Innovative research on refrigeration technology of cold chain logistics

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Abstract: With the increasing demand for frozen food in China, the need for better cold chain logistics is also becoming more urgent, promoting the development of related new technologies. This paper focuses on the research of ice slurry and intelligent temperature control technology in cold chain logistics, expounds on the research background, present situation and innovation research, and finally discusses the problems existing in cold chain logistics technology and corresponding solutions.

1. Introduction
In recent years, cold chain logistics in China has grown rapidly, with a total demand of nearly 200 million tons. But at present, cold chain logistics in China is still far behind, and advanced technology can not only greatly expand the service range of cold chain logistics and promote the further development and upgrading of trade, but also minimize the energy consumption in transportation and reduce costs, which is crucial for economic development. Many new technologies have been developed and applied to warehousing and transportation due to the rapid development of cold chain logistics.

2. Ice slurry technology
Ice is difficult to transport and cost much. Its sharp edge can easily cause external damage to food. Besides, ice cannot fully contact with food, resulting in low refrigeration efficiency, which drives the emergence of ice slurry as a new refrigeration medium [1].

2.1 Present research status of ice slurry
Ice slurry, also known as slurry ice and binary ice, is a new type of cold storage medium, which has both the cooling capacity of ice and the fluidity of aqueous solution [2]. Ice slurry is a kind of two-phase mixed solution composed of granular ice particles (0.2-0.8mm in diameter) and aqueous solution (salt water, sea water, etc.). Its cooling capacity is 1.8 to 4.3 times that of ordinary cold water [3]. Compared with other kinds of ice, ice slurry is widely used in food preservation in recent years because of its various advantages such as fast cooling capability, convenient transportation as well as fine and round ice particles. As the demand for ice gradually rises, researchers at home and abroad have made a lot of exploration and research on the preparation and application of ice slurry.
often utilized to produce ice slurry, and the equipment is shown in Figure 1.

In order to reduce energy consumption and improve ice production efficiency, Zhang et al. [4] studied the influence of two kinds of nucleating agents with different size range on the undercooling degree of the ice slurry produced with sea water, and found that the nucleating agents with small size range had more obvious effect on eliminating undercooling phenomenon. Wang et al. [5] established a dynamic simulation model of ice slurry production system, and obtained the response characteristics of the system in internal and external changes, as well as the conclusion that it was necessary to maintain relatively stable solution temperature and flow rate. Hu et al. [6] used ice slurry and crushed ice respectively to keep fresh of Penaeus vannamei. Compared with various parameters stored at 4 ℃, it was concluded that ice slurry could slow down water loss and had more favorable fresh-keeping effects. Zhang et al. [7] examined the quality indexes of perch in ice slurry and crushed ice conditions, respectively, and concluded that ice slurry was better for fresh-keeping compared with traditional ice preservation. Lan et al. [8] researched the effect of ice slurry with Ginkgo biloba suci and bamboo vinegar respectively on the quality of silvery pomfret during ice storage. Ice slurry with Ginkgo biloba suci and bamboo vinegar respectively could prolong the cold storage period of silvery pomfret from 9-12 days to 15-16 days and 17-18 days respectively. Yuan et al. [9] produced ozone ice by adding ozone into ice slurry, which greatly extended the shelf life of aquatic products. Lin et al. [10] analyzed the effect of ice slurry and the combination of ice slurry and hydrostatic extrusion on the preservation of large yellow croaker. It was found that the hydrostatic extrusion treatment of 300 MPa for 10 minutes had a certain sterilization effect on large yellow croaker, and the combination of ice slurry and hydrostatic extrusion had a better antiseptic effect.

![Fig. 1 The equipment for producing ice slurry by scraped- surface method](image)
1-Constant temperature cooling tank; 2-Coolant (in); 3-Screw-type ice slurry generator; 4-Coolant (out); 5-Motor; 6-Speed controller; 7-Ice slurry (out); 8-Filter screen; 9-Aqueous solution tank; 10-Pump; 11-Sea water (in); 12-Flow regulating valve

2.2 Innovation research of ice slurry technology

Compared with common ice, ice slurry has the merits of easy preparation, fluidity, full contact with objects and fast cooling capability, which can be used in various fields. In building air conditioning system, ice slurry can be used as secondary refrigerant to cool down buildings; in the field of mineral exploitation, ice slurry can be transported from the surface to the underground to solve the cooling problem. Ice slurry can not only be used for fresh-keeping and freezing of aquatic products, but also for filling and cooling in the internal space of some products with loose structure.

3. Intelligent temperature control technology

In order to ensure the quality, nutrition and flavor of aquatic products, cold chain logistics of aquatic products has high requirements for temperature control in the process of storage, transportation and distribution. Many researchers have studied the real-time intelligent temperature control system in
different logistics links.

3.1 Present research status of intelligent temperature control technology
The research of temperature control technology in foreign countries started early, and the distributed control system appeared at the end of 1980s. China began to explore temperature measurement and control technology in 1980s, and great progress had been made attributed to the development of computer and sensing technology. Based on RFID technology, Pi [11] constructed temperature control system for cold chain logistics, established the RFID real-time temperature control model through LabVIEW simulation program, and carried out simulation research. Zhou et al. [12] put forward the RFID real-time temperature control system for cold chain logistics. He studied the data flow mining method, and took the distributed outlier mining algorithm as the core of the real-time temperature control system. What’s more, he demonstrated the validity of the algorithm, and optimized the outlier mining algorithm. The integrated temperature sensor and Wi-fi active RFID tag proposed by Ma et al. [13] broke through the limitations of data transmission distance and the need for readers. Feng et al. [14] built a temperature control simulation system of mutton cold chain transportation with Matlab. Zhang [15] integrated and studied temperature control supply chain management, fruits and vegetables, as well as modern logistics, and finally enriched the theory of intelligent temperature control system.

3.2 Innovation research of intelligent temperature control technology
Automation continuing enhancing, machines generate much heat during operation. If not paid attention to, safety accidents may easily happen. Temperature control technology can monitor and control temperature in real time to ensure the safety of automatic production. In addition, temperature in cars may rise too high after exposed to the sun. The temperature control system in the car can automatically control temperature when the temperature in the car is too high, which not only facilitates people's life, but also avoids potential safety hazards to a large extent.

4. Summary and Prospect
This paper mainly studies the current research status and innovation of new technologies in the context of the increasing demand for cold chain logistics. Ice slurry technology and intelligent temperature control technology are of great significance to the storage, transportation and distribution links of cold chain logistics. There are many problems in cold chain logistics, such as backward infrastructure, insufficient cold chain transportation capacity, lack of knowledge about cold chain logistics, imperfect industry standards. Through further research and innovation of cold chain logistics, and by establishing and improving cold chain logistics standards and norms system, and enhancing professional training for cold chain logistics talents, cold chain logistics in China will have broader prospects in the future society.

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References
[1] Gao, M., Zhang, B., Deng, S.G., Wang, B., Aubourg, S. (2014) Using and Development of Ice Slurry Preservation in Food Industry. Food Industry, 35(02):178-182.
[2] Bellas I, Tassou S A. (2005) Present and future applications of ice slurries[J]. International Journal of Refrigeration, 28(1):115-121.
[3] Wang, Q., Zhang, B., Ma, L.K., Wang, B. (2014) Effect of Slurry Ice Treatment on the Quality of Fresh Litopenaeus vannamei. Modern Food Science & Technology, 30(10):134-140.
[4] Zhang, R.J., Cheng, Z.M., Yan, R.Y., Shen, K., Han, Z. (2014) The influence of nucleating agents with different particle size on the supercooling degree of seawater fluidized ice making process.
China Water Transport, 14(10):298-299.

[5] Wang, Z.P., Li, M.X., Wang, F.B., Ma, Y.T., Wang, L. (2018) Dynamic simulation of heat exchanger in slurry ice making system. Chemical Engineering, 46(08):21-27.

[6] Lan, W.Q., Hu, X.Y., Ruan, D.N., Liu, S.C., Xie, J. (2019) Effect of Slurry Ice on the Quality and Water Mobility of Pacific White Shrimps (Litopenaeus vannamei) during Storage. Food Science, 40(09):248-255.

[7] Zhang, W.J., Lan, W.Q., Lai, Q.Y., Zhang, J., Qiu, W.Q., Xie, J. (2019) Changes in quality, ATP-related compounds and microorganisms of perch (Lateolabrax japonicus) treated with different ice storages. Food and Fermentation Industries, 45(18):35-42.

[8] Lan, W.Q., Che, X., Xu, Q.L., Zhao, H.Q., Zhang, W.J., Xiao, L., Xie, J. (2017) Effect of Slurry Ice Made with Ginkgo biloba Leaf Extract or Bamboo Vinegar on the Quality of Pomfret (Pampus argenteus) during Ice Storage. Food Science, 38(23):249-256.

[9] Yuan, C.H., Liu, Y.L., Huang, Y.Q., Wang, J.H., Huang, S.E., Li, X.H., Wang, F.X., Yu, J. (2019) Ozone ice preparation technology and its research advances in food preservation. Food & Machinery, 35(05):224-230.

[10] Lin, X.D., Guo, R.Y., Kang, M.L., Cui, Y., Shang, H.T., Lin, X., Xie, H.Y., Lin, J.G. (2018) Effect of Slurry Ice Storage Combined with High Hydrostatic Pressure Treatment on the Microflora Analysis of Refrigerated Pseudosciaena crocea. Science and Technology of Food Industry, 39(13):287-291+310.

[11] Pi, S.H. (2013) The research of Temperature control system in Cold Chain Logistics Based on RFID. Chang’an University.

[12] Zhou, S.C. (2010) Real-time temperature control of RFID cold chain based on outlier mining. FuDan University.

[13] Ma, j. (2014) Research on temperature control system of meat cold chain logistics based on RFID technology. Logistics technology, (14):69-72.

[14] Feng, X., Li, Z.G. (2018) Prototype design of mutton cold chain transportation temperature control system based on fuzzy PID. Jiangsu Agricultural Sciences, 46(13):220-225.

[15] Zhang, X.M. (2014) Research on the modern logistics system for fruits and vegetables with the Thermostat Supply Chain Management based. Henan University of Technology.