, contributing to their hesitation.

However, some producers are optimistic about the future of cold chain investment, particularly in the context of an increasingly competitive market. Krishok Dairy and Food Products, based in the Rangpur district, exemplifies a forward-thinking approach to cold chain investment. Recognizing that a strong cold chain system—featuring refrigerated vehicles and energy-efficient cooling technologies—is not just an operational necessity but a strategic advantage,

Krishok Dairy has prioritized cold chain infrastructure to improve product quality, minimize financial losses, and enhance profitability and sustainability. This commitment positions Krishok Dairy as a leader in the competitive dairy market, reflecting its dedication to quality, environmental responsibility, and long-term success.

Moreover, smart dairy farming is gaining momentum in Bangladesh, incorporating technologies such as artificial intelligence, robotics, and automation [21]. This trend underscores the importance of pairing smart farming practices with a reliable cold chain throughout the supply chain. By maintaining strict temperature controls from farm to consumer, producers can ensure that dairy products remain fresh and safe, meeting the growing consumer demand for high-quality, hygienic products.

Integrating smart farming technologies with an efficient cold chain system not only improves product quality but also strengthens market competitiveness. These investments enable companies to address challenges in the local milk market, differentiate themselves in an increasingly sophisticated consumer landscape, and establish a reputation for consistent quality. Embracing both technological advancements in farming and robust cold chain infrastructure equips producers to expand their market reach, build consumer trust, and ensure the safety and freshness of their products.

3.5. Factors Influencing the Decision of the Consumers to Buy Frozen/Chilled Livestock Derived Food

The introduction of frozen food and value-added meat and milk products has added a new dimension to food consumption in Bangladesh, as consumers increasingly seek convenient, ready-to-eat, or easy-to-prepare options. Several factors, including socioeconomic, cultural, sensory, and psychological attributes, influence their purchasing decisions. Li [15] noted that socioeconomic factors play a key role in the decision to purchase processed livestock foods in Bangladesh. Thuiching [28] found that 53% of consumers selected frozen chicken primarily based on price, followed by halal certification, hygiene (16%), brand reputation (11%), and quality (4%). According to Bowman [3], about 47% of women considered food cost a key factor in their decisions regarding what to buy and how to prepare meals [28]. Economic and psychological factors are significant drivers of consumer behavior when it comes to processed food products [7].

In this study, consumers were asked about the factors influencing their purchasing decisions for chilled meat and milk. They reported that nutritional value, taste, price comparisons, product availability, proximity to their homes, expiry dates, and hygiene were important considerations. This aligns with findings from another study, which identified price, health, safety, convenience, and sensory appeal (appearance, freshness, taste) as key determinants of regular food choices [27].

In the case of milk and milk products in Bangladesh, sev-

eral factors influence consumer choices when purchasing chilled milk and related items. Increasing urbanization and the fast-paced nature of modern life have led to greater demand for convenient, ready-to-consume food items, including chilled milk products. Rising income levels, particularly among the middle class, have made these convenience-oriented products more affordable for consumers.

Hygiene and food safety are also vital considerations, with many consumers perceiving chilled milk to be safer due to its controlled temperature and reduced risk of spoilage compared to unrefrigerated alternatives. The availability of a wide range of chilled milk products, including flavored milk, yogurt, and cheese, caters to diverse consumer preferences, further driving demand. Additionally, effective marketing strategies and branding efforts by dairy companies play a significant role in influencing consumer choices, as consumers are often drawn to trusted brands that promise quality and freshness in their chilled milk products.

Therefore, the decision-making process for purchasing frozen or chilled livestock-derived foods in Bangladesh is complex, shaped by a combination of factors such as price sensitivity, health and safety concerns, convenience, sensory preferences, packaging, and brand influence. Understanding these factors is essential for producers and retailers to adapt their strategies to meet the evolving demands of consumers, especially as convenience-driven lifestyles and safety concerns continue to shape food consumption habits in Bangladesh.

3.6. Adoption and Utilization of Energy Efficient Cool Chain Solutions by the Producers and Market Actors

The cold chain system plays a crucial role in maintaining the integrity and quality of livestock products throughout the supply chain. In various farming operations across Bangladesh, including broiler farms, beef fattening, and dairy farms, cooling devices such as fans, evaporative cooling systems, and natural ventilation are commonly used. While farmers generally understand the importance of cooling mechanisms, refrigeration units are primarily found in medium and large-scale farms that rely on established cold chains managed by local Upazila subdistrict livestock offices for vaccine preservation and transportation. Additionally, government-owned cooling systems oversee the distribution of semen and artificial insemination services, ensuring the viability of genetic materials. However, challenges arise in maintaining international standards during transportation, slaughtering, and marketing processes, which can compromise food safety in the market.

Traditionally, butchers in Bangladesh sell fresh meat by slaughtering animals on-site, focusing mainly on immediate sales rather than reducing costs through frozen meat or investing in energy-efficient cold chain technologies. This widespread practice often overlooks the significant benefits

that modern, energy-saving equipment and techniques can provide. Typically, butchers aim to sell their entire meat stock within a day; however, some may remain unsold. In such cases, the unsold meat is either sold at a discounted price to contracted restaurants or temporarily stored in domestic refrigerators for sale the next day. Key informant interviews (KIIs) reveal that, on average, around 200 kilograms of meat are sold daily, with 15-20 kilograms occasionally needing refrigeration for overnight storage. Contracted restaurants, aware of the perishable nature of unsold meat, typically negotiate prices that are BDT 30-50 (USD 0.3-0.5) lower than the regular market rate. This practice allows butchers to recover some value from unsold meat, but often at the cost of its physical and microbiological quality.

The success of Ashek Ali's butcher shop highlights the critical role of robust and energy-efficient cold chain systems in preserving meat quality and building customer trust. By adopting cool chain technologies such as deep freezers, Ashek Ali's butcher shop in the Manikganj district has significantly improved food safety, reduced waste, and increased efficiency in handling larger orders. Promoting such systems within Bangladesh's meat distribution practices could enhance overall supply chain effectiveness, benefiting both businesses and consumers.

Several private sector companies in Bangladesh are involved in the production and distribution of energy-efficient cold chain solutions, including RFL Group, Walton, Grameen Shokti, Konka, and Jamuna. These companies manufacture and distribute both electric inverter-type and solar-powered cold chain equipment. For example, Nobabganj Machineries Limited produced 100 cooling tanks, 50 milk pasteurization plants, 40 portable mini cold storages, and 70 yogurt incubators in just one year for the domestic market [14]. Akiz Dairy also imported eight micro cane chillers from India, setting them up in a rural milking hub, capable of chilling milk from 35°C to 4°C even without grid power.

The US Department of Agriculture (USDA) Bangladesh Trade Facilitation Project (BTF) is working to develop the cold chain or temperature-controlled logistics (TCL) industry in Bangladesh as a key intervention to reduce post-harvest losses (PHL) of agricultural produce and boost the trade of high-value food items.

3.7. Food Safety and Hygiene's Practices in the Entire Livestock Supply Chain

The livestock supply chain in Bangladesh faces significant challenges in maintaining food safety and hygiene practices from farm to fork. Meat handling by butchers is often unhygienic, with meat sold in open markets exposed to germs and diseases, posing substantial public health risks. This lack of sanitation compromises health and safety across the supply chain.

Numerous studies highlight widespread deficiencies in infrastructure and practices within the meat and milk value

chains. Inadequate refrigeration facilities, poor drainage systems, and unsatisfactory cleanliness in butchery stalls emphasize the urgent need for improved hygiene standards. For example, a UNIDO study associated with the Livestock and Dairy Development Project (LDDP) found that about 63% of butchery stalls lacked refrigeration, and 53% did not have proper drainage systems [19]. Additionally, only around 47% of butchers maintained cleanliness in their slaughter facilities, which is critical in preventing meat spoilage and contamination. These statistics underline a significant opportunity to implement better hygiene practices and adopt cold chain systems [19].

These findings are consistent with our own research. Despite efforts by commercial facilities like Bengal Meat to comply with international standards, such as ISO 22000/2015 and Hazard Analysis and Critical Control Point (HACCP) plans, informal animal transportation and the lack of regulatory enforcement introduce additional risks. Slaughtering across the country often takes place in unsanitary conditions, with limited or no veterinary inspection, raising concerns over meat quality and safety. Similarly, live poultry handling in marketplaces lacks proper hygiene protocols, increasing the risk of disease transmission. This aligns with Sharma [24], who stressed the need for public health initiatives to enhance food safety knowledge and practices among meat handlers to prevent foodborne diseases (FBD).

Furthermore, the marketing of raw milk increases the risk of adulteration and contamination. Although some small-scale milk processors have implemented innovative methods to ensure milk safety, broader interventions are necessary, such as modernizing slaughterhouses and promoting chilled milk distribution. Strengthening hygiene and food safety controls throughout the milk and meat value chains can significantly reduce the risk of contamination, foodborne diseases, and economic losses [5, 16]. Recent initiatives, such as the World Bank-funded Livestock and Dairy Development Project (LDDP) and UNIDO's gap assessment, represent promising steps toward strengthening food safety policies and practices within the livestock supply chain. These efforts signal a critical shift toward ensuring both consumer health and the economic sustainability of Bangladesh's livestock sector [20].

3.8. Business Models and Investment Plan for Adopting Energy Efficient Cool Chain Solutions

Investing in energy-efficient refrigeration systems, coupled with improved inventory management practices, offers significant potential to reduce operational costs and extend the shelf life of perishable goods. This dual benefit supports both producers, particularly in the milk and meat sectors, and consumers in the long term.

An effective business model for energy-efficient cold chain adoption in Bangladesh could include the following key components:

However, several barriers must be addressed to promote investment in energy-efficient cold chain solutions and improve the current milk and meat supply chain in Bangladesh:

1) Financial Barriers: The initial investment costs can be prohibitive for producers, limiting their ability to adopt energy-efficient cooling technologies.

2) Lack of Information: There is a gap in knowledge regarding suitable technologies and best practices for energy-efficient cooling in the livestock sector, which hampers informed decision-making.

3) Consumer Affordability: The affordability of chilled or frozen livestock products remains a concern for general consumers, which must be addressed to enhance market demand.

4) Price Reduction Strategies: Reducing the costs of chilled products could help alleviate affordability issues for consumers.

To overcome these challenges, innovative business models such as "pay-as-you-go" or "cooling as a service" can be beneficial by alleviating the upfront cost burden on producers. Other key strategies include:

1) Policy Execution and Revision: Updating and enforcing existing policies and regulations to promote the adoption of clean and energy-efficient cooling solutions is crucial.

2) Financial Incentives: Government or NGO support in the form of financial incentives can encourage investment in clean and energy-efficient cooling technologies.

3) Awareness: Raising awareness among both producers and consumers about the potential advantages of these investments can pave the way for a more sustainable and economically viable milk and meat industry in Bangladesh.

It is important to note that purchasing chilled meat is a healthier choice compared to raw meat; however, refrigerant leaks from cooling systems can contribute to environmental degradation. To ensure environmental safety, it is essential to

utilize climate-friendly refrigerants. Therefore, the entire meat supply chain should be equipped with sustainable cooling facilities that promote public health and environmental well-being.

Transitioning butchers from selling fresh meat in traditional shops to offering chilled meat sourced from government-managed slaughterhouses is critical. However, many butchers express skepticism about this approach, fearing that consumers may be unwilling to purchase chilled meat due to psychological barriers. Transforming this traditional mindset can be achieved through several interventions, including:

1) Training and Education: Providing training to butchers about the benefits of chilled meat and proper handling practices.

2) Awareness Campaigns: Implementing awareness-raising activities to inform consumers about the health benefits of chilled meat and milk.

3) Financial Access: Improving access to financing options for butchers to invest in refrigeration facilities.

4) Inspection Practices: Ensuring ante-mortem and post-mortem inspections to guarantee meat quality and safety.

The implementation of the Animal Slaughter and Meat Quality Control Act of 2011 could further facilitate the transition from traditional to modernized systems where chilled meat is marketed effectively.

For the meat supply chain to succeed, all stakeholders—including processors, consumers, policymakers, and investors—must collaborate to create an enabling environment that popularizes chilled and frozen meat products. Based on field visits, key informant interviews, and consultations with various stakeholders in the meat value chain, a comprehensive business model for the frozen/chilled meat supply chain has been developed, as illustrated in the accompanying diagram (Figure 2).

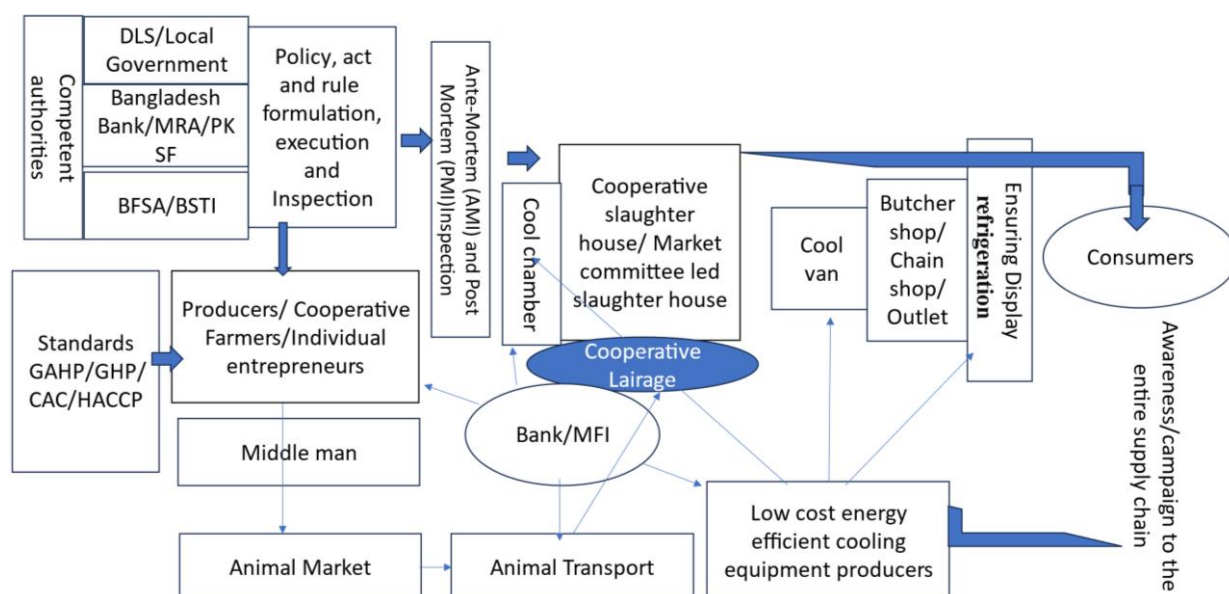


Figure 2. Proposed business model of the frozen/chilled meat supply.

In Bangladesh, the milk marketing system can be broadly divided into traditional raw milk sales and commercialized chilled and processed dairy products. Informal channels dominate the milk supply chain, accounting for approximately 80% of total milk production. In this traditional system, dairy owners or middlemen, such as farias or ghosh, sell raw whole milk directly to tea stalls, consumers, and sweetmeat shops for the production of channa (a type of cheese). Some middlemen also process raw milk into channa before selling it to local sweetmeat shops.

Sweetmeat makers use this raw milk to produce various dairy products, including yogurt, butter, cheese, butter oil (ghee), and a variety of sweets, with about 60% of milk from informal channels being used for these purposes. However, the lack of proper cold chain practices in the informal sector leads to significant post-harvest losses and the production of unsafe products. The traditional milk market often suffers from inefficiencies in cooling, as middlemen typically handle milk in ways that do not prioritize its preservation. Due to the perishable nature of milk and the high temperatures it is fre-

quently exposed to, the nutritional quality of the milk deteriorates rapidly. To address these issues, passive cooling solutions should be introduced to help middlemen maintain the milk's quality.

In contrast, the commercial marketing system, which includes pasteurized milk, UHT milk, yogurt, butter, cheese, and ice cream, accounts for only 20% of total milk production. A UNIDO diagnostic assessment of the dairy and beef value chains in Bangladesh [12] supports these findings, although it did not specifically address the cold chain system.

To address the challenges in the milk supply chain, developing a business model for the frozen/chilled milk supply chain could significantly improve handling and processing practices, ensuring product safety and reducing losses. The proposed business model for the frozen/chilled milk supply chain, illustrated in the accompanying diagram (Figure 3), aims to incorporate enhanced cooling solutions, improved transportation methods, and better distribution channels to effectively meet market demand while ensuring milk safety and quality.

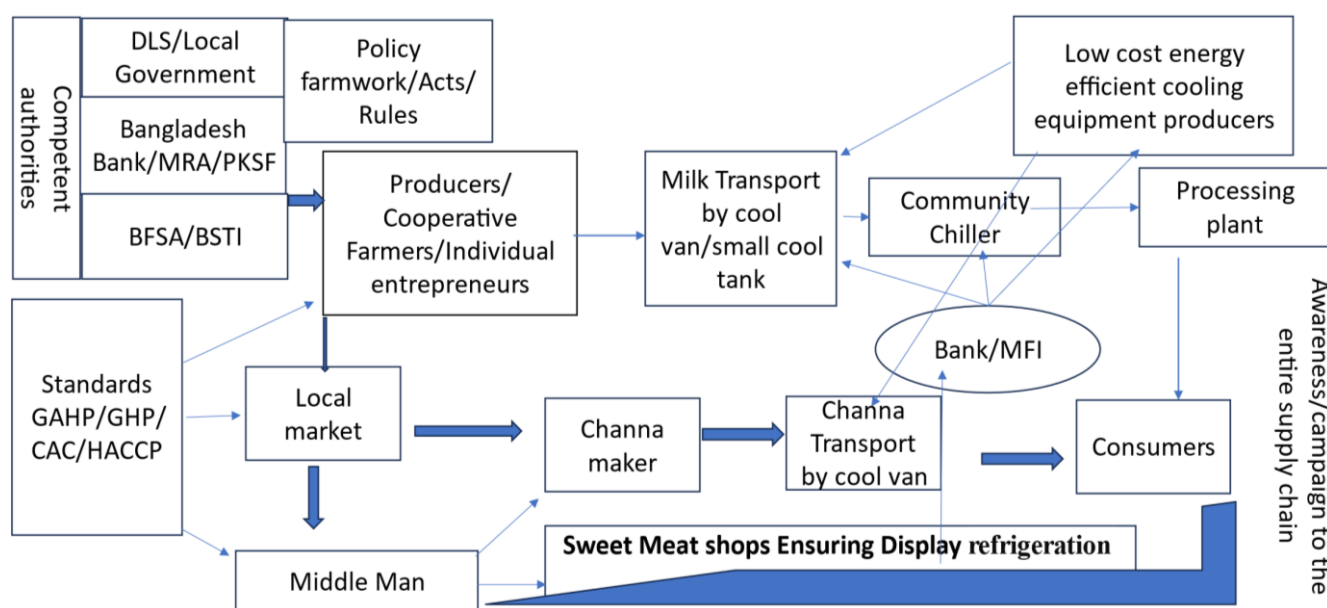


Figure 3. Proposed business model of the frozen/chilled milk supply chain.

Private sector investment plans and business models for frozen livestock commodities in Bangladesh focus on enhancing cold chain infrastructure, adding value through advanced processing and packaging, expanding access to export markets, and promoting collaboration across the entire value chain. These investments are essential for improving the competitiveness and sustainability of Bangladesh's livestock sector, while addressing the growing demand for high-quality frozen products in both domestic and international markets.

Figures 1 and 2 outline key activities under various sub-projects and priority interventions, emphasizing the roles

of multiple competent agencies. Table 1 presents an investment plan, along with the relevant agencies, to promote the adoption of energy-efficient cold chain solutions for livestock commodities in Bangladesh. To align these investment activities with both national and international compliance standards, these agencies must collaborate effectively. This coordinated approach will ensure the adoption of energy-efficient cold chain systems, adherence to regulatory standards, enhancement of food safety, and the overall growth and modernization of Bangladesh's livestock industry.

4. Conclusions

Investing in energy-efficient refrigeration systems, combined with improved inventory management practices, offers significant potential to reduce operational costs and extend the shelf life of perishable goods. This dual advantage benefits both producers—particularly in the milk and meat sectors—and consumers in the long term. An effective business model for adopting energy-efficient cool chains in Bangladesh could include the nine key components. These components are briefly outlined below:

1. **Innovative Financing Models:** Implementing financing options such as "pay-as-you-go" or "cooling-as-a-service" models can help alleviate the initial cost burden for producers, enabling them to access advanced cooling technologies without significant upfront investments.
2. **Collaborative Value Chain Development:** Encouraging partnerships among stakeholders—including producers, processors, distributors, and retailers—will ensure the efficient use of energy-saving cool chain solutions. This collaboration will also help create a more integrated supply chain that aligns with both domestic and export market needs.
3. **Supportive Policies and Financial Incentives:** Government and NGO incentives, such as grants, low-interest loans, and subsidies for energy-efficient equipment, can encourage private sector investments. Policy support aimed at enforcing energy-efficient standards in the cool chain will further accelerate adoption.
4. **Consumer Awareness and Education Campaigns:** Raising awareness among consumers about the benefits of chilled or frozen products will help build market demand. These efforts can address potential psychological barriers, encouraging consumers to view chilled products as

safer and higher-quality options.

5. **Climate-Friendly Refrigerants and Sustainable Practices:** To minimize environmental impacts, energy-efficient cooling solutions should use climate-friendly refrigerants. Integrating sustainable practices into the cool chain will not only ensure regulatory compliance but also align with global standards for environmental protection.
6. **Training and Capacity Building:** Providing training programs for producers, butchers, and other stakeholders on the benefits of cold storage, food safety, and quality assurance will strengthen the entire supply chain and improve consumer trust in chilled and frozen products.

Incorporating these elements into a business model for energy-efficient cool chains can ensure that Bangladesh's livestock industry meets growing demand sustainably.

By addressing both economic and environmental concerns, this approach will create a resilient market for high-quality milk and meat products, fostering growth in both domestic and international markets.

In conclusion, while the outlined strategies present promising avenues for enhancing cold chain adoption in Bangladesh's livestock value chains, addressing behavioral barriers remains crucial for their effective implementation. Despite the clear benefits of cold chain technology in preserving meat, milk, and other animal-derived foods, reluctance or resistance to change among stakeholders—including producers, processors, and consumers—may hinder its widespread adoption. Overcoming ingrained practices, skepticism, and cultural preferences will require targeted education, awareness campaigns, and community engagement efforts to foster acceptance and trust in energy-efficient cold chain solutions. By addressing these behavioral barriers alongside the proposed interventions, Bangladesh can unlock the full potential of cold chain technology to improve food safety, quality, and market access across its livestock value chains.

Table 1. Investment plan to foster adoption and utilization of energy-efficient cool chain for livestock commodities in Bangladesh.

Proposed program and sub-programs/Project interventions	Implementing organization
1. Improve market infrastructure, slaughter house, cool chain and value chain facilities:	
Construction or rehabilitation of markets	Ministry of Local Government (MLG), City Corporation, Department of Livestock Services (DLS), Department of Environment (DoE), Private sector, Development partners (DPs)
Capacity building of value chain actors and market promotion	DLS, Bangladesh Livestock Research Institute (BLRI) DPs, Hortex Foundation, Commercial Bank/Micro-finance Institute (MFI), Private sector
Promote meat & milk processing and value addition products	Research Institutes,/University, DLS, Bangladesh Standard Testing Institute (BSTI), Bank/, MFI, Ministry of Commerce (MoC)
Establishing milk chilling and processing centers.	Ministry of Fisheries and Livestock (MOFL), BSTI,
Establishing meat processing centers	MOI, DPs, Private sector
2. Develop energy efficient cool chain and storage facilities:	

Proposed program and sub-programs/Project interventions	Implementing organization
Commercialization of low-cost energy efficient cooling equipment for milk & meat supply chain	Ministry of Industry (MoI), DoE, DLS
Reducing postharvest loss through Improving transportation, cool chain and storage facilities	DLS, Hortex Foundation, private sector and DPs
Promote supply of safe and nutritious food through quality assurance with the adoption of good animal husbandry practices (GAHP)/Good Hygiene Practice (GHP) and build facilities for inspection, accredited testing and certification systems	MOFL, DLS, BSTI, MOI, DPs, and Private sector
Promote awareness of the consumers to reduce behavioral barriers to chilled and frozen livestock food	MOFL, DLS, LGEDs DPs, and Private sector
Supporting research and development	MOFL, BLRI and Universities and private sectors
Facilitating collaboration and public-private partnerships	MOFL, DLS, BLRI and Universities and private sector, DPs

Abbreviations

KII	Key Informant Interviews
FY	Financial Year
GAIN	Global Alliance for Improved Nutrition
BDT	Bangladesh Taka (Currency)
USD	US Dollar
RFL	Rangpur Foundry Ltd
USDA	US Department of Agriculture
TCL	Temperature-controlled Logistics
BTF	Trade Facilitation Project
UNIDO	United Nations Industrial Development Organization
FBD	Foodborne diseases
LDDP	Livestock and Dairy Development Project
DLS	Department of Livestock Services
PKSF	Palli Kormo Sahayak Foundation (Rural Employment Supporting Foundation)
BSTI	Bangladesh Standard Testing Institute
BFSA	Bangladesh Food Standard Authority
GHP	Good Hygiene Practice
HACCP	Hazard Analysis and Critical Control Points
CAC	Codex Alimentarius Commission standard
MFI	Microfinance Institutes
UHT	Ultra Heat Treated Milk
MLG	Ministry of Local Government
DOE	Department of Environment
DP	Development Partner
BLRI	Bangladesh Livestock Research Institute
MOC	Ministry of Commerce
MOFL	Ministry of Fisheries and Livestock
MOI	Ministry of Industry
GAHP	Good Animal Husbandry Practices

Author Contributions

Sheikh Mohammad Fakhru Islam: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Sarker Mohammad Rajiur Rahman: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Validation, Writing – original draft

Siddika Bhuiyan Mishu: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



Sheikh Mohammad Fakhurul Islam is a retired professor at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh, Department of Agricultural Economics. He completed his PhD in Agricultural Economics from University of Philippines in 1995, and his Master of Agricultural Economics in Agricultural Marketing from Bangladesh Agricultural University in 1987. He has sound experience of working as a think tank, teaching at universities, working as researcher and development professional at various international organizations such as World Bank, FAO, WFP, UNDP, ADB, EU, USAID, DFID, IRRI, ILRI, IFPRI, etc. He has participated in multiple international research collaboration projects in recent years. He currently serves Team Leader at IRGDSL-WB Cool Chain Project for Livestock in Dhaka, Bangladesh. He has numerous publications and has been invited as a Keynote Speaker,

Technical Committee Member, Session Chair, and Judge at national and international conferences.



Sarker Mohammad Rajiur Rahman completed Ph.D. in Dairy Science from Bangladesh Agricultural University and PGD in Disaster Management from the University of Dhaka. He is a development professional with over 25 years of leadership experience in government, private, and international organizations, including NGOs and UN agencies like FAO, IFAD, and UNIDO. Currently serving as National Livestock and Nutrition Expert for the IRGDSL-WB Cool Chain Project in Dhaka, Bangladesh, he specializes in livestock value chains, agribusiness development, policy analysis, food safety, and climate-smart livestock practices. An accomplished researcher, keynote speaker, and reviewer, he has numerous publications and conference presentations.



Siddika Bhuianmishu is an international development professional based at The World Bank in Washington, D.C. She has previously worked with prominent development organizations such as the FAO and IFAD at the United Nations. At the World Bank, Siddika primarily focuses on the Agricultural and Food Global Practice, as well as the Energy and Extractives unit. She holds a Master's degree in Agricultural and Resource Economics from the University of Delaware and is currently pursuing a second Master's degree in Data Science at the University of Maryland.

Research Field

Shaikh Mohammad Fakhurul Islam: Agricultural Economics, Livestock Value Chain, Consumer's perceptions on demand for chilled meat and milk behavioral barriers in embracing cold chain solutions, Investment in cool chain, Food quality and safety.

Sarker Mohammad Rajiur Rahman: Livestock food and nutrition, Livestock Value Chain, Consumer's perceptions on demand for chilled meat and milk, behavioral barriers in embracing cold chain solutions, Investment in cool chain, Food quality and safety.

Siddika Bhuianmishu: Agricultural Economics, Livestock Value Chain, Consumer's perceptions on demand for chilled meat and milk behavioral barriers in embracing cold chain solutions, Investment in cool chain, Food quality and safety.