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A Study on Cold Chain Challenges and Farmer Readiness for Perishable Exports in Satara, Maharashtra, India

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Abstract— *The globalization of Agri-food trade has amplified the importance of efficient cold chai logistics, particularly for perishable commodities such as dairy, seafood, and fresh produce. This study titled Cold Chain Logistics for Perishable Exports, investigates the infrastructural and operationc challenges in maintaining temperature-sensitive supply chains from farm gate to international markets. Using empirical data from 89 farmers in Satara district, Maharashtra, the research assesses the curren level of awareness, adoption, and readiness among producers regarding cold chain technologies ana export standards. The analysis reveals critical gaps in refrigeration infrastructure, limited farmer access to cold storage and transport facilities, and significant knowledge deficiencies in handling export-grade perishables. Furthermore, the study underscores the role of policy interventions, public-private partnerships, and targeted capacity-building programs in bridging these gaps. By proposing a strategic framework to enhance cold chain logistics, this research contributes to strengthening the export potential of India's perishable agri-sector while reducing post-harvest losses and ensuring product integrity in global markets.*

Keywords— ***Cold Chain Logistics, Perishable Exports, Refrigeration Infrastructure, Temperature-Controlled Transport, , Fresh Produce, Farmer Readiness, Supply Chain Gaps.***

I. INTRODUCTION

Agriculture remains a cornerstone of economic development, particularly in nations with agrarian-based economies. Although global demand for perishable agricultural commodities—such as dairy products, seafood, and fresh fruits and vegetables—continues to rise, many producers and exporters struggle to

access international markets. This is largely due to underdeveloped cold chain infrastructure and insufficient logistical support. These shortcomings limit their ability to compete in global trade, ultimately causing missed opportunities in high-value export markets.

The main barriers include a lack of reliable cold storage facilities, inadequate temperature-controlled transportation systems, and the absence of real-time monitoring tools. These inefficiencies frequently lead to spoilage, shipment rejections, and financial losses, undermining the profitability of perishable exports. To address these issues, a comprehensive analysis of existing cold chain logistics systems is essential. This includes evaluating current storage and transport practices and assessing the readiness of farmers to meet export standards for perishable goods.

Moreover, strengthening the role of logistics providers and industry associations is critical. These entities can act as catalysts in bridging infrastructure gaps through shared resources, training programs, and the implementation of best practices. Building collective capacity at the grassroots level can empower farmers and exporters to meet global requirements more efficiently.

This research is grounded in key economic and

developmental frameworks. The Theory of Comparative Advantage highlights the importance of focusing on high-value perishable exports, where countries have the potential to outperform competitors. Additionally, Systems Theory underscores the interdependence of various components in the cold chain—storage, transport, monitoring, and coordination—all of which must function cohesively to maintain product quality and reduce losses.

Technological innovations such as IoT-enabled temperature tracking, GPS monitoring, and advanced refrigeration solutions offer significant promise in improving cold chain efficiency. These technologies can enhance visibility, reduce spoilage, and ensure compliance with international quality standards.

The insights derived from this study will benefit a wide range of stakeholders. Farmers and producers will gain a better understanding of the infrastructure and protocols necessary for successful export of perishable goods. Policymakers can use the findings to design targeted interventions, including infrastructure funding, cold chain incentives, and export facilitation schemes. For logistics providers and exporters, the research offers practical guidance on overcoming transportation and storage challenges while enhancing coordination across the supply chain.

On a macroeconomic level, improving cold chain readiness can lead to reduced post-harvest losses,

Enhanced export earnings, and strengthened global competitiveness of the agricultural sector. Ultimately, these developments can contribute to rural economic growth, increased farmer incomes, and a more resilient and sustainable food supply chain.

India has emerged as a significant player in global agricultural and processed food exports, with total agricultural and allied exports reaching US $51.91 billion in 2024–25, marking a 6.5% year-on-year growth. Within this framework, the Agricultural and Processed Food Products Export Development Authority (APEDA) has played a pivotal role, covering exports worth US $27.9 billion, an impressive 11% increase over the previous year. Key perishable segments such as marine products (US $7.4 billion), spices (US $4.45 billion), buffalo meat (US $4 billion+), fresh fruits (US $1.17 billion), processed fruits and juices (US $1 billion), and dairy exports (up 54%) have shown strong performance, underlining India's growing potential in the global food value chain.

However, this growth masks underlying infrastructure challenges, particularly in cold chain logistics, essential for minimizing post-harvest losses and maintaining export-grade quality. Despite being the world's largest milk producer and the second-largest producer of fruits and vegetables, India still suffers post-harvest losses of 5–16% in fruits/vegetables, 5–10% in fish, and 2–7% in meat/poultry, primarily due to fragmented and insufficient cold chain systems.

To address these gaps, the Ministry of Food Processing Industries (MoFPI), under the Pradhan Mantri Kisan SAMPADA Yojana (PMKSY), has sanctioned 372 integrated cold chain and value-addition projects, adding 38 million metric tonnes of storage capacity and generating over 223,000 jobs. These initiatives focus on capital-intensive infrastructure like pack-houses, cold rooms, ripening chambers, blast freezers, and refrigerated transport, with grants of up to INR 10 crore per project.

Despite these efforts, challenges persist. The Indian cold chain market, currently valued at INR 2.05 trillion (~US $24.6 billion), is projected to grow at 16–18% CAGR, reaching over INR 5 trillion (~US $60 billion) by 2028–29. Yet, there remains a gap of 3.2 million MT in cold storage, 69,000 pack-houses, 50,000+ refrigerated vehicles, and 8,000 ripening chambers. Moreover, 80–85% of cold storage facilities remain unorganized, often used for single commodities, reducing efficiency and scalability.

II. REVIEW OF LITERATURE

Akshay Kumar S & Dr. Krithika J (2025): This study examines key challenges in cold chain logistics and their impact on operational performance. Using descriptive analysis and stakeholder feedback, it identifies strengths like controlled handling and basic facilities, while highlighting gaps in tracking and environmental efficiency. The findings stress the need for better infrastructure, safety, and response systems to enhance cold chain effectiveness.

MOFPI (2025): The "Integrated Cold Chain and Value Addition Infrastructure" scheme aims to establish seamless cold chain and preservation infrastructure from the farm gate to the consumer. It supports the development of facilities across the supply chain, including pre-cooling, sorting, grading, waxing, and packing at the farm level, along with multi-product/temperature cold storage, controlled atmosphere (CA) storage, IQF, blast freezing, and distribution through reefer vans and mobile cooling units. The scheme emphasizes flexibility in project planning, prioritizing farm-level infrastructure for horticulture, non-horticulture, dairy, meat, poultry, and fish/marine (excluding shrimp) products.

Singh, R. & Deshmukh, P. (2025):

This research explores the role of digital technologies in improving cold chain logistics in India's agri-food sector. Through case studies and stakeholder interviews, the study reveals that adoption of IoT-enabled temperature monitoring and GPS tracking systems enhances real-time visibility and minimizes spoilage. While digital readiness is increasing, infrastructural gaps and high costs remain barriers. The study underscores the importance of policy support and capacity-building initiatives to drive tech-led transformation in cold chains.

Iyer, S. & Patil, M. (2025):

This study investigates the effectiveness of public-private partnerships (PPPs) in expanding cold chain networks in rural India. By evaluating existing PPP models, the research finds that collaborative investments significantly reduce post-harvest losses and improve market access for perishable products. However, challenges such as regulatory delays and lack of technical manpower persist. The study calls for streamlined policy frameworks and training programs to strengthen PPP implementation in the cold chain sector.

Lee, H. & Nakamura, T. (2025 Japan):

This paper examines cold chain efficiency in East Asia's seafood export sector, focusing on operational sustainability. Using a comparative analysis of logistics practices across Japan, South Korea, and Taiwan, the study finds that automated cold storage and energy-efficient reefer technologies improve overall sustainability. Nonetheless, limited cross-border coordination hinders performance. The findings emphasize regional collaboration and harmonized standards to advance cold chain sustainability in global seafood trade.

Rodriguez, M. & Carter, J. (2025 USA):

This study analyses the impact of climate change on cold chain logistics for pharmaceuticals in North America. Utilizing climate risk models and supply chain simulations, the research identifies increased vulnerabilities in temperature-sensitive drug transport during extreme weather events. Results highlight the need for adaptive infrastructure, smart insulation materials, and climate-resilient route planning. The study urges proactive investment in climate-proof logistics systems to ensure product safety and compliance.

OBJECTIVES:

- Identify key transport challenges for dairy, seafood, and fresh produce exports, focusing on spoilage, delays, and poor packaging.
- Evaluate cold chain infrastructure—refrigeration tech, storage, and transport methods—used in maintaining product quality.
- Assess farmer awareness and readiness for cold chain logistics and export-oriented post-harvest handling.

RESEARCH QUESTIONS:

- What types of farm equipment are most effective for implementing vermicomposting practices?
- How efficient and advanced are current cold chain systems for dairy, seafood, and fresh produce?
- How aware and prepared are Indian farmers for cold chain and export logistics?
- What strategies can boost farmer access to cold chain systems and export participation?

III. MATERIALS AND METHDS

The methodology combined both qualitative and quantitative approaches to offer a comprehensive understanding of the issue.

Research Design:

A mixed-methods research approach was employed, integrating both primary and secondary data collection techniques. This helped triangulate findings and provides a more in-depth analysis of the cold chain ecosystem in the context of agricultural exports.

Primary Data Collection:

Primary data was collected through a structured questionnaire via in-person interviews and Google Forms from a target group of **89 farmers**, primarily from **Satara Taluka, (Maharashtra)** which focused on

- Availability and usage of cold storage and transportation facilities.
- Farmers' awareness of cold chain infrastructure and export standards.
- Challenges faced during post-harvest handling and transportation.

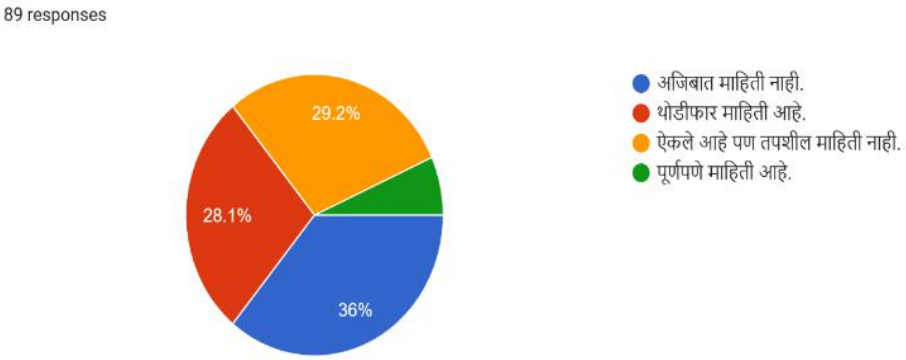
Data for the study was collected from a total of **89 valid respondents,** primarily comprising producers engaged in dairy farming, inland seafood aquaculture (with indirect links to trade), fruit and vegetable cultivation such as pomegranate, onion, grapes, and leafy greens, as well as organic and high-value perishable crop farming. The majority of participants were from rural areas, **with 72% belonging to villages in Satara district and 80.9% specifically from Satara Taluka**. This respondent profile provided a diverse yet localized perspective on cold chain logistics and export preparedness among perishable commodity producers.

Secondary Data Collection:

Secondary data was gathered from credible national and international sources to support and validate the findings of the study. Key sources included the Agricultural and Processed Food Products Export Development Authority (APEDA), the Marine Products Export Development Authority (MPEDA), the Ministry of Food Processing Industries (MoFPI), the Food and Agriculture Organization of the United Nations (FAO), and the ITC Trade Map Database. These sources provided valuable insights into export trends, commodity-specific handling requirements, cold chain infrastructure gaps, and international quality and certification standards relevant to the export of perishable agricultural products.

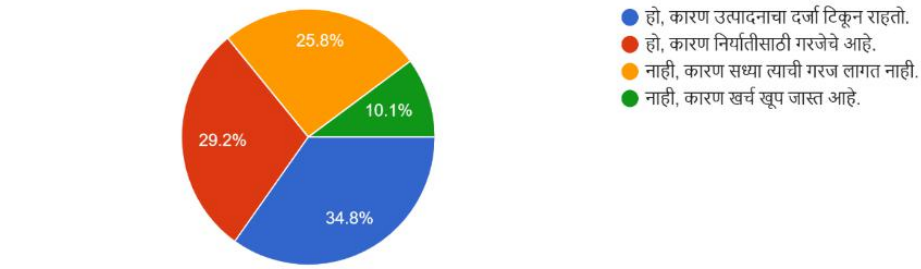
IV. RESULTS & DISCUSSIONS

Q.1 How would you rate your level of awareness about Cold Chain Logistics (i.e., the use of cold storage, refrigeration, and temperature-controlled transport for preserving perishable products)?



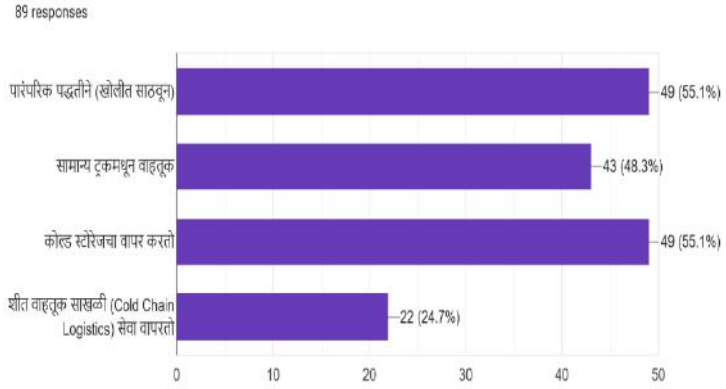
A majority of farmers show limited awareness of cold chain logistics, with 29.2% having no knowledge at all and 28.1% only vaguely familiar with the concept. This indicates that over 57% lack sufficient understanding, highlighting a critical need for basic awareness and education programs, especially in rural areas. While 36% of farmers are somewhat aware and could become early adopters with the right support, only 6.7% are fully informed, reflecting the low penetration of cold chain knowledge. These findings underscore the urgent need for targeted training, practical demonstrations, and outreach initiatives to build capacity and improve the export potential of perishable agricultural products.

Q.2 Do you think Cold Chain Logistics is necessary for your produce?



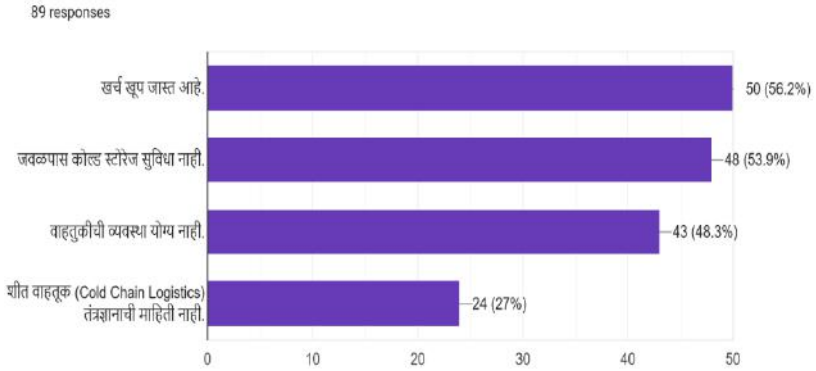
The survey reveals that 60.6% of farmers consider cold chain logistics necessary—34.8% for maintaining product quality and 25.8% for supporting exports. This shows a growing recognition of its value in preserving freshness and accessing distant markets. However, 29.2% of respondents feel it is not currently needed, likely because they sell locally or grow less perishable crops. Additionally, 10.1% cited high cost as a barrier, highlighting the need for affordable solutions, subsidies, or shared infrastructure to improve adoption. Overall, the findings suggest both awareness and economic support are key to expanding cold chain usage among farmers.

Q.3 How do you currently store and transport your perishable farm produce?



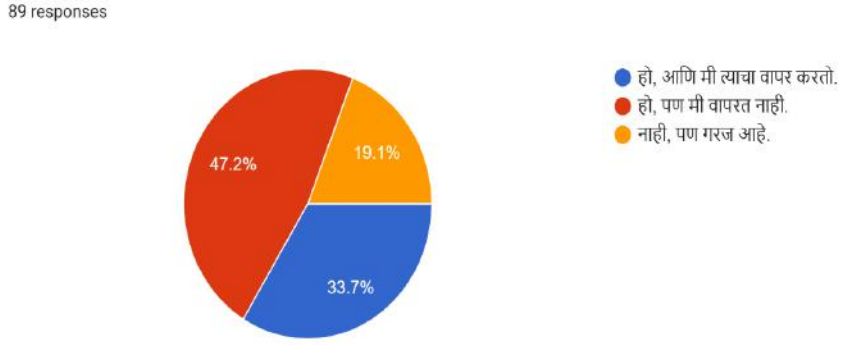
The survey shows that 55.1% of farmers still rely on traditional storage methods, such as room or household storage, which are often unsuitable for perishables. Interestingly, the same percentage (55.1%) also report using cold storage, indicating that many are likely using a combination of traditional and modern methods. Additionally, 48.3% transport goods using non-refrigerated trucks, increasing the risk of spoilage during transit. Only 24.7% of respondents use complete cold chain logistics (including both storage and refrigerated transport), revealing limited adoption and access. These findings highlight the need to expand awareness, improve infrastructure, and make cold chain solutions more affordable and accessible to reduce post-harvest losses and improve export readiness.

Q. 4. What challenges do you face in using Cold Chain Logistics for the export process?



The survey indicates that the high cost of cold chain logistics is the biggest barrier, with 56.2% of farmers citing it as a major concern. This is closely followed by the lack of nearby cold storage facilities (53.9%), pointing to serious infrastructure gaps in rural areas. Additionally, 48.3% of farmers report inadequate transportation facilities, making it difficult to maintain quality during transit. Lack of knowledge or technical understanding was noted by 27% of respondents, further limiting adoption. These insights emphasize the need for cost-effective models, infrastructure development, and targeted training programs to improve adoption of cold chain logistics for perishable exports.

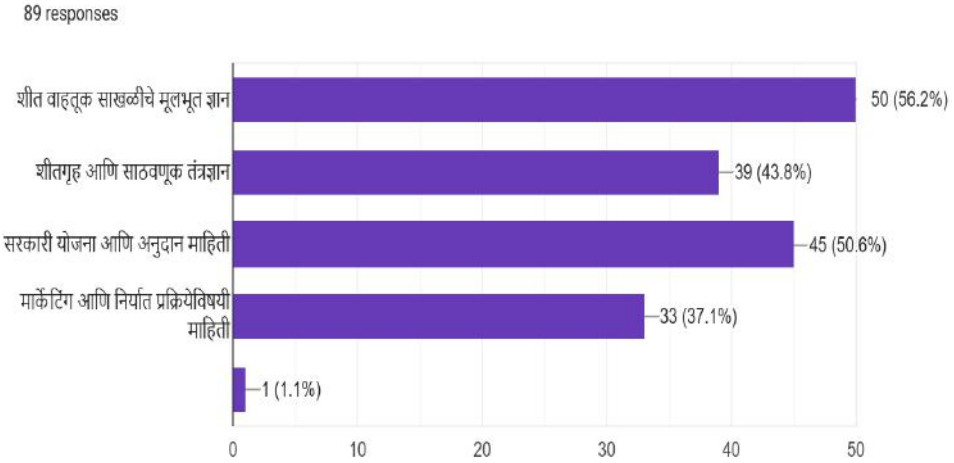
Q. 5. Are facilities like cold storage, pre-cooling, and cold chain infrastructure available in your area?



The survey reveals that only 19.1% of farmers both have access to and actively use cold chain facilities, indicating low adoption despite availability. Interestingly, 47.2% report that such facilities are available in their area but

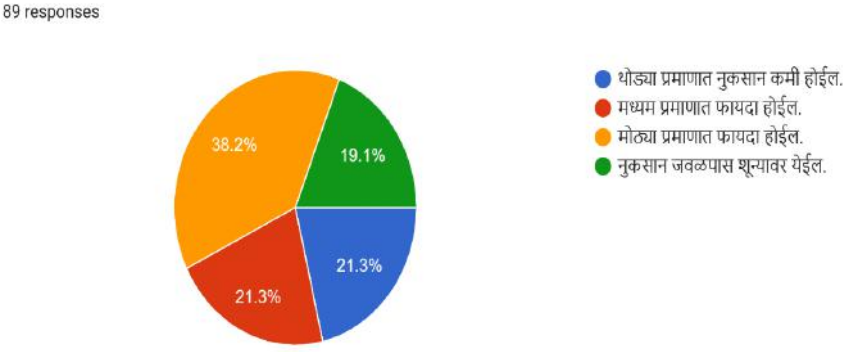
they do not use them, likely due to high costs, lack of awareness, or trust issues. Additionally, 33.7% of respondents do not have access to cold chain infrastructure but express a clear need for it, highlighting a demand-supply gap. These findings point to the need for improving utilization rates, expanding infrastructure, and offering capacity-building programs to encourage adoption and ensure effective use of existing resources.

Q.6. what kind of training or assistance do you expect to help you better understand and use Cold Chain Logistics and technology?



The survey highlights that the highest demand (56.2%) among farmers is for basic knowledge of cold chain logistics, indicating the need to start with foundational awareness programs. 50.6% of respondents also expressed interest in learning about government schemes and subsidies, showing the importance of financial guidance. 43.8% are seeking technical knowledge related to cold storage and preservation technologies, while 37.1% want training on marketing and export processes, reflecting an increasing interest in connecting cold chain practices with commercial opportunities. These insights emphasize the need for well-structured training modules focusing on awareness, technology, financial schemes, and market access to support cold chain adoption among farmers.

Q.7. In your opinion, how much post-harvest loss can be prevented using Cold Chain Logistics?



The survey reveals that a majority of farmers have strong confidence in cold chain logistics, with 42.7% believing it can offer large-scale benefits and 15.7% stating it could reduce losses to nearly zero. Combined, over 58% of respondents see cold chain systems as a powerful tool for minimizing post-harvest losses. On the other hand, 30.3% expect moderate benefits, and 11.2% feel it would only reduce losses to a small extent, possibly due to limited awareness or lack of exposure to cold chain use. These insights highlight the importance of demonstrating real-world success stories, pilot projects, and farmer testimonials to build greater trust and encourage adoption.

V. CONCLUSIONS

1. A notable percentage of farmers (29.2%) are completely unfamiliar with cold chain logistics, while only a small fraction (6%) has full knowledge. This highlights a substantial gap in awareness and underscores the need for structured informational campaigns and educational outreach.
2. A majority of farmers recognize the importance of cold chain logistics, with 31% emphasizing its role in maintaining produce quality and 26% identifying it as essential for exports. However, around 34.8% still

do not see an immediate need, primarily due to cost concerns or current market limitations.

3. Most farmers continue to use conventional storage methods (55.1%) and non-refrigerated transport (48.3%) for their produce. With only 24.7% utilizing integrated cold chain services, there is clear potential for transitioning toward more advanced and efficient post-harvest handling solutions.
4. Major barriers reported include the high cost of cold chain systems (56.2%), lack of local cold storage infrastructure (53.9%), and insufficient access to refrigerated transport (48.3%). These factors collectively hinder wider adoption and usage.
5. Although 47.2% of respondents stated that cold storage is available in their area, a significant portion does not make use of these facilities. This suggests that awareness, trust, affordability, or operational knowledge may be limiting factors in utilization.
6. Nearly half of the surveyed farmers (48.3%) were unaware of any government or private sector initiatives offering support for cold chain logistics. This points to a critical need for better communication and outreach regarding available subsidies, schemes, and infrastructure support.
7. Farmers expressed a clear need for practical knowledge, with 56.2% seeking training in basic cold chain operations and 50.6% wanting detailed information on government schemes. This indicates a strong interest in capacity-building efforts to better manage perishable goods.
8. Only 19.1% of farmers currently use cold chain facilities, indicating low adoption despite growing awareness.
9. Over 60% of farmers recognize the necessity of cold chain logistics, especially for maintaining quality and enabling exports.
10. Positive outlook: Over 58% of farmers believe cold chain logistics can significantly or completely reduce post-harvest losses.

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