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CHALLENGES AND TECHNOLOGICAL REQUIREMENTS OF COLD CHAIN LOGISTICS IN AGRICULTURE SECTOR WITH SPECIAL REFERENCE WITH COIMBATORE CITY

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ABSTRACT

The study is created to know about the challenges and technological requirements in cold chain logistics among the agriculture sector with that to know about their perception and strategies adopted by them in managing the challenges in cold chain logistics. The study is conducted with the cold chain logistics employees who face the issue in low utilization of existing cold storage facility for agriculture sector. The tools used to know the challenges, perception and strategies took place by using simple frequency, ranking analysis and factor analysis. The data has been collected from 63 respondents from the various cold chain logistics companies. It concludes that the logistics employees face issues such as technological issues and lack of awareness for low utilization of existing infrastructure and need government support to boost the cold chain logistics.

KEYWORDS: *Cold Chain, Logistics, Agricultural, Infrastructure, Technology, Challenges.*

INTRODUCTION

Agriculture is more than just an economic activity it is the backbone of food security and rural livelihoods. In India, millions of people depend on agriculture either as their primary occupation or as a source of income. A large share of agricultural output consists of perishable products such as fruits, vegetables, milk, meat, fish, and flowers. These products are highly sensitive to temperature and environmental conditions, and even small delays or improper handling can lead to rapid quality loss. Ensuring that agricultural produce reaches consumers in a fresh and safe condition remains a major challenge from the point of harvest to final consumption.

Cold chain logistics plays a key role in overcoming these challenges by maintaining the required temperature conditions throughout the supply chain. It involves a coordinated network of cold storage facilities, refrigerated transportation, appropriate packaging, handling systems, and information flow that together help preserve the quality of perishable products. An efficient cold chain reduces spoilage, extends shelf life, and ensures food safety. For farmers, this means lower post-harvest losses and better returns, while consumers benefit from improved availability of fresh and high-quality agricultural products.

Despite its importance, cold chain logistics in the agriculture sector continues to face several practical difficulties. One of the most common issues is the shortage of adequate cold storage facilities, especially in rural and production-dominated areas. Many existing cold storages are located near urban markets rather than close to farms, making access difficult for farmers. In addition, several facilities are designed to handle only specific crops and are not suitable for a wide variety of perishable products. These limitations often result in delays, overcrowding, and increased wastage during storage and transportation.

OBJECTIVIES

1. To evaluate key technological barriers and infrastructure gaps in automated and cold chain logistics.
2. To identify major technical failures in cold storage handling and management.
3. To assess the challenges of low utilization in existing cold chain infrastructure.

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REVIEW OF LITERATURE

1. **Huan Liu et al..,(2024):** This paper "A Deep Reinforcement Learning Based Algorithm for Multi Objective Agricultural Site Selection and Logistics Optimization Problem", investigates an advanced optimization approach for cold chain logistics of fresh agricultural products. The objective of the study is to minimize distribution cost, carbon emissions and product loss during transportations. The study developed a location routing model with time windows and proposed a hybrid deep reinforcement learning and swarm intelligence algorithm. Testing on datasets with 30-100 customers showed better performance than benchmark methods, demonstrating its efficiency and scalability for real world cold chain logistics.
2. **Jaya Laksana et al..,(2024):** This paper "Volatile Compounds and Quality Characteristics of Fresh Cut Apples and Mixed Fruits Coated with Ascorbic Acid during Cold Storage", investigates how ascorbic acid coating and cold storage affect the quality and aroma of fresh cut apples and mixed fruits. The objective of the study is to identify freshness markers and spoilage indictors while tracking changes in color, texture and microbial growth during storage. To identify this, this researcher dipped fresh cut fruits in 0.01% ascorbic acid, packed and stored at 4°C, 8°C and 15°C for various durations and quality parameters such as moisture content, acidity, color, firmness, microbial growth and volatile compounds were analysed using fast gas chromatography flame ionization detection and an electronic nose system, with the results statistically evaluated through ANOVA and Pearson correlation. The findings showed that storage at 4°C is best maintained in appearance and texture, while methanethiol and ethyl acetate indicated spoilage. The study concludes that ascorbic acid coating with storage below 8°C effectively preserves quality and extends shelf life, offering a practical solution for cold chain management.
3. **Daqing Wu et al..,(2023)**: This paper "Research on the Time-Dependent Vehicle Routing Problem for Fresh Agricultural Products based on Customer Value", aims to address inefficiencies in urban cold chain logistics caused by rising consumer demand for fresh agricultural products and increasing road congestion. The objective of this study is to develop a multi objective optimization model CV- GVRP that minimizes total distribution cost while maximizing customer value, factoring in carbon emissions, time dependent traffic conditions, and customer satisfaction. To achieve this, the researchers construct a mixed integer linear programming model and solve it using an enhanced NSGA-II algorithm integrated with greedy local optimization. The methodology includes modeling vehicle speed as a segmented function based on traffic delays, incorporating carbon trading price variability and calculating customer value from both current demand and potential influence. According to the finding CV-GVRP model improves delivery efficiency, reduces logistics costs and enhances customer value by accounting for time dependent traffic and carbon trading. This paper concludes that this approach supports sustainable logistics and offers a strategic tool for green supply chain planning.
4. **Yingdan Zhang et al..,(2023):** This paper "Exploring Symbiosis: Innovatively Unveiling the Interplay between the Cold Chain Logistics of Fresh Agricultural Products and the Ecological Environment" aims to examine the relationship between cold chain logistics for fresh agricultural products (CCLFAP) and the ecological environment across 30 Chinese provinces from 2015 – 2021. The objective is to identify which logistics factors affect ecological outcomes and whether sector growth promotes sustainability or risks ecological harm. The methodology involved constructing indicator systems for both cold chain logistics and the ecological environment, using data from statistical year books and government reports. Machine learning models (Random Forest, XGBoost) were applied to assess development levels, while Pearson correlation, heat maps and a Generalized Additive Model (GAM) analyzed linear and nonlinear relationships. The finding showed that overall cold chain development improves EE, with positive impacts from employees, trading volume, refrigerated vehicles and storage capacity. Negative effects arise from high per capita consumption, patents and road density, while some factors show nonlinear outcomes. The paper concludes that CCLFAP growth supports sustainability when technology and infrastructure are optimized, but unchecked expansion increases ecological pressures. Policies promoting green technology and eco-friendly infrastructure are recommended.
5. **Mahmmound Muhammed Syam et al..,(2022):** This paper titled "Mini Containers to Improve the Cold Chain Energy Efficiency and Carbon Footprint", focuses on reducing the high energy consumption and greenhouse gas emissions associated with conventional refrigerated transport in cold supply chains. The main objective of this study is to introduce and evaluate a mini container concept as an alternative to traditional refrigerated trucks particularly for small scale and partial load fresh produce transportation. The authors develop a thermal and energy performance model to calculate heat loads, refrigeration energy intensity and indirect GHG emissions for transporting tomatoes using mini containers under two contrasting climatic conditions. Phoenix (hot) and Chicago (cold). The methodology includes detailed heat load analysis considering conduction, product cool down, respiration, infiltration and transportation along with energy and emission comparisons between MCs and conventional reefers. Results indicate

that for partial loads below 72% in Phoenix and 85% in Chicago, mini containers significantly reduce energy consumption and eliminate indirect GHG emissions when powered by renewable energy. The study concludes that mini containers offer a sustainable, energy efficient and environmentally friendly solution for cold chain logistics, especially for small and medium growers, while also reducing food waste and carbon footprint

METHODOLOGY

Research methodology refers to a structured and systematic approach used to address and solve research problems. It involves understanding the scientific methods and processes through which research is conducted. A research design, on the other hand, serves as a detailed plan, framework, and strategy for investigation, formulated to effectively find answers to specific research questions and issues.

The study was carried out at Coimbatore city, involving 63 participants who are involved in cold chain logistics. This survey helps us to find out the challenges and technological requirements in cold chain logistics.
Type of research: Descriptive Research.
Sampling technique: Simple random sampling.
Sampling Area: Coimbatore city.
Sample size: 63.

ANALYSIS & INTREPRETATION

S.No	Personal profile of the Respondents	Frequency	Percentage
	Years of experience		
1	Below 5 yrs	5	7.9
2	5 – 9 yrs	23	36.5
3	10 – 14 yrs	22	34.9
4	Above 14 yrs	13	20.6
	Annual turnover		
1	Less than 5 cr	5	7.9
2	5 – 10 cr	18	28.6
3	11-15 cr	26	41.3
4	Above 15 cr	14	22.2
	Handling capacity		
1	Less than 200 MT	7	11.1
2	200 – 400 MT	17	27.0
3	401 – 600 MT	23	36.5
	Above 600 MT	16	25.4
	Role in company		
1	Operational manager	2	3.2
2	Logistics manager	32	50.8
3	Cold storage supervisor	25	39.7
	Others	4	6.3
	Total	**63**	**100.0**

Interpretation

From the above table it was found that majority 59.0% of the respondents are between the age of 20 – 25 yrs, 60.0% of the respondents are male, 55.2% of the respondents are post graduates and 35.2% of the respondents are living in Urban area.

Statements	Mean Rank	Rank
Compatibility issues	2.83	IV
High implementation cost	2.39	V
Lack of IT support or technical expertise	2.87	III
Data migration difficulties	3.20	II
Slow integration process or delays	3.65	I

INFERENCE

From the above table it is inferred that by applying ranking method for challenges faced by integrating logistics software.

1) Slow integration process or delays is ranked 1 with the mean score of 3.65
2) Data migration difficulties are ranked 2 with the mean score of 3.20

3) Lack of IT support or technical expertise is ranked 3 with the mean score of 2.87
4) Compatibility issues is ranked 4 with the mean score of 2.83
5) High implementation cost is ranked 5 with the mean score of 2.39

Statements	Mean Rank	Rank
High cost of service	2.46	V
Inconvenient or inaccessible location	3.22	II
Lack of awareness or training	2.79	IV
Limited government support or mandate	3.14	III
Availability of alternative storage option	3.38	I

INFERENCE

From the above table it is inferred that by applying ranking method for technological barriers faced in cold operations

1) High cost of services is ranked 1 with the mean score of 3.38
2) Inconvenient or inaccessible location is ranked 2 with the mean score of 3.22
3) Lack of awareness or training is ranked 3 with the mean score of 3.14
4) Limited government support or mandate is ranked 4 with the mean score of 2.79
5) Availability of alternative storage options is ranked 5 with the mean score of 2.46

ROTATED COMPONENT MATRIX

	Component			
	1	2	3	
Limited adoption of advanced technologies such as AI, blockchain, and analytics tools affects cold chain optimization(T10)	.708			Technological Limitation (19.985)
Poor network connectivity affects real-time communication and remote monitoring of cold chain equipment(T7).	.651			
Automation technologies in warehousing and material handling are limited, reducing cold chain efficiency(T3)	.624			
Shortage of technically skilled personnel limits the effective use of digital and automated systems(T6)	.551			
High investment cost restricts the adoption of advanced cold chain technologies(T8)		.511		Cost and Availability (37.094)
GPS tracking and vehicle telematics systems for refrigerated transport are unreliable or unavailable. (T4)		.682		
Adequate real-time temperature monitoring technology is not available for effective cold chain operations(T1)		.670		
Cybersecurity measures are insufficient, making digital cold logistics operations vulnerable to risks(T9)			.542	Technology Integration (51.831)
Data visibility and traceability across the cold supply chain are inadequate for effective decision-making(T5)			.881	
Integration of IoT systems across logistics processes is insufficient to support efficient cold chain management(T2).			.745	

FINDINGS

Simple Percentage Analysis

- Most of the respondents (36.5%) are of 5 – 9 yrs of experience.
- Most of the respondents (41.3%) are of 11 - 15 Cr of annual turnover.
- Most of the respondents (36.5%) are of 401 – 600 MT of handling capacity.
- Most of the respondents (50.8%) are Logistics manager.

Ranking Analysis

- Most of the respondents feels that they Slow integration process or delays with a mean score of 3.65
- Most of the respondents feels that they Availability of alternative storage option with a mean score of 3.38

Factor Analysis

- In factor analysis there are 10 statements, it has rotated and divided into 3 groups. They are Technological limitation, Cost and availability and technology integration**.**

SUGGESTIONS

1. Cold storage units, pre cooling centres and pack houses should be set up closer to farms so that produce can be stored quickly after harvest, reducing transport delays and preventing spoilage.
2. Modern technologies such as IoT based temperature monitoring, GPS tracking and automated handling systems should be used more widely to improve monitoring, tracking and overall efficiency in cold chain operations.
3. Regular maintenance of cold storage equipment is very important. By following proper maintenance schedules and upgrading old machinery, operators can avoid frequent breakdowns and improve reliability.

CONCLUSION

- The study highlights that limited infrastructure near farms, frequent power cuts, outdated equipment, poor maintenance practices and weak road connectivity are major barriers to efficient cold chain operations. High operating costs, lack of skilled workers and low awareness among farmers further reduce the use of cold storage and refrigerated transport services. While some level of digital monitoring is in place, advanced technologies such as IoT based system and fully integrated platforms are still not widely adopted.
- In conclusion, a strong and well managed cold chain system is crucial for improving food quality, reducing waste and increasing farmers income in Coimbatore City. By addressing the identified challenges through better infrastructure, reliable power supply, modern technology and supportive policies, the cold chain sector can become more efficient, sustainable and beneficial to the agricultural community.

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