

# Cold Chain Logistics for Fresh Agricultural Products Supply Chain Coordination, Quality Control, and Future Research Directions

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## ABSTRACT

Cold chain logistics for agricultural products plays an essential role in modern agricultural circulation, food quality assurance, and supply chain management. With the expansion of e-commerce and the increasing demand for fresh, safe, and diversified agricultural products, cold chain logistics has become a key mechanism for reducing post-harvest losses, improving product quality, and enhancing farmers' income. This paper reviews existing studies on agricultural cold chain logistics from three perspectives: dual-channel supply chains for fresh agricultural products, quality control and contract coordination in agricultural supply chains, and the current development of cold chain logistics. The review shows that previous studies have made important contributions to channel coordination, freshness preservation decisions, product quality control, source allocation, and third-party logistics participation. However, several limitations remain, including simplified behavioral assumptions, insufficient consideration of real market uncertainty, and limited research on technological innovation and multi-channel integration. Future studies should further integrate digital technologies, cold chain monitoring systems, and realistic behavioral mechanisms to improve the explanatory power and practical applicability of agricultural cold chain logistics research.

## KEYWORDS

Agricultural Products; Cold Chain Logistics; Fresh Agricultural Products; Dual-Channel Supply Chain; Quality Control; Contract Coordination.

## 1. INTRODUCTION

Agricultural products are indispensable to daily life, and their storage, transportation, distribution, and retailing are closely related to food safety and social welfare. Cold chain logistics for agricultural products has therefore become increasingly important in the agricultural economy and food circulation system. In the context of globalization, rising living standards, and changing consumption patterns, consumers have placed higher requirements on the freshness, safety, and diversity of agricultural products.

As a specialized logistics system, agricultural cold chain logistics covers the entire process from production to final consumption, including pre-cooling, refrigerated storage, cold-chain transportation, warehousing, and retail distribution. Through accurate control of temperature and humidity, cold chain logistics can effectively slow product deterioration, reduce losses during circulation, and improve the quality and safety of agricultural products. It can also increase the economic returns of farmers by reducing waste and enhancing market competitiveness.

Existing studies have examined agricultural cold chain logistics from multiple perspectives, including supply chain coordination, freshness preservation, quality control, contract design, and logistics

infrastructure. Based on the reviewed literature, this paper discusses three main research areas: dual-channel supply chains for fresh agricultural products, quality control and contract coordination in agricultural supply chains, and the current situation and development of agricultural cold chain logistics.

## **2. DUAL-CHANNEL SUPPLY CHAINS FOR FRESH AGRICULTURAL PRODUCTS**

With the rapid development of Internet technology and e-commerce platforms, agricultural product sales have gradually shifted from traditional offline channels to integrated online and offline channels. This dual-channel supply chain model provides consumers with more convenient access to fresh agricultural products from different regions. At the same time, it also creates new coordination challenges. Fan et al. examined channel conflicts in dual-channel supply chains for fresh agricultural products under an e-commerce environment<sup>[1]</sup>. When online channels are introduced, suppliers and retailers may face conflicts related to pricing, freshness preservation, promotion, consumer experience, and benefit distribution.

Channel selection and product quality differentiation are also important issues in dual-channel supply chains. Ha et al. found that manufacturers may prefer to place high-quality products on online platforms while offering lower-quality products through offline channels<sup>[2]</sup>. Wang et al. further showed that when the cost difference between online and offline channels is small, quality differentiation benefits offline retailers more; when quality differentiation is limited, manufacturers may obtain greater advantages<sup>[3]</sup>. These findings indicate that channel operating costs and product positioning jointly influence channel strategy and profit distribution.

Freshness preservation is a distinctive feature of fresh agricultural product supply chains. Tang and Peng incorporated time and temperature factors into a freshness function and market demand function to study coordination mechanisms in a fresh food supply chain where traditional retail channels and online direct channels coexist<sup>[4]</sup>. Their differential game model, which considers the freshness preservation effort of supply chain members, provides a useful analytical framework for improving coordination efficiency and competitiveness. In a similar vein, Chen and Cai considered consumer sensitivity to freshness and channel preferences and constructed a sequential game model involving producers, retailers, and cold chain logistics service providers under self-operated preservation and outsourced preservation scenarios<sup>[5]</sup>. Chen, Cai, and Cao further investigated source allocation strategies in dual-channel agricultural supply chains under limited supply and freshness competition<sup>[6]</sup>.

## **3. QUALITY CONTROL AND CONTRACT COORDINATION IN AGRICULTURAL SUPPLY CHAINS**

Quality control is another central topic in agricultural supply chain research. Under innovation-driven conditions, Zhu et al. developed a quality control model for a three-level distribution channel consisting of a manufacturer, two competing retailers, and final consumers<sup>[7]</sup>. Their study explored how distribution channel strategies and product quality control decisions can be designed to improve supply chain performance. Shen et al. examined product quality control in dual-channel supply chains under uncertain demand and used game analysis to identify optimal strategies for manufacturers and retailers under different conditions<sup>[8]</sup>.

Traceability systems have also attracted increasing attention in agricultural supply chain quality management. Chen et al. studied cooperative investment and pricing decisions in a dual-channel supply chain with a traceability system<sup>[9]</sup>. Such systems can enhance the traceability of agricultural product quality and strengthen consumer trust. Tang et al. considered quality loss in the dual-channel sale of fresh agricultural products and analyzed market-clearing strategies under a given level of

output<sup>[10]</sup>. These studies suggest that quality control should not be treated as an isolated production issue; rather, it should be integrated with channel choice, pricing, demand response, and consumer trust.

Contract coordination is essential for improving the stability and efficiency of agricultural supply chains. Yue et al. investigated coordination contracts in a retailer-led fresh dual-channel supply chain<sup>[11]</sup>. Since retailer-led supply chains are characterized by strong market power on the retail side, retailers' decisions can substantially affect the operational efficiency of the whole system and the benefit distribution among members. Feng et al. evaluated contract efficiency in a fresh agricultural product supply chain with the participation of third-party logistics providers under retailer dominance<sup>[12]</sup>. The involvement of third-party logistics can provide specialized logistics services, reduce logistics costs, and improve operational efficiency, but it also requires appropriate contract mechanisms to coordinate the interests of supply chain members.

#### **4. CURRENT DEVELOPMENT OF AGRICULTURAL COLD CHAIN LOGISTICS**

The development of e-commerce has expanded the market for fresh agricultural products, but it has also exposed weaknesses in cold chain logistics infrastructure. Chen and Huang analyzed the current situation and development of e-commerce cold chain logistics for fresh agricultural products in China<sup>[13]</sup>. They pointed out that although agricultural products have gained broader market access through e-commerce, cold chain logistics networks remain insufficient, and full-process cold chain services are still difficult to achieve in many regions.

In practice, simple preservation methods such as “foam boxes plus ice” are still widely used, but these methods have limited preservation effects and low standardization. High cold chain logistics costs, weak profitability, shortages of professional talent, and insufficient technological innovation also restrict industry development. To improve cold chain logistics for fresh agricultural products, it is necessary to strengthen infrastructure construction, increase cold chain coverage, and improve standardization. Advanced technologies, such as cold chain monitoring systems, modified-atmosphere preservation, and intelligent temperature-control equipment, should be promoted to enhance product quality and reduce losses.

Policy support and industry collaboration are also important. Governments should provide targeted support for cold chain logistics enterprises, improve market regulation, and ensure the quality and safety of fresh agricultural products. At the same time, enterprises should strengthen cooperation and build cold chain logistics alliances to realize resource sharing, complementary advantages, and coordinated development across production, transportation, warehousing, and sales.

#### **5. OVERALL EVALUATION AND FUTURE PROSPECTS**

Overall, research on agricultural cold chain logistics has produced valuable findings in several areas. In supply chain coordination, scholars have used game models and contract mechanisms to analyze cooperation and competition among members of dual-channel agricultural supply chains. These studies have proposed coordination strategies that improve system efficiency and stability. In freshness preservation and source allocation, existing research has incorporated factors such as consumer freshness sensitivity, channel preference, limited supply, and preservation effort, thereby offering decision-making support for enterprises. In quality control and market-clearing strategies, studies have explored how to maintain product quality and achieve effective sales under complex market conditions. In contract coordination, scholars have analyzed how different contract forms influence benefit distribution and coordination among supply chain members.

Despite these contributions, several limitations remain. Some studies rely on simplified assumptions, such as fully rational consumers or completely symmetric market information, which may deviate from real market conditions. In practice, consumer behavior is affected by income, trust, habit, channel experience, and risk perception. In addition, the complexity of some models and the difficulty of solving them may limit their practical application. Future research should relax restrictive assumptions, incorporate behavioral factors, and make models more consistent with real operating environments.

Future studies should also pay more attention to technological innovation and multi-channel integration in agricultural cold chain logistics. Digital technologies such as the Internet of Things, blockchain, big data analytics, and intelligent temperature monitoring can improve the transparency and efficiency of cold chain operations. At the same time, the integration of online platforms, offline retailers, logistics service providers, and agricultural producers requires new coordination mechanisms. Further research should combine theoretical modeling with empirical data and case studies to provide stronger theoretical support and more practical guidance for the sustainable development of agricultural cold chain logistics.

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