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Research on Countermeasures for Transport Route Optimization of Fresh Cold Chain Logistics

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Abstract

With the rapid development of the social economy and the impact of sudden food safety incidents in recent years, the public has gradually begun to attach importance to the safety and hygiene of fresh food. Fresh products have become an important part of the domestic market because of their importance and increasing demand. However, due to the perishability and timeliness of fresh agricultural products, cold chain transportation has become a necessary choice. Taking fresh products as the research object, this paper expounds the concepts and characteristics of fresh food and cold chain logistics. Based on an analysis of the problems existing in fresh cold chain logistics transportation, it proposes optimization countermeasures. The route optimization countermeasures proposed in this study can help fresh cold chain logistics enterprises reduce logistics costs, improve overall operational efficiency, and ensure product quality.

Keywords

Fresh Products; Cold Chain Logistics; Transportation Routes.

1. Research Background and Significance

In recent years, due to the impact of emergencies such as food safety incidents, the transportation of fresh food and strategic materials such as medicines and vaccines has become increasingly important. In logistics transportation, quality assurance for fresh food, medicines, and vaccines is a very critical issue, which requires scientific transportation route planning and the application of cold chain logistics transportation technology. However, in China's current fresh cold chain logistics system, due to limitations in infrastructure and management levels, fresh food is susceptible to ambient temperature, humidity, vibration, and other factors during transportation, resulting in quality decline, waste, and loss.

Socioeconomic development has promoted the public's demand for high-quality fresh products. According to relevant statistics, the total demand for cold chain logistics in the past five years increased from 302 million tons in 2021 to 381.4 million tons in 2025, with a cumulative growth of approximately 26.3%, see Figure 1. This has increased the requirements and challenges for the transportation of fresh agricultural products, making research and improvement in China's cold chain logistics transportation increasingly important. However, because China's cold chain logistics started relatively late and infrastructure construction lags behind, problems such as high cold chain logistics distribution costs, low vehicle loading rates, and long distribution times have arisen [1]. Therefore, it is necessary to conduct specific research on China's fresh cold chain logistics and analyze its transportation status and problems. Through scientific and reasonable route planning and the application of transportation technology, the preservation level of fresh food can be improved, losses and waste can be reduced, people's demand for healthy and safe food can be met, and the coordinated development of agriculture and the logistics industry can be promoted.

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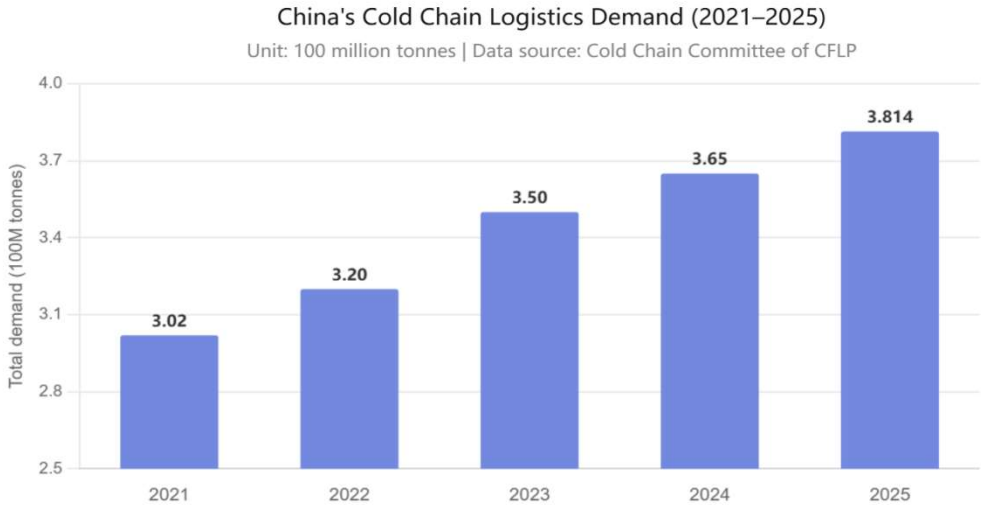


Figure 1. Total Cold Chain Logistics Demand in China over the Past Five Years

2. Domestic and Foreign Research Status

Regarding the problems of fresh cold chain logistics transportation, domestic and foreign experts and scholars have conducted relevant research. The representative viewpoints are mainly as follows.

Regarding the problems existing in fresh cold chain logistics transportation, Liu Mingjun argued that China's lagging cold chain technology, incomplete equipment, and imperfect related measures are key issues that need optimization [2]. Zhou Ran, after comparing the development status of fruit cold chain logistics at home and abroad, concluded that China's fruit cold chain logistics faces problems such as a lack of professional talent and funds as well as backward technology [3]. Fu Kaifang found that China's current fresh agricultural product cold chain logistics has problems such as backward infrastructure and equipment, insufficient professional foundations among personnel, and imperfect relevant laws and regulations, which require further upgrading and improvement [4].

Regarding cold chain logistics vehicle distribution, Li Fang successfully applied JIT production to cold chain logistics distribution and achieved information sharing and real-time monitoring, thereby better selecting appropriate transportation plans [5]. Lan Hongjie, based on the mode selection of food cold chain logistics for the Beijing Olympic Games, created a new evaluation index system, providing reference opinions for the subsequent selection of cold chain logistics modes [6].

Regarding cold chain distribution costs, Sun Lijun proposed an integrated cold chain distribution scheme allowing different temperatures to coexist, greatly reducing the distribution cost of refrigerated trucks [7]. Guo Hongxia proposed measures such as information sharing and logistics service outsourcing to reduce logistics distribution costs [8]. Rong Aiying, through extensive case analysis, proposed that combining product quality with supply chain management in the production and transportation of fresh products can reduce production and distribution costs [9]. Chang Daofang proposed the theory of "service radius", reflecting the relationship between cold chain logistics transportation and service time [10].

Overall, existing research has discussed fresh cold chain logistics transportation from multiple levels, including problem identification, distribution mode optimization, and cost control. Domestic scholars focus on analyzing China's shortcomings in cold chain development and proposing improvement paths at the technical, platform, and institutional levels, while foreign scholars rely more on models and cases to conduct quantitative analysis of distribution

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schemes, service boundaries, and quality-cost coordination mechanisms. However, in general, most studies tend toward single-link optimization, and there is still room for further expansion in research on full-chain coordination of fresh cold chains and multi-objective balance under dynamic environments, which also leaves a research entry point for this study.

3. Overview of Fresh Products and Cold Chain Logistics

3.1. Definition of Fresh Products

Fresh products generally refer to fresh foods that have not been processed or subjected to preservation treatment after harvesting or slaughtering, including but not limited to fruits, vegetables, meat, seafood, poultry eggs, see Table 1. These foods have relatively short shelf lives and need special preservation treatment such as refrigeration or freezing within a short period to maintain their freshness and quality. Because fresh products are perishable and deteriorate easily, higher requirements are placed on the guarantee of their cold chain logistics process, including temperature control and hygiene requirements in links such as harvesting/slaughtering, processing, packaging, storage, and transportation.

Table 1. Categories of Fresh Products

Fresh Food Categories	Category Breakdown
Plant-Based	Vegetables, fruits, flowers, etc.
Animal-Based	Meat, poultry, eggs, seafood, etc.
Prepared Foods	Cooked meat products, soy products, deli meats, etc.
Frozen Foods	Frozen fruits, frozen vegetables, frozen meats, etc.
Chilled Foods	Fresh condiments, fresh dairy products, etc.

3.2. Characteristics of Fresh Products

Perishability: Fresh products usually have high water and nutrient content and are easily affected by factors such as microorganisms, enzymes, and chemical reactions, leading to deterioration.

Seasonality: Different types of fresh products are affected by seasons and climate change, and their production and sales seasons are also different. They need to be produced and sold in different seasons and regions.

Suitable temperature and humidity. According to the type of fresh product, the storage temperature and humidity requirements differ. They need to be stored and transported under specific temperature and humidity conditions to maintain their quality and safety.

Fragility: Fresh products are usually relatively fragile and require special protective measures during transportation and handling to avoid damage or breakage.

3.3. Definition of Cold Chain Logistics

Cold chain logistics refers to a logistics mode in which goods that need to be transported, stored, and sold under low-temperature or constant-temperature conditions (such as fresh food and medicines) maintain their quality and safety throughout the entire logistics chain through specific logistics equipment, transportation modes, management systems, and other means. Its purpose is to ensure temperature control throughout the logistics process and prevent product damage, deterioration, contamination, and other problems. In 2006, the national standard Logistics Terminology defined cold chain logistics as a distribution network that uses low-temperature transportation at different temperatures according to the transportation characteristics of goods to ensure that goods quality remains unchanged.

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3.4. Characteristics of Cold Chain Logistics

Goods are perishable. Most goods in cold chain logistics are perishable foods, medicines, and other special commodities, so measures need to be taken to ensure the freshness and safety of goods during transportation.

High temperature control requirements. In the cold chain logistics process, the temperature of goods needs to be strictly controlled and monitored to ensure that goods remain within the required temperature range throughout the entire transportation process, thereby ensuring goods quality and safety.

Urgent transportation time. Because goods are perishable, transportation time is relatively urgent, requiring cold chain logistics enterprises to complete the transportation of goods in a relatively short time to ensure goods quality and safety.

Professional equipment and technical support are required. Cold chain logistics requires the use of professional transportation equipment and technologies, such as temperature control systems, transport boxes, and insulation materials, to ensure that goods remain within the required temperature range throughout the entire transportation process[11].

4. Problems in Fresh Cold Chain Logistics Transportation

4.1. Insufficient Implementation of Industry Standards and Absence of Market Supervision

China has issued multiple national standards for cold chain logistics, but their implementation shows a structural imbalance of "emphasis on cold storage but neglect of cold transportation." Some logistics enterprises illegally shut down in-transit refrigeration equipment to reduce costs, causing cold chain breaks. Some fresh food e-commerce platforms relax temperature control requirements for cooperating third-party logistics providers to compress distribution costs, thereby affecting the quality of fresh products. At the same time, consumers have insufficient understanding of cold chain logistics and focus more on price in decision-making, with relatively low attention to quality and safety, making China's fresh cold chain market mixed in quality. As a result, compliant enterprises cannot obtain reasonable revenue compensation for their standardized operation costs[12].

4.2. Lack of a Sound Cold Chain Logistics System

Due to multiple aspects such as insufficient infrastructure construction, imperfect logistics distribution links, and lack of quality supervision, there is no complete cold chain preservation system in the logistics transportation process, and it is impossible to provide a stable and safe low-temperature environment to guarantee the quality and safety of fresh products. Because of the lack of a sound cold chain logistics system, many fresh products suffer from quality decline, loss, and waste during transportation, seriously affecting the quality of agricultural products and the profitability of enterprises.

4.3. Outdated Cold Chain Infrastructure and Low Technical Level

China's cold chain logistics for fresh agricultural products started relatively late compared with other industries and has had a short development time. For employees engaged in cold chain logistics work, they need to master knowledge in multiple areas such as logistics management, agricultural product refrigeration technology, and food characteristics. However, at present, employees' professional knowledge is relatively insufficient and needs to be compensated through practical training. Cold chain logistics enterprises need to strictly control the storage environment of agricultural products and maintain temperature stability; otherwise, losses are likely to occur, causing economic losses. Therefore, the cold chain logistics industry needs to continuously inject new vitality and cultivate support from various new types of talent[13].

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4.4. Shortage of Specialized Cold Chain Logistics Talent

At present, employees in the cold chain logistics industry lack professional knowledge. Personnel engaged in cold chain logistics work need to master comprehensive knowledge in multiple aspects such as logistics management, agricultural product refrigeration technology, and food characteristics. However, the educational focus of most universities remains on theoretical teaching, neglecting the importance of practical teaching, resulting in a gap between students' professional knowledge and skills and enterprise needs. The cold chain logistics industry needs support from various new types of talent to continuously inject new vitality into the industry.

5. Countermeasures for Fresh Cold Chain Logistics Transportation

5.1. Improve the Implementation Mechanism of Industry Standards and Establish a Sound Multi-Party Collaborative Supervision System

Further refine supporting implementation rules for cold chain transportation links, reverse the imbalance of "emphasis on cold storage but neglect of cold transportation," and rely on digital temperature-control traceability systems to achieve dynamic in-transit monitoring of fresh cold chains, see Figure 2. Establish a multi-department joint supervision and credit reward-punishment mechanism, consolidate the audit and control responsibilities of fresh food e-commerce platforms for third-party logistics service providers, and at the same time strengthen cold chain safety education to guide consumers to value the quality and safety of fresh products. Through regulatory constraints, platform control, and market demand, jointly promote the implementation of standards and improve the current situation of mixed quality in the industry.

5.2. Conduct Full-Process Temperature Monitoring for Fresh Cold Chain Logistics

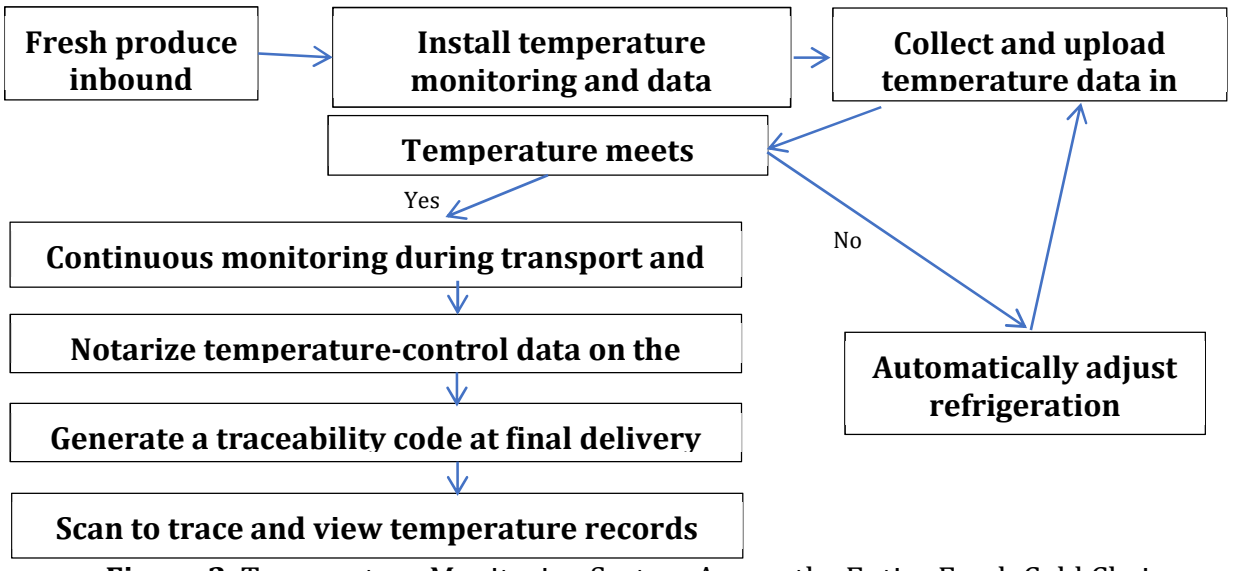


Figure 2. Temperature Monitoring System Across the Entire Fresh Cold Chain

In response to the perishable and deterioration-prone characteristics of agricultural products, the government should encourage cold chain logistics enterprises to adopt low-temperature preservation technology throughout the entire process and install temperature detection instruments to obtain product temperature information at all times. Establish a temperature monitoring management system to adjust temperature changes in real time, use internet

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platforms combined with blockchain technology to achieve traceability of agricultural products, and improve consumers' awareness of and satisfaction with agricultural product cold chain logistics. To achieve full-process temperature monitoring of fresh cold chain logistics, it is necessary to adopt multiple means and technologies and establish a sound management system and traceability system to ensure temperature control and product quality safety in cold chain logistics.The temperature monitoring system for the whole fresh cold chain logistics process is shown below.

5.3. Accelerate the Use of Facilities and Equipment Related to Fresh Cold Chain Logistics and Implement a Standardized Logistics System

Because China has a large population and a very large fresh agricultural product market, the construction of cold chain logistics infrastructure should be accelerated to achieve the hardware preparation for logistics construction, including establishing unified standards and investing in the construction of corresponding cold storage and temperature control facilities, so as to ensure low-temperature preservation of fresh agricultural products throughout the entire process and reduce losses and waste. To ensure preservation during transportation and reduce loss rates, advanced foreign technologies should be introduced to meet the standard requirements of cold chain logistics. China's agricultural product cold chain logistics systems have different standards in different enterprises and regions. The state should promulgate a unified cold chain logistics standard system to improve the operational efficiency of the domestic overall logistics network and create greater economic value.

5.4. Encourage Cold Chain Logistics Personnel to Learn Specialized Knowledge

The state can invite domestic and foreign experts to provide consulting services and promote mutual learning among industry talent. Enterprises can establish professional cold chain logistics departments or teams responsible for internal cold chain logistics management and technology research and development, provide employees with professional training and learning opportunities, and establish reward systems to motivate employees to learn. They should regularly cooperate and exchange with universities or relevant departments, participate in cold chain logistics-related scientific research and education projects, cultivate talent reserves, and maintain good connections with industry experts.

6. Conclusion

Fresh products are indispensable food for the Chinese people. The quality and safety of fresh products are increasingly emphasized by all sectors, making discussion of fresh cold chain logistics risk issues one of the directions valued by the research community and bringing it into the scope of livelihood issues. This paper analyzes four problems existing in China's fresh cold chain logistics transportation and, in response to the current status of fresh cold chain transportation in China, proposes suggestions in multiple aspects, including improving the implementation mechanism of industry standards and establishing a sound multi-party collaborative supervision system, encouraging cold chain logistics personnel to learn specialized knowledge, and expanding funding costs to support research and development of agricultural product cold chain technology.

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