Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 20, No. 2, 2025

Research on Optimization Strategies for Cold Chain Logistics of Fresh Food in Cross border E-commerce

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Abstract: In recent years, with the rapid development of global economic integration and e-commerce, cross-border e-commerce has become an important growth point in international trade. Fresh food, as a high demand category in cross-border e-commerce, places extremely high demands on the logistics supply chain due to its perishability and strong timeliness. Cold chain logistics, as a core link in ensuring the quality and safety of fresh food, directly affects consumers' shopping experience and the operating costs of enterprises. However, the current cold chain logistics of fresh food in cross-border e-commerce still faces many challenges, such as complex cross-border transportation links, insufficient temperature control technology, high logistics costs, and low efficiency of end of pipe delivery, resulting in high product loss rates and unstable delivery times, which restrict the further development of the industry. At the same time, consumers' demands for the quality, freshness, and delivery speed of fresh food are increasing day by day. In addition, countries are tightening their regulations on food safety and cold chain standards. Enterprises urgently need to optimize their cold chain logistics systems to enhance their competitiveness. In recent years, the application of emerging technologies such as the Internet of Things, big data, and blockchain has provided new solutions for the intelligence and visualization of cold chain logistics. However, how to deeply integrate these technologies with cross-border logistics scenarios and build an efficient, low-cost, and sustainable cold chain logistics network remains a key issue worthy of in-depth research. Therefore, this article focuses on the optimization strategy of cross-border e-commerce fresh food cold chain logistics and conducts systematic research in this field. The research provides theoretical and practical guidance for the development of cross-border fresh cold chain logistics, which is of great significance for promoting high-quality industry development, ensuring food safety, and promoting global fresh trade.

Keywords: Cross border e-commerce; Fresh food; Cold chain.

1. Introduction

With the acceleration of globalization and the flourishing development of the digital economy, cross-border e-commerce has become an important link connecting the global fresh food market. In recent years, the demand for imported fresh food among Chinese consumers has shown explosive growth [1]. From Chilean cherries, Thai durians to Norwegian salmon, various high-quality fresh products have entered ordinary households through cross-border e-commerce platforms. In 2024, the transaction volume of fresh food in China's cross-border e-commerce exceeded 800 billion yuan, a year-on-year increase of 35%. Behind the continuous expansion of the market size is the unremitting pursuit of consumers for a better quality of life.

However, fresh food has special properties such as perishability and strong timeliness, and its cross-border circulation places extremely high demands on cold chain logistics. Cold chain logistics, as the lifeline of cross-border fresh food trade, directly determines the freshness, quality, and safety of products, and is also a core link that affects consumer experience and corporate competitiveness. At present, China's cross-border e-commerce fresh food cold chain logistics still faces many challenges: the high loss rate caused by unstable temperature control in the international transportation process, and the loss rate of some categories exceeding 20%; The delivery delay caused by the poor connection of multimodal transportation, with an average delivery cycle of 7-15 days for cross-border orders; The regulatory barriers caused by the lack of unified cold chain standards among countries, as well as the uneven distribution of cold chain infrastructure and lagging technological applications, not only drive up the operating costs of enterprises, but also constrain the sustainable development of the cross-border fresh e-commerce industry.

2. Overview of Cross border Cold Chain Logistics

2.1. Definition of Cross border Cold Chain Logistics

Cross border cold chain logistics refers to a systematic logistics activity that meets the circulation needs of fresh food between different countries and regions by using a series of professional temperature control technologies and logistics management methods to ensure that products are in a suitable temperature environment from the production source to the end consumers [2]. It not only covers the basic links of traditional cold chain logistics such as warehousing, transportation, and distribution, but also involves special processes such as customs clearance, inspection and quarantine, and international transportation cooperation in cross-border trade. Compared with domestic cold chain logistics, the core difference of cross-border cold chain logistics lies in its cross-border nature, which requires dealing with different countries' laws and regulations, technical standards, cultural differences, and complex geographical environments. For example, in the transportation process, it may be necessary to connect through various methods such as sea refrigerated containers, aviation cold chain lines, and land refrigerated trucks, and each link needs to maintain precise temperature control to ensure the quality and safety of fresh food. At the same time, cross-border cold chain logistics also relies on information technology to achieve full process visual

tracking. Through technologies such as global positioning system (GPS), temperature sensors, and blockchain, real-time monitoring of the status of goods is provided, providing reliable logistics support for cross-border fresh trade and serving as a key link connecting the global fresh food market.

2.2. Basic Principles of Cross border Cold Chain Logistics

The efficient operation of cross-border cold chain logistics requires adherence to multiple core principles, which together form the fundamental framework for ensuring the cross-border circulation of fresh food [3]. The first principle is the precision of temperature control. Fresh food is extremely sensitive to temperature, and different categories of products have strict temperature range requirements. For example, frozen meat needs to be kept below -18 ℃, and tropical fruits need to be controlled at 10-15 ℃. Cross border cold chain logistics must use professional equipment and technical means to ensure that the temperature fluctuations throughout the entire process are controlled within the allowable range, avoiding product deterioration caused by temperature loss of control. Secondly, there is the principle of timeliness. The freshness of fresh food decreases over time, and cross-border logistics links are long and complex. Therefore, it is necessary to optimize transportation routes, simplify customs clearance processes, and improve transit efficiency to minimize circulation time. For example, air transportation can be used to shorten the delivery cycle of intercontinental fresh food, or multimodal transportation can be used to reduce transit waiting time. Furthermore, there is the principle of full traceability throughout the entire process. As cross-border logistics involves multiple countries and regions, once quality issues arise, it is necessary to quickly locate the responsible link. Therefore, it is necessary to establish a traceability system that covers the entire chain of production, transportation, warehousing, and sales, recording product sources, temperature data, inspection and quarantine information, etc., to achieve "traceable sources, traceable destinations, and accountable responsibilities". In addition, compliance principles must be followed. Different countries have different import quarantine standards, packaging requirements, labeling specifications, etc. for fresh food. Cross border cold chain logistics must strictly comply with relevant regulations to ensure smooth customs clearance of goods, while also complying with environmental protection requirements to reduce the negative impact of cold chain transportation on the environment.

2.3. Cold Chain Composition of Fresh Food

The fresh food cold chain is a complex system composed of multiple closely connected links, which work together to ensure the stable quality of products from the origin to the consumer end [4]. Firstly, there is the pre-processing stage, which is the starting point of the cold chain, including the picking, fishing, and preliminary processing of fresh food after slaughter, such as cleaning, grading, packaging, etc. For example, pre cooling treatment is required after fruit picking to quickly reduce field heat, delay respiration, and lay the foundation for subsequent cold chain links; Meat needs to be cooled and acidified to enhance its texture and extend its shelf life. Next is the warehousing process, which is divided into refrigerated and frozen warehouses based on the characteristics of fresh food, equipped with temperature monitoring systems, shelf storage equipment, etc., to achieve temporary storage and management of bulk products. In the warehousing process, attention should be paid to inventory turnover to avoid a backlog of goods leading to a decrease in quality, while improving storage and retrieval efficiency through scientific warehouse location planning. Next is the transportation link, which is the core link of cross-border cold chain, including various methods such as international sea freight, air freight, and land freight. Ocean freight usually uses refrigerated containers, which can be remotely controlled to maintain a stable temperature; Air transportation relies on professional aviation refrigerated containers, which are suitable for high-value and high time efficient products; Land transportation mainly relies on refrigerated trucks, flexibly connecting ports, airports, and terminal markets. During transportation, it is necessary to ensure proper connection between different modes of transportation to reduce temperature fluctuations. Finally, there is the terminal distribution process, where products are delivered from local warehouses or distribution centers to consumers using small refrigerated trucks, insulated boxes, and other equipment to ensure temperature control for the "last mile". At the same time, intelligent scheduling systems are used to optimize distribution routes, improve delivery efficiency, and ultimately complete the full chain closed-loop of fresh food cold chain [5].

3. Challenges Faced by Cross-Border E-Commerce Fresh Food Cold Chain Logistics

3.1. Difficulties in Temperature Controlled Transportation

The temperature controlled transportation of fresh food in cross-border e-commerce is one of the most complex links in the cold chain logistics chain, and its core contradiction lies in how to maintain a stable temperature environment during long-distance and multi link transportation. Firstly, there is a natural discontinuity in the connection of international transportation modes. For example, during the lifting process of sea freight refrigerated containers at ports, the temperature inside the container may fluctuate due to exposure to high temperatures, while during the transfer of aviation cold chains, if the ground temperature control equipment is insufficient, the short 30 minute loading and unloading time may cause the temperature at the center of the cargo to rise by more than 5 ℃. Secondly, climate differences in different regions exacerbate the difficulty of temperature control. From tropical fruits in equatorial regions to frozen seafood in cold regions, intercontinental transportation requires dealing with extreme temperature differences of -30 ℃ to 25 ℃, making it difficult for ordinary refrigeration equipment to achieve dynamic temperature regulation. In addition, the long-term nature of cross-border transportation amplifies temperature control risks. Taking sea freight as an example, the fresh food transportation cycle from South America to China is usually 25-35 days. Even advanced refrigerated containers may experience temperature loss due to equipment failures, human operational errors, etc. Data shows that about 12% of fresh products in this type of transportation experience quality loss due to temperature control issues. Finally, the temperature control loopholes in the "last mile" delivery are particularly prominent. In some areas, the end delivery vehicles lack real-time temperature control function, and delivery personnel

frequently open and close the doors in pursuit of efficiency, resulting in the failure of the refrigeration environment. The loss rate in this link can even reach up to 20%.

3.2. High Costs

The cost pressure of cross-border e-commerce fresh food cold chain logistics runs through the entire chain, becoming a key bottleneck restricting the development of the industry. From the perspective of hardware investment, the purchase and maintenance costs of professional cold chain equipment are significantly higher than those of ordinary logistics. The cost of an international standard refrigerated container is about three times that of an ordinary dry cargo container, and 15% of the annual purchase cost needs to be invested in refrigeration system maintenance; The unit price of professional cold chain transport vehicles generally exceeds 800000 yuan, which is 2-3 times that of ordinary trucks. In terms of operating costs, the energy consumption expenditure of cross-border cold chain is astonishing. Refrigerated containers consume 30-50 kWh of electricity per day during sea transportation, and the total electricity cost accounts for 25% of the transportation cost; The freight cost of air cold chain is 1.5-2 times that of ordinary goods, and the freight cost per kilogram of fresh food by air from Europe to China exceeds 60 yuan. In addition, the additional costs of cross-border links are layered, including inspection and quarantine fees from customs of various countries (averaging 3-5% of the value of the goods), cold chain insurance fees (annual premium of about 2% of the value of the goods), and demurrage fees caused by customs clearance delays (up to thousands of yuan per day). The cost of labor cannot be ignored, as technical personnel with cross-border cold chain operation qualifications earn salaries more than 40% higher than ordinary logistics practitioners, and the global shortage of such professionals further drives up labor costs. Data shows that the comprehensive cost of cross-border fresh food cold chain is about 3-4 times that of ordinary cross-border logistics, directly compressing the profit margin of enterprises.

3.3. Technical bottleneck constraints

There are multiple bottlenecks in the technical application of cross-border e-commerce fresh food cold chain logistics, which seriously hinder the improvement of industry efficiency and the guarantee of quality. In terms of hardware technology, the energy consumption and temperature control accuracy of refrigeration equipment are prominent issues. The widely used mechanical compression refrigeration equipment currently has an energy utilization rate of only 30% -40%, far below the international advanced level, and is prone to sudden drops in refrigeration efficiency in extreme temperature environments; Although the new magnetic refrigeration and adsorption refrigeration technologies have lower energy consumption, they are expensive and have not yet been widely applied. The unit price of equipment is more than five times that of traditional equipment. There are also significant shortcomings in information exchange technology. The technical standards and data formats used by cold chain information platforms in different countries and enterprises vary greatly. For example, the EU's cold chain data exchange is mostly based on the EDIFACT standard, while China mainly uses XML format, resulting in "information silos" in cross-border data sharing, and the success rate of data docking is less than 60%. In terms of data collection and transmission, the error range of traditional temperature sensors is generally within ± 2 ℃, which is difficult to meet the accuracy requirement of ± 0.5 ℃ for high-end fresh products; Moreover, in ocean transportation, unstable satellite signals result in a real-time data transmission interruption rate of up to 30%, making it impossible to achieve true full process visual monitoring. In addition, the application depth of intelligent decision-making systems is insufficient, and most enterprises still rely on manual experience to plan transportation routes. The popularity rate of intelligent scheduling systems based on big data is less than 20%, resulting in a transportation empty load rate 15-20 percentage points higher than the international advanced level. Technological lag has become a core obstacle to the upgrading of cross-border cold chains.

3.4. Food Safety Risks

The food safety risks faced by cross-border e-commerce fresh food in the cold chain logistics link present complex and transnational characteristics, seriously threatening consumer health and industry reputation. Firstly, the differences in food safety standards among countries pose hidden dangers. For example, Japan has more than 500 pesticide residue testing items for imported vegetables, while some exporting countries only have 100-200 testing items. The differences in standards have led to some products that were qualified in the exporting country being judged as unqualified after entering the importing country. In 2023, China's customs returned 12000 batches of cross-border fresh products due to excessive pesticide residues. The most common risk is microbial growth caused by temperature control failure. Studies have shown that when the temperature fluctuation of refrigerated meat exceeds 5 ℃, the growth rate of Escherichia coli will increase by 3-5 times. About 15% of batches in cross-border transportation will experience temperature abnormalities exceeding 8 ℃, directly leading to product spoilage. The issue of packaging damage cannot be ignored. Cross border transportation of fresh food involves multiple loading, unloading, and transit processes, with an average packaging damage rate of 8% -12%. Among them, seafood products have a damage rate of over 15% due to leakage of ice packs and moisture in cardboard boxes. After damage, not only does it accelerate product deterioration, but it may also cause cross contamination. In addition, the lack of transparency in supply chain information exacerbates risk transmission. Some companies use inferior cold chain equipment or forge temperature control records to reduce costs. In the "pseudo cold chain" incident exposed by a cross-border e-commerce platform in 2024, the involved companies disguised imported fruits transported at room temperature as cold chain transportation by tampering with temperature data, causing thousands of consumers to experience gastrointestinal discomfort after consuming them. The broken traceability chain of cross-border fresh produce also makes it difficult to trace risks. About 40% of imported fresh produce cannot provide complete cross-border cold chain records. Once safety issues arise, it is difficult for consumers to protect their rights.

3.5. Shortcomings in the Regulatory System

The regulatory system for cold chain logistics of fresh food in cross-border e-commerce is significantly fragmented and uncoordinated, which seriously restricts the standardized development of the industry. Firstly, the differences in regulatory standards among countries have created natural

barriers. For example, the EU's microbiological requirements for imported fresh produce differ from those of ASEAN countries in more than 20 testing items. The US FDA requires a retention period of 2 years for cold chain temperature records, while some developing countries only require a retention period of 6 months. These conflicting standards require companies to customize completely different cold chain solutions for different markets, increasing compliance costs by more than 30%. Secondly, there is a serious lack of cross-border regulatory cooperation mechanisms. The cross-border circulation of fresh food involves multiple regulatory entities such as producing countries, transit countries, and importing countries. However, there is currently a lack of a unified international coordination organization, resulting in a cross-border dispute resolution cycle of 3-6 months. A case showed that a batch of imported beef detained due to labeling discrepancies was ultimately detained at the port for more than 45 days due to the three countries' regulatory authorities shirking responsibility, resulting in total losses. There is also a problem of cross departmental responsibilities in domestic regulation. Customs, market supervision, agriculture and rural areas have their own regulatory powers, but lack a unified data sharing platform. The same batch of goods may face duplicate testing, and the regulatory process in the customs clearance stage alone is 5-8 steps longer than that of ordinary goods, with an average extension of more than 24 hours in customs clearance time. In addition, regulatory technology is relatively lagging behind, and most countries still rely on manual sampling, with a sampling rate of less than 5%, making it difficult to cover the entire quantity of goods; However, the traceability system of cross-border cold chain has not yet formed a closed loop, and about 60% of cross-border fresh products cannot achieve interconnectivity of full process supervision data, which makes it difficult to quickly trace and hold accountable problematic products.

4. Optimization Strategy for Cold Chain Logistics of Fresh Food in Cross-Border E-Commerce

4.1. Driven by Technological Innovation

Technological innovation is the core driving force for breaking through the bottleneck of cross-border e-commerce fresh food cold chain logistics, which requires a dual approach of hardware upgrading and digital transformation. In terms of hardware equipment, new energy-saving refrigeration technologies such as magnetic refrigeration and thermoelectric refrigeration should be vigorously promoted. These technologies can reduce energy consumption by 30% - 50% compared to traditional compression refrigeration, and can achieve more accurate temperature control (with an error range reduced to ± 0.5 ℃), especially suitable for high-end seafood, berries and other products that are sensitive to temperature. At the same time, modular cold chain equipment suitable for cross-border multimodal transportation is being developed, such as intelligent refrigerated containers that can quickly switch between sea and air transportation modes. The built-in adaptive temperature control system can automatically adjust the cooling power according to the transportation mode. Currently, this technology has reduced cross-border transportation loss rates by 12% in pilot projects in Europe and America.

At the level of digital transformation, building a cross-border cold chain traceability platform based on blockchain is key. By storing production information, inspection and quarantine data, and temperature control records on the blockchain, the full lifecycle traceability of "one item, one code" can be achieved. Consumers can scan the code to view all information of the product from the place of origin to the dining table. This technology has increased consumer trust by 25% in the cross-border fresh food pilot of Hainan Free Trade Port in 2024. In addition, the introduction of artificial intelligence and big data optimization scheduling system automatically generates the optimal transportation route and transit plan by analyzing historical transportation data, real-time weather conditions, customs clearance efficiency and other factors. After a cross-border e-commerce enterprise applied the system, the average cross-border delivery time was shortened by 18% and the empty load rate was reduced by 15 percentage points. The deep application of Internet of Things technology is also indispensable. Multi dimensional sensors are installed in refrigeration equipment to collect real-time data such as temperature, humidity, vibration, gas concentration, etc., which are transmitted to the cloud monitoring platform through 5G network. Once an abnormality occurs, an alert is immediately triggered, and the response speed is more than 10 times faster than traditional manual inspection.

4.2. Mode Innovation Integration

Model innovation is an important way to improve the efficiency of cross-border e-commerce fresh cold chain logistics. It needs to break the limitations of traditional single model and build a diversified integration system. The integration of online and offline (O2O) models can effectively shorten the supply chain chain, such as setting up cross-border fresh food experience stores at major import ports. After consumers place orders online, they rely on pre installed cold storage to achieve "online ordering, offline 3-hour delivery". This model has been piloted in cities such as Shanghai and Guangzhou, with order fulfillment efficiency increased by 40% and return rates reduced to below 5%. At the same time, experience stores can also serve as offline display windows, enhancing consumer trust through physical displays and driving online sales growth of over 30%.

The upgrade of multimodal transport mode is the key to solving the problem of cross-border long-distance transportation, and a combination of transportation networks such as "sea+railway+road" and "air+land" should be established. For example, by opening the "China Europe Cold Chain Express" and relying on dedicated refrigerated containers to achieve constant temperature transportation, the time for transporting European meat and dairy products to China is shortened by 15 days compared to sea transportation, and the cost is reduced by 60% compared to air transportation; Promote the "sea+land transportation connection" model on Southeast Asian routes, and establish regional cold chain hubs in countries such as Vietnam and Thailand to achieve seamless integration between cross-border sea transportation and local land transportation, improving delivery efficiency by 25%. In addition, the development of an integrated model of "non vessel operating common carrier+cold chain logistics" has enabled professional logistics companies to integrate sea freight, customs clearance, warehousing, distribution and other links, providing "door-to-door" full process services. After adopting this model, a certain enterprise reduced customer logistics management costs by 20% and the order error rate decreased to below 3%.

The shared cold chain model can effectively activate idle resources by building a cross-border cold chain resource sharing platform, integrating the transportation needs of small and medium-sized e-commerce enterprises, and achieving LCL transportation and cold storage sharing. For example, in the southern region of China, more than 30 small and medium-sized cross-border e-commerce companies jointly purchase refrigerated transportation capacity through a shared platform, reducing unit transportation costs by 18%; The application of shared cold storage has increased the utilization rate of storage resources from 60% to 85%, significantly reducing the initial investment threshold for small and medium-sized enterprises.

4.3. Strengthen infrastructure construction

Infrastructure is the hardware support for the development of cross-border e-commerce fresh cold chain logistics, and it needs to be systematically upgraded to address the current issues of uneven layout and outdated technology. In terms of cross-border hub node construction, we should focus on building an international cold chain logistics hub along the "the Belt and Road". At major import ports such as Shanghai Yangshan Port, Qingdao Port and Guangzhou Nansha Port, we should build a comprehensive cold chain logistics park with bonded functions, equipped with ultra-low temperature cold storage (-60 ℃), multi temperature zone sorting center, intelligent three-dimensional storage system and other facilities, and at the same time access to the customs "single window" to achieve "one inspection, global access". At present, the customs clearance efficiency of Yangshan Port cold chain park has increased by 50% compared with the traditional model.

The improvement of transportation network needs to take into account both international and domestic levels. The international end should strengthen cross-border cold chain dedicated lines, open fresh food charter routes such as "China South America" and "China Middle East", and use fully cargo modified cold chain aircraft to achieve wide temperature control from -20 ℃ to 25 ℃, meeting the transportation needs of different types of fresh food; 1000 standardized refrigerated trucks will be deployed on Southeast Asian routes to standardize vehicle specifications and temperature control standards, solving the problem of "mismatched vehicle models and difficult temperature control standardization" in cross-border land transportation. We will focus on building a cold chain distribution network domestically, and establish regional distribution centers in provincial capital cities and regional center cities, equipped with automatic sorting equipment and short distance distribution fleets, to achieve efficient connection between "ports distribution centers terminals". After a logistics enterprise built this network in North China, the delivery time in the region was shortened from 48 hours to 24 hours.

The shortcomings of rural cold chain also need to be addressed by accelerating the construction of small and medium-sized cold storage facilities in county-level areas, equipped with mobile refrigerated trucks, to solve the "last mile" temperature control problem. For example, in Yunnan's fresh flower cold chain logistics, the loss rate of fresh flowers was reduced from 30% to 12% through the construction of county-level cold storage+cold chain through train mode, effectively supporting the development of cross-border fresh flower e-commerce. At the same time, we will promote the intelligent transformation of traditional cold storage by installing temperature monitoring systems, automatic loading and unloading equipment, energy management systems, etc. The transformed cold storage will reduce energy consumption by 20% and increase operational efficiency by 35%.

4.4. Improve the Regulatory System

The improvement of the regulatory system is the institutional foundation for ensuring the standardized development of cross-border e-commerce fresh food cold chain logistics, and requires the construction of a multi-level and cross regional collaborative regulatory framework. Establishing an international coordination mechanism for cold chain standards is the primary task, promoting the signing of cold chain standard mutual recognition agreements between China and major trading partners, and reaching consensus on temperature control, packaging specifications, inspection and quarantine, traceability requirements, and other aspects. For example, jointly developing the "Cross border Fresh Cold Chain Logistics Operation Guidelines" with ASEAN countries, unifying 15 key indicators. After the implementation of this agreement, the clearance time for bilateral fresh food has been shortened by 30%, and the repeat testing rate has been reduced by 40%. At the same time, actively participate in the formulation of international standards, transform China's technological achievements in blockchain traceability, intelligent temperature control and other fields into international standards, and enhance the industry's discourse power.

Domestic regulation needs to strengthen coordination and linkage, establish a cross-border cold chain joint meeting system led by the General Administration of Customs and involving multiple departments such as the State Administration for Market Regulation, the Ministry of Transport, and the Ministry of Agriculture and Rural Affairs, report regulatory data on a monthly basis, and coordinate the resolution of cross departmental issues. Establish a nationwide unified cross-border cold chain supervision information platform, integrating inspection and quarantine data, temperature control records, customs clearance information, etc. from various departments, achieving "one-time entry and multi department sharing". After the platform is launched, the declaration time of enterprises is reduced by 50%, and the collaborative efficiency of regulatory departments is improved by 60%. Innovate regulatory techniques, promote the "Internet+supervision" model, conduct off-site supervision by accessing real-time data from cold chain logistics platforms, and implement "key supervision+random sampling" for high-risk categories. The coverage rate of spot checks has increased from 5% to 20%, and the efficiency of investigating and punishing illegal and irregular behaviors has increased threefold.

The full chain coverage of the traceability system is the core lever of supervision, which requires cross-border fresh food to be accompanied by a unique traceability code, recording the entire process information from production, processing, transportation, warehousing to sales, achieving "scan code and traceability". Establish a cross-border cold chain credit supervision mechanism to evaluate the compliance, temperature control performance, and problem-solving efficiency of enterprises. A-level enterprises can enjoy preferential policies such as customs clearance convenience and sampling reduction, while D-level enterprises are blacklisted and restricted from imports. This differentiated supervision has increased the compliance rate

of enterprises to over 90%.

4.5. Talent Cultivation and Introduction

The supply of professional talents is the intellectual guarantee to support the high-quality development of cross-border e-commerce fresh cold chain logistics, and it is necessary to build a full chain talent system of "training+introduction+retention". The reform of the talent cultivation system in universities needs to be accelerated. Cross border cold chain courses should be offered in logistics management, food science and engineering, international economics and trade, and other majors. Special courses such as "International Cold Chain Logistics Practice", "Cross border Fresh Food Safety Management", and "Cold Chain Technology and Application" should be added. At the same time, training bases should be jointly established with cross-border e-commerce and logistics enterprises, and enterprise mentors should be introduced to participate in teaching, achieving a seamless connection between "on campus learning+enterprise practice". After a certain university established this direction, the employment rate of graduates reached 98%, and the professional matching rate exceeded 80%.

Vocational skills training should cover practitioners across the entire industry chain. Standardized training courses should be developed for different positions such as cold storage operators, cold chain transport drivers, and customs clearance specialists. Through theoretical lectures and practical exercises, their abilities in temperature control operation, equipment maintenance, emergency response, etc. should be improved. Establish a cross-border cold chain vocational skill level recognition system, divided into three levels: primary, intermediate, and advanced, directly linked to salary and job promotion, to encourage employees to actively improve their skills. After the implementation of this system in a certain province, the skill compliance rate of cold chain operators has increased from 60% to 85%.

The introduction of high-end talents is a quick way to fill the talent gap. A special talent introduction plan is formulated, focusing on introducing experts with rich experience in international cold chain standard setting, intelligent temperature control technology research and development, cross-border logistics management and other fields. Supporting policies such as relocation subsidies, research funding, and children's education are provided. At the same time, a talent exchange mechanism has been established with internationally renowned cold chain enterprises and research institutions. Every year, key personnel are selected to study advanced technology and management experience overseas. After introducing five international experts through this method, a certain enterprise has achieved three breakthroughs in the research and development of intelligent dispatch systems, and its technical level has reached international advanced level. In addition, creating a favorable environment for talent development, establishing incentive mechanisms guided by abilities and performance, and rewarding teams and individuals who have made outstanding contributions in cold chain technology innovation, efficiency improvement, security, etc., will enhance the attractiveness and sense of belonging of industry talents.

5. Conclusion

Cross border e-commerce fresh food cold chain logistics is crucial for trade development, currently facing multiple challenges such as temperature control, cost, and technology. Through technological and model innovation, strategies such as strengthening infrastructure, improving supervision, and cultivating talents can solve problems. In the future, we need to continue to break through technology, deepen international cooperation, promote efficient and safe development of the industry, and contribute to the prosperity of global fresh food trade.

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