Journal of Food and Nutrition Research, 2025, Vol. 13, No. 1, 43-52
Available online at http://pubs.sciepub.com/jfnr/13/1/5
Published by Science and Education Publishing
DOI:10.12691/jfnr-13-1-5

Statistical Analysis of Cold Chain Logistics Standards for Agricultural and Sideline Food in China

Ge Gao[1], Gongming Lan[2], Shipeng Gao[1], Ziyan Zhang[1], Jing Chen[1], Changlin Cheng[1], Xinxing Li[3], Lin Chen[4], Bo Li[5,*]

[1]College of Logistics, Beijing Wuzi University, Beijing 101149, China
[2]Alstom Sifang (Qingdao) Transportation Ltd, Shandong 266111, China
[3]College of Information and Electrical Engineering, China Agricultural University, Beijing 100083, China
[4]China International Engineering Consulting Corporation, Beijing 100048, China
[5]Chinese Academy of Environmental Planning, State Environmental Protection Key Laboratory of Environmental Planning and Policy Simulation, Beijing, 100043, China
*Corresponding author: libo@caep.org.cn

Received December 29, 2024; Revised January 31, 2025; Accepted February 06, 2025

Abstract To understand the development status and standardization progress of cold chain logistics for agricultural and sideline food in China, we conducted a statistical analysis based on data from the Logistics Standard Catalog Manual (2023). The quantity, category, and content of the currently implemented cold chain logistics standards for agricultural and sideline products were examined. Despite the increasing number and variety of standards, issues remain, such as incomplete standard categories and significant differences in the number of standards issued for different categories. This study provides a comprehensive understanding of the current situation, offering valuable references for policymakers and helping enterprises to grasp standardization requirements.

Keywords: *Agricultural and sideline food, Fruits and vegetables, Cold chain logistics standards, Statistical analysis*

Cite This Article: Ge Gao, Gongming Lan, Shipeng Gao, Ziyan Zhang, Jing Chen, Changlin Cheng, Xinxing Li, Lin Chen, and Bo Li, "Statistical Analysis of Cold Chain Logistics Standards for Agricultural and Sideline Food in China." *Journal of Food and Nutrition Research*, vol. 13, no. 1 (2025): 43-52. doi: 10.12691/jfnr-13-1-5.

1. Introduction

Growing attention to life quality and stricter quality requirements have driven improvements in various standards, posing higher expectations for standardization across industries [1]. Developed countries' standardization of cold chain logistics can be categorized into two phases: gradual and leapfrog development [2]. Many developed nations have supported cold chain logistics through financial incentives and tax breaks, fostering the creation of logistics standards and regulatory frameworks by businesses and the industry, thereby standardizing cold chain logistics infrastructure and equipment [3,4]. However, global and regional logistics standards often conflict.

In China, the evolution of cold chain logistics has been marked by two distinct phases: from the founding of the People's Republic of China to the onset of economic reforms, and from the reform and opening up period to the present [5]. Over the last 45 years, the logistics industry has progressed through three stages: initiation, rapid expansion, and transformation [6,7]. Throughout these periods, cold chain logistics services and standardization have continuously evolved [8]. Every step in the cold chain logistics process necessitates the development of corresponding operational standards and standardized procedures, such as distribution, warehousing, and supply chain management, which impact the growth and advancement of related enterprises [9,10].

Despite extensive research on the standardization and management systems for agricultural product supply chains, there is a notable absence of statistical analyses on the actual release of standards for agricultural and sideline food in cold chain logistics [11,12,13]. This paper addresses this gap by examining the status of standards for agricultural and sideline food in cold chain logistics in China. Data from the "Logistics Standard Catalog Manual" (2023) were utilized to analyze the quantity, year of issuance, and content of cold chain logistics standards currently in effect for agricultural and sideline food in China.

2. Standard Statistical Analysis

2.1. Standard Quantity Analysis

According to the "Logistics Standard Catalog Manual" (2023), a total of 1305 current national and industry standards for logistics that have been issued in China have been collected and classified into four parts based on their content: basic standards, public standards, professional standards, and standardization guidance documents. Among them, there are a total of 149 standards for agricultural and sideline food in cold chain logistics (excluding grain and oil logistics standards and food

safety standards), which are divided into three categories: basic standards, facility and equipment standards, and technical, operational, and management standards. They are also classified into mandatory standards and recommended standards according to their nature. In addition to cold chain standards, there are 17 other standards for agricultural and sideline food logistics. The cold chain logistics for agricultural and sideline food account for 89.7% of all the food logistic standards.

As shown in Figure. 1, among them, there are 13 basic standards, accounting for 8.7% of the total statistical standards. The basic standards are comprehensive summaries of cold chain logistics. There are a total of 40 standards for facility and equipment, accounting for approximately 26.9% of the total statistical standards. The facility and equipment standards involve specific requirements and specifications for the use of facility and equipment in cold chain logistics processes. There are 96 technical, operational, and management standards, accounting for approximately 64.4% of all. These standards are specific technical and operational requirements for agricultural and sideline food, as well as operational norms in cold chain logistics processes.

Among these three categories of standards, the technical, operational, and management categories have the highest number of standards, accounting for nearly three-quarters of the total statistics. The main reason is that there are differences in the operation of cold chain logistics technology for different categories of agricultural and sideline products. Therefore, different temperatures and storage environments need to be controlled in the storage, transportation, and processing stages, resulting in a much higher number of technical, operational, and management standards than the other two types of standards [14] .

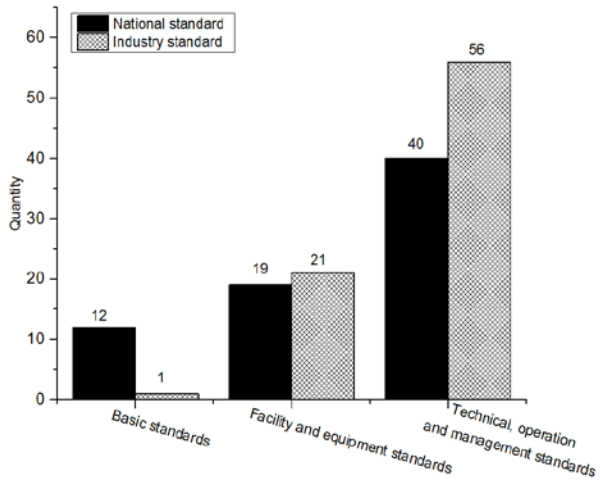

Figure 1. Distribution of standard types for cold chain logistics of agricultural and sideline food

2.2. Standard Type Analysis

Among the 149 national and industry standards, there are 7 mandatory standards and 142 recommended standards. It is widely known that mandatory standards are mandatory for enterprises and individuals related to the standards to implement and comply with, while recommended standards are recommended for adoption as recommendations. Therefore, most standards are published to improve and popularize as technical indicators in this field.

The number of national standards is 71, accounting for 47.7%, including 12 basic standards, 19 facility and equipment standards, and 40 technical management standards. The number of industry standards is 78, accounting for 52.3%, including 1 basic standard, 21 facility and equipment standards, and 56 technical, operational, and management standards. Compared with the Logistics Standard Catalog Manual (2021), the proportion of national standards has slightly increased. Among these industry standards, 12 industries are involved, including machinery, ships, transportation, automobiles, forestry, agriculture, and railway transportation. It is obvious that agricultural food and cold chain logistics involve a wide range of industries and require collaborative efforts from all industries to achieve great development [15].

There are 12 national standards among the 13 basic standards. As the basic standards for agricultural and sideline food in cold chain logistics, they mostly meet the technical requirements for basic management needs in this field. Therefore, national standards are the main parts in the basic standards. Both national and industry standards are abundant in the categories of facility equipment, technology, operation, and management, with the number of industry standards slightly higher than the number of national standards. This indicates that standards for facility equipment, technology, operations, and management are not only need to meet the basic technical requirements of the field, but also involve different related industries, so it is necessary to follow the unified technical requirements of the industries involved. This shows that there are still many differences in the cold chain logistics of agricultural food, involving a wide range of industries and requiring more research and standardization to promote the development of standardized cold chain logistics for agricultural food.

2.3. Standard Year Analysis

As shown in Figure 2, from 1991 to now, the number of standards released during the five-year period is calculated as follows. The earliest standard that is still being implemented was published in 1979, and there were three standards that were still being implemented before 1990. Before 2005, the difference in the number of standards released every 5 years was relatively small, around 3, with an average of less than 1 standard released per year. During the two five-year periods from 2006 to 2010 and 2011 to 2015, there was a significant difference in the number of standards issued for cold chain logistics of agricultural and sideline food. A total of 95 standards were issued during these two five-year periods, including 35 standards issued between 2006 and 2010 and 60 standards issued between 2011 and 2015, ushering in a surge in standards. The average number of standards issued each year exceeded 12, an increase of nearly 10 times compared to previous years.

However, in the five years after 2015, there was a degree of decline in the number of standards released. From 2016 to 2020, the number of standards released was

25, with an average of 5 standards released each year. The reason for this situation is that the newly issued national standards and regulations in 2015 were more stringent in terms of standard formulation and review, resulting in a certain decrease in the number of standards released after 2015. From 2021 to present, 18 standards have been released over a period of 3 years, with an average of 6 standards released each year. Since 2021, the newly added standards have strengthened the standardization of origin logistics services, cold chain transportation supervision, cold chain logistics technology specifications and cold chain food traceability etc.

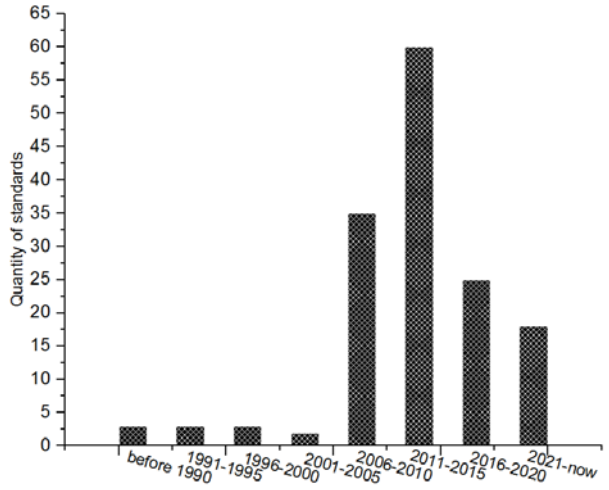

Figure 2. Distribution of cold chain logistics standards for agricultural and sideline food by year

3. Analysis of the Content of Cold Chain Logistics Standards for Agricultural and Sideline Food

3.1. Basic Standards

The basic standards for cold chain logistics of agricultural and sideline food are the technical and management norms that meet their basic needs in the cold chain logistics process of agricultural and sideline food. Therefore, the 13 basic standards mainly based on national standards mainly introduce the terminology of cold chain logistics and the basic requirements for cold chain logistics classification.

Four new standards were released in 2023, namely GB/T 42503-2023 “Specification for agricultural products cold chain logistics service in producing area”, GB/T 43260-2023 “Imported cold-chain food traceability-Requirements for traceability information management”, GB/T 43265-2023 “Imported cold-chain food traceability-Data elements of traceability system”, and GB/T 43268-2023 “Imported cold-chain food traceability-General rules for traceability system”. Other standards have not changed from the standards in the 2021 catalog statistics.

For example, GB/T 42503-2023 “Specification for agricultural products cold chain logistics service in producing area” specifies the basic requirements, service guarantee, service content and requirements, service quality evaluation and improvement of cold chain logistics services for agricultural products in production areas. GB/T 43260-2023 “Imported cold-chain food traceability-Requirements for traceability information management”, GB/T 43265-2023 “Imported cold-chain food traceability-Data elements of traceability system”, and GB/T 43268-2023 “Imported cold-chain food traceability-General rules for traceability system” are aimed at the entire process and traceability system information management, processing, exchange, sharing, system establishment and implementation in the supply chain of imported cold chain food. They specify the overall requirements, information content, traceability system, key elements, system implementation, system management, and other related content.

There is only one industry standard among the existing 13 basic standards for agricultural and sideline food in cold chain logistics, which does not comprehensively cover all aspects. On the one hand, this statistical data only covers national standards and industry standards, and does not involve other types of standards such as local standards, enterprise standards, and group standards, resulting in certain deficiencies in the quantity and content of basic standards. In addition, the cold chain logistics of this field in Europe and America are still in the process of development and continuous supplementation and improvement [16].

3.2. Facility and Equipment Standards

In terms of facility and equipment standards, there are two newly released standards. The national standard GB 29753-2023 “Road transportation-Perishable foodstuffs and biological products-Safety requirement and test methods of refrigerated vehicle”, released in 2023, specifies the classification, technical requirements, testing methods, and markings of refrigerated vehicles. And the industry standard JT/T 389-2022 “Specification for van tailer” released in 2022, which specifies the technical requirements, test items and methods, inspection rules, as well as labeling, packaging, transportation, and storage of van trailers.

There are still several standards in the facility and equipment category that were issued earlier and are still in use and implementation. For example, the industry standard CB 3040-1978 “Hatch cover of cold storage” issued and implemented in 1978, and the industry standard TB/T1805-1986 “General technical conditions for ice refrigerated trucks” issued and implemented in 1986. The formulation, publication, and implementation of standards have a certain timeliness, and when facilities and equipment are updated or replaced, their standards should also be modified or reformulated. When the standard part is relatively old, it indicates that there is also a certain lag in the facilities and equipment. There is a need for new facilities and equipment to be updated and replaced, and the formulation of relevant standards should also closely follow.

We divide the statistical standards for facility equipment into refrigerated truck standards, cold storage standards, refrigerated container standards, and other facility equipment standards. As given in Figure 3, among the 40 standards for facility equipment, there are 13 standards for cold storage, accounting for 32.5%, 8 standards for refrigerated trucks, accounting for 20%, 5 standards for

refrigerated containers, accounting for 12.5%, 3 standards for refrigerators, accounting for 7.5%, 1 standard for refrigerated tanks, accounting for 2.5%, and 10 standards for other facility equipment, accounting for 25%.

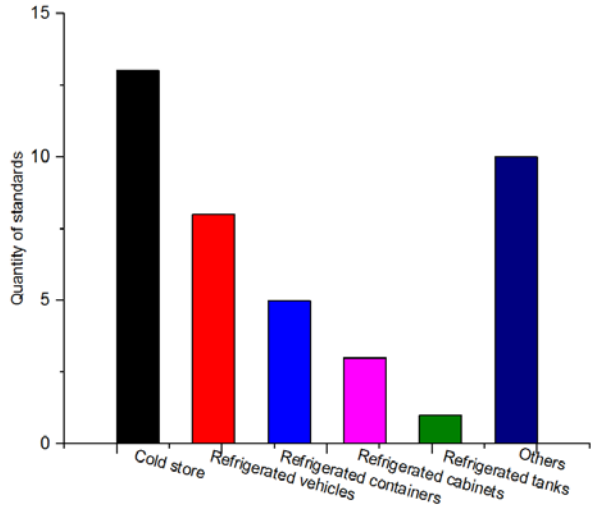

Figure 3. Distribution of cold chain logistics standards for Facility and Equipment

3.2.1. Cold Store

Among the 13 standards for cold storage, 6 are national standards, which basically include the regulatory requirements for cold storage, from the design specifications to the testing methods, to the application specifications and management specifications. Both GB/T 28009-2011 “Safety code for cold store” and GB/T 30134-2013 “Cold store management regulation” specify safety requirements for cold storage design, construction, operation management, and long-term shutdown of refrigeration systems. The main thermal performance testing specifications and methods for food cold storage are specified in GB/T 30103.1-2013 “Methods of testing for thermal performance on cold store Part 1: Temperature and humidity testing”, GB/T 30103.2-2013 “Methods of testing for thermal performance on cold store Part 2: Air velocity testing”, and GB/T 30103.3-2013 “Methods of testing for thermal performance on cold store Part 3: Heat flux testing for environmental enclosure”.

Cold storage, as an important facility and equipment in the cold chain logistics operation process of agricultural and sideline food, directly affects the quality and physical and chemical properties. Whether perishable goods are stored in a cold storage in a standardized manner will directly affect the value of the goods, and strict cold storage regulations can ensure that the goods are well preserved during storage in the cold storage. In recent years, the application of energy technology has emerged in the released cold storage standards. While improving the cold storage regulatory system, the energy conservation and environmental protection issues of cold storage are also being considered, which makes the development of cold storage more towards sustainable and green development [17].

3.2.2. Refrigerated Vehicle

Two of the eight standards for refrigerated trucks are national standards, while other six are industry standards. GB 29753-2023 “Road transportation perishable foodstudies and biological products safety requirements and test methods of refrigerated vehicles” and GB/T 40475-2021 “Technical requirements for lecturetype of refrigerated and insulated vehicles” stipulate the classification, technical requirements, test methods and markings, as well as vehicle requirements, carriage requirements, special configuration requirements, etc. for refrigerated vehicles. WB/T 1060-2016 “Technical specifications for functions and selection of refrigerating vehicles for transporting food on road” specifies the general requirements and functional selection of food refrigerated trucks. There are standard QC/T 449-2010 “Technical conditions and test methods of insulated and refrigerated vehicles” that specify the technical requirements, testing methods, and rules for insulated and refrigerated trucks. As well as QC/T 23-2014 “Milk tank” that specify the product classification, technical requirements, and experimental methods for milk tankers.

As an important facility equipment in the cold chain of food transportation process, refrigeration plays a crucial role. Any detail of the refrigerated truck in the refrigerating process can cause significant changes in the quality and value. The transmission speed of refrigerated trucks, the performance of the vehicle itself, and the temperature control system of the vehicle all need to be strictly regulated, and the 8 industry standards for refrigerated trucks cannot cover all the standard regulations related to refrigerated trucks [18,19].

3.2.3. Refrigerated Containers, Refrigerated Cabinets and Refrigerated Tanks

In the five standards for refrigerated containers included in the statistics, regulations have been made regarding the types, materials, and safety of use of refrigerated and insulated containers. For example, GB/T 13145-2018 “Specification and management requirements of the stacking yard for refrigerated containers” specifies the technical management requirements that mechanical refrigerated container yards should possess.

The three standards for refrigerated cabinets, such as JB/T 7244-2018 “Refrigerated cabinets”, specify the terminology, definitions, technical requirements, experimental methods, as well as labeling, packaging, transportation, and storage of refrigerators. GB/T 21001.2-2015 “Refrigerated display cabinets-Part 2: Classification, requirements and test conditions” and GB/T 21001.3-2015 “Refrigerated display cabinets-Part 3: Test rating” set requirements for the structure, characteristics and performance of refrigerated display cabinets for selling and displaying food, and supplemented their safety and performance test evaluation methods and evaluation criteria standards, respectively.

One item, GB/T 10942-2017 “Refrigerated bulk milk tanks”, specifies the scope, terminology, technical requirements, test methods, and test reports of bulk milk refrigerated tanks for secondary milking capacity (24 hours) and fourth milking capacity (48 hours) at farms and milk collection points.

Refrigerated containers, refrigerated cabinets and refrigerated tanks are commonly used facilities and equipment in the cold chain logistics of food. The technical requirements and strict testing regulations for them help to

better store and transport agricultural products, ensuring the quality of goods during this process [20].

3.2.4. Other Facilities and Equipment

In addition to the equipment mentioned above, there are also many facilities and equipment in cold chain logistics for agricultural and sideline food [21]. For example, refrigerated display cabinets used for sales display, cold chain temperature recorders used for the entire cold chain logistics process, as well as cold chain pallets, cold storage plates, etc. These facilities and equipment are all related to the healthy and comprehensive development of food cold chain logistics, and are indispensable parts. Among the 10 items of other facilities and equipment, there are relevant standards such as GB/T 35145-2017 "Cold chain temperature logger", GB/T 38375-2019 "Guide for planning and design of food low temperature distribution center", SC/T 9020-2006 "Technical specification for the low temperature cold storage and transportation equipment of aquatic products", as well as standards related to packaging materials such as GB/T 30768-2014 "Paper and plastics laminated films and pouches for food packaging" and GB/T 31550-2015 "Corrugned boxes for packaging in transportation under low temperature".

3.3. Technical, Operation, and Management Standards

In the standards of cold chain logistics for agricultural and sideline food, the number of technical, operational, and management standards is the largest, because there are different technical and management standards for different types of products. In 2023, national standards GB/T 42482-2023 "Technical specification for packaging, storage and cold chain transportation of fresh white jelly fungi" and industry standard NY/T 4285-2023 "Technical specification for cold chain logistics of fresh fruits", were released. In 2022, industry standards NY/T 4165-2022 "Code of practice for electronic commerce and cold chain logistics of citrus fruits", NY/T 4166-2022 "Code of practice for electronic commerce and cold chain logistics of apple", NY/T 4167-2022 "Technical requirements for cold chain circulation of litchi" and JT/T 1443-2022 "Technical requirements for cold chain transport monitoring and management platform" were published.

Further, these standards were refined into seven specific category standards, including 20 comprehensive categories, 56 fruits and vegetables, 8 meat products, 6 aquatic products, 3 frozen products, and 1 dairy product, as well as 1 dry product and 1 soy product. As shown in Figure. 4, the proportion of standard quantities for fruits and vegetables is 58.3%. Because so many varieties of fruits and vegetables in agricultural food, and there is a significant gap in the technical and management requirements for different types of fruits and vegetable products in the cold chain logistics, resulting in a much larger number of such standards than the other six categories. However, frozen products and dairy products require temperature control technology and management requirements that can generally be met by general standards in the cold chain transportation process, so the number of such standards is relatively small [22].

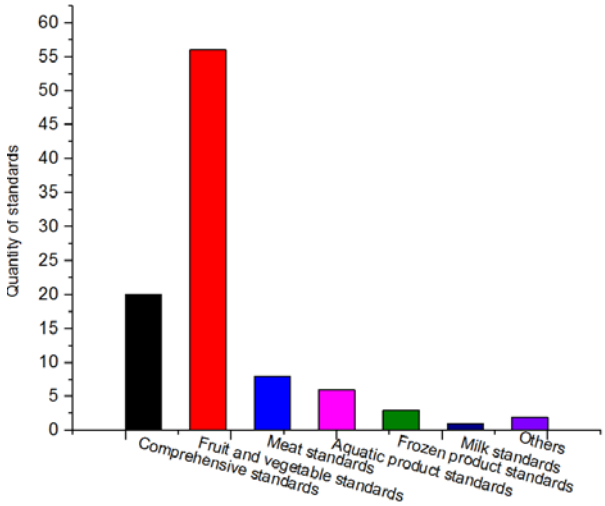

Figure 4. Distribution of cold chain logistics standards for Technical, operation, and management

3.3.1. Comprehensive Standards

There are 20 comprehensive standards, accounting for 20.8% of the technical, operational, and management standards. They are a general specification for the technology, operation, and management of agricultural and sideline food in cold chain logistics, and are formulated as a whole. In the comprehensive standards, there is a standard GB/T 22918-2008 "Technical requirements for temperature-controlled transportation of perishable food" that requires temperature control throughout the entire process of agricultural and sideline food in cold chain logistics. The overall requirements and document regulations for establishing and implementing HACCP system in food cold storage in terms of quality control are specified in GB/T 24400-2009 "The evaluation rule on the HACCP certification of food freezer".

There are many standards that specify the technical requirements for the specific processes of cold chain logistics for agricultural and sideline food. These standards regulate the operational processes of food in cold chain logistics from certain specific aspects and are key standards for cold chain logistics, such as GB/T 24616-2019 "Packaging, labeling, transport and storage for chilled and frozen foods in logistics", GB/T 40956-2021 "Specification for handover of food cold chain logistics", WB/T 1103-2020 "Specification for terminal distribution cold chain of food", GB/T 28843-2012 "Management requirement for traceability in food cold chain logistics" etc.

3.3.2. Fruit and Vegetable Standards

There are 56 standards for fruits and vegetables, accounting for 58.3% of the technical, operational, and management standards, indicating the high number of published standards for fruits and vegetables. Due to the variety of fruit and vegetable products, there are significant differences in environmental requirements for different types of fruits and vegetables during storage and transportation. When formulating related regulatory requirements, it is necessary to specify specific types of fruits and vegetables, which leads to a much larger number of standards for fruits and vegetables than for other categories [23].

The overall standards for vegetables and fruits include GB/T 23244-2009 “Fruit and vegetables-Principles and techniques of the controlled atmosphere method of storage”, GB/T 26432-2010 “Guidelines for storage and transportation technique of vegetables”, GB/T 29373-201 “Traceability requirements for agricultural products-Fruits and vegetables”, NY/T 4285-2023 “Technical specification for cold chain logistics of fresh fruits” etc. The specific specifications for fruit and vegetable varieties require a wide range of standards, such as GB/T 8559-2008 “Apple-cold storage”, GB/T 15034-2009 “Mangoes-cold storage”, GB/T 8867-2001 “Simple controlled atmospheres cold storage technique of garlic bolt” etc.

Table 1 has given the circulation and storage conditions of the main agricultural products in industry standards and relevant local standards, mainly from the aspects of precooling temperature, storage and transportation temperature, and humidity, including Chinese cabbage, cabbage, root vegetables, green leafy vegetables, onions and garlic, eggplants, beans, melons, aquatic vegetables, fresh edible fungi, perennial and miscellaneous vegetables, etc.

The precooling temperature is mainly in the range of 0-13°C, which is suitable for most vegetables. The purpose of procooling is to quickly lower the initial temperature (usually around 30°C) to the desired endpoint temperature. Among them, the precooling temperature for root vegetables (radish, carrot, turnip, etc.), green leafy vegetables (celery, spinach, lettuce, lettuce, etc.), aquatic vegetables (lotus root, water chestnut, water celery, water bamboo, etc.), fresh edible mushrooms (shiitake mushrooms, original mushrooms, enoki mushrooms, etc.), and some miscellaneous vegetables (bamboo shoots, asparagus, enoki mushrooms, etc.) is relatively low, within the range of 0-2°C. The precooling temperature for Chinese cabbage (regular cabbage, etc.), cabbage (cauliflower, mustard greens, broccoli, cabbage, etc.), scallions and garlic (onions, scallions, garlic, ginger, etc.) should be within the range of 0-5°C. In addition, due to the fact that most eggplants (eggplants, green peppers, peppers, tomatoes, etc.) and melons (cucumbers, loofah, winter melon, zucchini, etc.) are cold sensitive vegetables that are not tolerant to low temperatures, their precooling temperature is relatively high, around 10°C. The storage and transportation temperature range is generally consistent with the precooling temperature range. The precooling temperature for green beans is 8-10°C and the freezing and preservation temperature is -18°C because it is used to enter rapid freezing storage.

The storage humidity of vegetables is an important factor affecting their shelf life and quality [24]. Appropriate humidity can reduce the evaporation of water from vegetables, maintain their freshness and edible quality [25,26]. The storage humidity of vegetables is mostly controlled between 80-98%, and the specific humidity requirements may vary depending on different types of vegetables. For most vegetables, the suitable storage humidity is 85% to 95%. For example, the optimal storage humidity for vegetables such as Chinese cabbage, eggplant, green pepper, lotus root, etc. are within this range. However, wet loving vegetables such as cucumber, bitter gourd, pumpkin, etc. have a suitable storage humidity between 80% and 85%. Low humidity (less than 85%) can easily cause vegetables to lose water, resulting in wilting and reduced freshness, while high humidity (greater than 95%) can easily breed bacteria, leading to microbial infection and decay. Therefore, in order to effectively store vegetables, it is necessary to control the environmental conditions during storage based on the characteristics of different vegetables, to maintain appropriate humidity, thereby extending the shelf life of vegetables and maintaining their edible quality [27].

The industry standards and local standards for the main leafy vegetables and eggplants are mostly divided into special grade, first grade, second grade, third grade, and outer grade according to their quality level characteristics. Table 2 shows the quality grading indicators for the main leafy vegetables and eggplants. Based on their appearance and wear characteristics, the grading standards for first and second grade leafy vegetables and eggplants are mainly listed, including cabbage (Chinese cabbage, seaweed), broccoli (broccoli&cauliflower, mustard greens), root vegetables (radish, carrots), leafy vegetables (celery, spinach), onions and garlic (garlic, onions, green onions, ginger, leeks), and eggplants (tomatoes, green peppers&peppers, eggplants). The appearance and loss characteristics mainly revolve around distinguishing quality (freshness, uniformity, tenderness, etc.), quality loss, and moisture loss.

For example, NY/T 1267-2007 “Radish” stipulates that the requirements for first grade radishes are normal shape, individual weight difference not exceeding 10%, smooth skin, positive color, no cracked roots, fibrous roots, white rust, rough skin, wrinkles, deformities, and mechanical injuries; The requirements for second grade radish are that the shape is relatively normal, the individual weight difference is not more than 20%, the skin is smooth, the color is good, the roots are cracked, white rust, rough skin, wrinkles, and mechanical damage are 10%, and slight bending is allowed.

Table 1. Temperature and humidity conditions for the circulation and storage of main agricultural products

Category	Common variety examples	Temperature (precooling)	Temperature (storage&transportation)	Humidity	Statistical sources
Chinese cabbage	Chinese cabbage, regular cabbage (rapeseed, bok choy), cabbage sprouts, etc	0°C-5°C	0°C-3°C (transportation)	85%-95%	NY/T 2868-2015；GH/T 1131-2017
cabbage	cauliflower, mustard greens, broccoli, cabbage, etc	0°C-4°C	0°C-4.5°C (transportation)	90%-98%	DB 21/T 2364-2019；DB 43/T 1622-2019
root vegetables	carrots, carrots, turnips, etc	0°C-1°C	0°C-3°C	90%-95%	NY/T 1267-2007；NY/T 717-2003
green vegetable	celery, spinach, asparagus, lettuce, water spinach, coriander, chrysanthemum, fennel, amaranth, mugwort,	0°C-1°C	0°C-5°C	90%-98%	DB 37/T 3766-2019；NY/T 964-2006；DB 22/T 2429-2016

Category	Common variety examples	Temperature (precooling)	Temperature (storage&transportation)	Humidity	Statistical sources
	etc				
bulb vegetable	onion, scallion, scallion, garlic sprout, garlic moss, leek, garlic, ginger	0°C-5°C (excluding ginger and chili peppers)	0°C-5°C (excluding ginger and chili peppers)	80%-90% (excluding onions and garlic)	SB/T 10882-2012；GH/T 1190-2021；SB/T 10578-2010；DB 21/T 2809-2017；NY/T 579-2002；DB 37/T 3490.2-2019
solanaceous vegetable	eggplant, green pepper, chili, tomato, etc	9°C-12°C	8°C-13°C (transportation) (excluding ripe tomatoes)	85%-95%	GH/T 1129-2017；DB 21/T 2490-2015；GH/T 1193-2021
beans	green beans	8°C-10°C	-18°C (quick freezing storage)	85%-95%	DB 32/T 1464-2009；
melon	cucumber, luffa, winter melon, zucchini, bitter gourd, pumpkin, bergamot, snake melon, jiegua, gourd, etc	7°C-13°C	7°C-15°C	55%-70%/ 90%-95%	SB/T 10881-2012；GB/T 18518-2001；SB/T 10572-2010
aquatic vegetables	lotus root, water chestnut, water celery, water bamboo, etc	0°C-3°C	2°C-4°C	85%-95%	DB 42/T 1696-2021；T/ZNZ 004-2018
edible fungi	oyster mushroom, shiitake mushrooms, enoki mushrooms, shiitake mushrooms, fungus (excluding dry fungus), etc	0°C-2°C	2°C-8°C (transportation)	> 95%	DB 32/T 1863-2011；NY/T 1934-2010
perennial and miscellaneous vegetables	bamboo shoots, asparagus, goldenrod (yellow cauliflower), toon, etc	1°C-2°C	2°C-5°C (transportation) 1°C-2°C (storage)	about 95%	T/SMLIA 0002-2021；GB/T 16870-2009

Table 2. Quality grading indicators for main leafy vegetables and eggplant fruit vegetables

Category	Example	First level (special grade)		Second level		Statistical sources
		Category	Loss characteristics	Appearance characteristic	Loss characteristics	
Chinese cabbage	Chinese cabbage	The vegetable has a compact body, thick leaves, tight tissue, and high toughness; neat appearance, well maintained, dignified and consistent shape, uniform color.	No mechanical damage, normal leaf color, no old shoots, burnt edges, swelling, or lateral bud sprouting; the net weight of a single piece is ≥ 3.5 kg, the difference in net weight of a single piece in the same packaging is ≤ 5%.	The vegetable has a compact body, thick leaves, tight tissues, and high toughness; the appearance is neat and well maintained; the shape is basically consistent, and the color is relatively uniform.	No mechanical damage; there is a slight deviation in leaf color, with no aging, burnt edges, swelling, or sprouting of lateral buds. The net weight of a single piece is 2.5-3.5 kg, and the difference in net weight of a single piece in the same packaging is ≤ 10%.	SB/T 10879-2012
	brassica campestris	The characteristics of the same variety include purple (fresh) red stem color, no wax powder or even and consistent wax powder, crisp and tender stem texture, no bitterness, few and pointed stem leaves, extremely short or no stem petioles, and no open flowers in the stem inflorescence.	Well repaired, clean, fresh, without decay, yellow leaves, odor, frost damage, pest and disease damage, and mechanical damage. There is no aging of the pit core. The length of the stem satisfies 25 cm< length ≤ 35 cm, and the thickness of the stem satisfies 1.5 cm< thickness ≤ 3.0 cm.	The characteristics of the same variety include a bright red color, no wax powder or even and consistent wax powder, crisp and tender stems, no bitterness, few pointed and small stems and leaves, short petioles of stems and leaves, and less than 3 flowers per stem inflorescence.	Well maintained, clean, fresh, free from decay, yellowing, odor, frost damage, pests and diseases, and mechanical damage, with no signs of heart aging. The length of the bolt ranges from greater than 20 cm to 25 cm (inclusive), i.e., The length of the bolt ranges from greater than 20 cm to 25 cm (inclusive), i.e., 20cm< bolt length ≤ 25 cm, and the thickness of the bolt ranges from greater than 1.2 cm to 1.5 cm (inclusive), that is 1.2 cm< bolt thickness ≤ 1.5 cm.	NY/T 778-2004
cabbage	broccoli & broccoli	(1) Consistent appearance; the flower ball is round and intact; the flower ball is compact, full, and not loose; the color is dark green and consistent; the flower buds are small,		(1) The appearance is basically consistent; the flower ball is relatively round and intact; the flower ball is still tight and slightly loose around it; the color is dark green and basically		DB 21/T 2364-2019 NY/T 941-2006

Category	Example	First level (special grade)		Second level		Statistical sources
		Category	Loss characteristics	Appearance characteristic	Loss characteristics	
		compact, and not yet open; the stems are fresh and tender, and the branching stems are short. Short flower stem (2) No hollow, no mechanical damage.		consistent; the flower buds are compact but have not yet bloomed; the stems are fresh and tender, and the branching stems are short. The flower stem is relatively long and has no hollow (2) Mechanical damage is allowed, but not obvious.		
root vegetable	cabbage mustard	The flower stems are of uniform length and thickness; the stems and leaves are thick green, smooth and tender, and the leaf shape is intact; no pests or other injuries.		The length of the flower stems is basically the same, and the thickness is relatively uniform; the stems and leaves are thick green, fresh and tender, and the leaf shape is basically intact; no pests or other injuries.		NY/T 1064-2006
	radish	Normal shape, individual mass difference not exceeding 10%, smooth skin, positive color.	No cracked roots, fibrous roots, white rust, rough skin, wrinkles, deformities, or mechanical injuries.	The shape is relatively normal, with individual mass differences not exceeding 20%, smooth skin, and good color.	Root cracking, white rust, rough skin, wrinkles, mechanical damage 10%, slight bending allowed.	NY/T 1267-2007
	carrot	Consistent appearance; Smooth, fleshy roots with the inherent color of the variety, consistent in color.	The fleshy roots are evenly developed, with a crisp and tender texture and no cracks; no cold damage or mechanical injury; no green or purple at the top.	The appearance is basically consistent; smooth, fleshy roots with the inherent color of the variety, and the color is basically consistent.	The development of fleshy roots is generally uniform, with slight healed cracks; no obvious cold damage or mechanical injury; green or purple is allowed within 2 cm below the top.	NY/T 1983-2011
green vegetable	celery	It has the unique appearance and color characteristics of this variety. Clean, neat, compact, fresh and tender, with neat incisions (if any).	No pityriasis, tillering, brown stem, no damage caused by freezing, pests, mechanical or other reasons.	It has the unique appearance and color characteristics of this variety. Clean, neat, compact, fresh and tender, with less fiber content, and neat incisions (if any).	There is basically no pityriasis, tillering, brown stem, and no damage caused by freezing, pests and diseases, mechanical or other reasons.	NY/T 1729-2009 ;
	spinach	Same variety. Neat, clean, intact, fresh and tender.	No bolting, tillering, or damage.	Same variety. Neat, clean, intact, and tender.	No bolting or tillering, basically no damage.	NY/T 1985-2011
	garlic	The bulbs are well developed and fully swollen, and the garlic cloves are tightly arranged, firm, and full. The outer skin of the garlic head is intact. Garlic cloves have a regular shape and consistent color.	No mechanical injuries, no root hairs; garlic bulb diameter ≥ 50 mm, stem length ≤ 20 mm. The difference in garlic bulb diameter within the same packaging is ≤ 10%.	The bulbs are fully swollen, the garlic cloves are arranged and tightly closed, without any wrinkles or shrinkage, the color is basically consistent, and the shape of the garlic heads is upright.	The outer skin of garlic is basically intact, without mechanical damage or root hairs; garlic bulb diameter ≥ 40 mm, stem length < 20 mm; the difference in the transverse diameter of garlic cloves in the same packaging is ≤ 15%.	SB/T 10882-2012
bulb vegetable	onion	The appearance and color of the bulb are intact, the size is uniform, full and hard; smooth outer scales.	No cracked skin, no damage; remove the roots and false stems cleanly and neatly.	The appearance and color of the bulb have slight defects, with a relatively uniform size and a fuller, harder texture.	The area of dry cracking on the outer scales does not exceed 1/5 of the surface of the bulb, and there is basically no damage; there are a few root hairs, and the removal of the pseudostem is basically neat.	NY/T 1584-2008
	scallion	Has the unique appearance and color of this variety. Clean, neat, upright, lush and thick, with moderate elasticity, tender texture, and low fiber content.	Scallion white has no cracking, hollowing, juice overflow, or obvious dehydration, and there are no disease spots or mechanical damage caused by freezing, pests or diseases.	Has the unique appearance and color of this variety. Clean, neat, upright, with thick and tender scallions, and less fiber.	Scallion white has basically no rupture, bending, juice overflow, and no disease spots or mechanical damage caused by freezing, pests and diseases.	DB 21/T 2809-2017
	ginger	Same variety, complete and plump shape, full and plump, uniform size, consistent yellow	No broken skin, dry skin, burnt skin, wrinkles, discoloration, blackening,	Same variety, complete and plump in shape, plump and full, uniform in size, consistent yellow	Allow slight wrinkling; No broken skin, dry skin, discoloration, brown skin, blackening, browning.	DB 37/T 2606-2014

Category	Example	First level (special grade)		Second level		Statistical sources
		Category	Loss characteristics	Appearance characteristic	Loss characteristics	
		and bright color, smooth surface, clean and dry.	browning.	bright color, smooth surface, clean and dry.		
	leek	Variety: same variety , uniformity > 80%	No chives, no wilting, no withered shoots	Variety: same variety, uniformity > 70%	Leek shoots < 5cm, no wilting, withered shoots < 0.2cm.	NY/T 579-2002
	tomato	Consistent appearance, good fruit shape and color, smooth skin, and fresh green calyx; The fruit is solid and elastic.	Suitable maturity, without sunburn, fading spots, scars, hail damage, frostbite, wrinkling, and mechanical damage.	The appearance is basically consistent, with good fruit shape and color, smooth skin, and fresh green calyx; The fruit is solid and elastic.	Mature or slightly undercooked, without sunburn, fading spots, scars, hail damage, frostbite, wrinkling, malformed fruit, cracked fruit, or mechanical injury.	GH/T 1193-2021
solanaceous fruits	green pepper & chili	The appearance is consistent, and the stem, sepals, and fruit have the inherent color of the variety, with consistent color; crispy and tender texture.	The cut of the fruit stem is horizontal and neat (only applicable to lantern shaped), without cold damage, freezing damage, burns, or mechanical damage, and without decay.	The appearance is basically consistent, with the stem, sepals, and fruit exhibiting the inherent color of the variety, and the color is basically the same; basically no softness sensation.	The cut of the fruit stem is horizontal and neat (only applicable to lantern shaped), without obvious cold damage, freezing damage, burns, or mechanical damage.	NY/T 944-2006
	eggplant	The appearance is consistent and the neatness is high. The stem, calyx, and fruit have the inherent color of the variety, with a bright color.	Complete formation of non wilting seeds; No cold damage, freezing damage, burns, or mechanical damage.	The appearance is basically the same, with the stem, calyx, and fruit showing the inherent color of the variety, and the color is relatively bright.	The non wilting seeds have formed, but they are not hard; no obvious cold damage, freezing damage, burns, or mechanical damage.	NY/T 1894-2010

3.3.3. Meat Standards

The 8 cold chain logistics technologies, operations, and management standards for meat products basically include the regulatory system for meat products, accounting for 8.3%. GB/T 20575-2019 “Specification of good manufacturing practice for fresh and frozen meat processing”, GB/T 22289-2008 “Requirement for processing chilled pork”, SB/T 10731-2012 “Operation specification for perishable food cold chain livestock poultry meat”, WB/T 1059-2016 “Specification for cold chain logistics operation of meat and meat products” have standardized the basic operational requirements for meat and meat products in the cold chain logistics process from different perspectives.

In addition, there are regulatory requirements for specific logistics operations, such as GB/T 20799-2006 “Fresh and frozen meat transport conditions”, GB/T 28640-2012 “Practices for cold chain transportation of livestock&poultry meat”, SB/T 10730-2012 “Technical requirements for perishable food cold chain livestock poultry meat”, and other standards that specify the cold chain logistics transport conditions for meat products.

3.3.4. Aquatic Product Standards

There are 6 standards for cold chain logistics technology, operations, and management for aquatic products, including standards for seafood, accounting for 6.3%. Regarding the standards for the transportation, storage, processing, and distribution of aquatic products, such as GB/T 26544-2011 “General requirements of aquatic products package for air transportation”. GB/T 31080-2014 “Service specification of cold chain logistics for aquatic products” specifies the basic service requirements for cold chain logistics of aquatic products. GB/T 29568-2013 “Traceability requirements for agricultural products-fish & fishery products” specifies the construction of a traceability system for aquatic product supply chains and the disciplinary requirements for traceability information.

There are also relevant standards related to specific types of aquatic products, such as GB/T 27624-2011 “Manufacturing practice for processing of fresh and frozen cultured Takifugu rubrics”, SC/T 3006-1988 “Operation code for storytelling the frozen fish”, and WB/T 1100-2018 “Operation specification of cold chain logistics for live seafood”. Most of the standards in this category are specifications for the overall technology and management of aquatic products, while there are few standards for specific types of aquatic products. Compared to fruit and vegetable standards, aquatic product standards still need to be further improved.

3.3.5. Other Standards

There is 1 standard for dairy product, 1 standard for dry product and 1 standard for soy product, accounting for 3.2% of the total. In terms of technology, operations, and management standards, there are also standards for frozen products and dairy products, which have a much lower number of publications compared to other categories. The content introduced in these standards has certain limitations [28]. On the one hand, there are certain limitations in the level of standard statistics, and relevant enterprise standards and group standards for frozen products and dairy products are not covered [29]. On the other hand, the general cold chain transportation requirements have already met the cold chain transportation requirements for such products, and there is no need to establish specific standards for such products [30].

4. Conclusion

As the significance of agricultural and sideline food in cold chain logistics grows, the number of standards has significantly increased. Since 2021, the proportion of national standards has risen from an average of less than one standard published per year before 2005 to an average of over 10 standards published annually after 2005. In recent years, related standards, particularly those concerning logistics services specifications and cold chain technology, including food traceability, have been published.

There are significant differences in the variety of published standards. In terms of technology, operation, and management standards, the number of fruit and vegetable standards is notably higher than that of other categories. The current national standards and industry standards cover a broad range of industries and require coordinated development. The advancement of agricultural and sideline food in cold chain logistics necessitates the joint development and progress of various industries.

ACKNOWLEDGMENTS

This work was supported by National Natural Science Foundation of China (72002015, 7214100059), European Union Project of Switch Asia (ACA/2021/428-472), Ministry of Education Humanities and Social Science Planning Fund Project (23YJA630011), Inner Mongolia Science and Technology Plan Project (2022YFDZ0020).

References

[1] Next-generation immunization supply chains are needed to improve health outcomes. PATH, Gavi: The Vaccine Alliance, Bill & Melinda Gates foundation, John Snow Inc, and Village Reach; 2015.

[2] Hongxia Zhao, Sheng Liu, Changqing Tian, Gang Yan ,Da Wang. An Overview of Current Status of Cold Chain in China. International Journal of Refrigeration. 2018(19): 197-208.

[3] Zaffran M, Vandelaer J, Kristensen D, Melgaard B, Yadav P, Antwi-Agyei KO, et al. The imperative for stronger vaccine supply and logistics systems. Vaccine 2013; 31(suppl. 2).

[4] Sabot O, Yadav P, Zaffran M. Maximizing every dose and dollar: the imperative of efficiency in vaccine delivery. Seattle (USA); 2011.

[5] Village Reach. Keeping the cold chain cold vaccine supply chains: reaching the final 20 policy paper series. Seattle (USA); 2014.

[6] Kenya National Bureau of Statistics and ICF Macro. Kenya demographic and health survey; 2014.

[7] Lloyd J, Lydon P, Ouhichi R, Zaffran M. Reducing the loss of vaccines from accidental freezing in the cold chain: the experience of continuous temperature monitoring in Tunisia. Vaccine 2015; 33(7): 902–7.

[8] Setia S, Mainzer H, Washington ML, Coil G, Snyder R, Weniger BG. Frequency and causes of vaccine wastage. Vaccine 2002; 20(7-8): 1148-56.

[9] Techathawat S, Varinsathien P, Rasdjarmrearnsook A, Tharmaphornpilas P. Exposure to heat and freezing in the vaccine cold chain in Thailand. Vaccine 2007; 25(7): 1328-33.

[10] Nelson CM, Wibisono H, Purwanto H, Mansyur I, Moniaga V, Widjaya A. Hepatitis B vaccine freezing in the Indonesian cold chain: evidence and solutions. Bull World Health Organ 2004; 82(2): 99-105.

[11] Murhekar MV, Dutta S, Kapoor AN, Bitragunta S, Dodum R, Ghosh P, et al. Frequent exposure to suboptimal temperatures in vaccine cold-chain system in India: results of temperature monitoring in 10 states. Bull World Health Organ 2013; 91(February): 906-1013.

[12] Chukwuma G, Okoye L, Ngwoke K, Esimone C. The potency of yellow fever vaccines sold in open markets in eastern Nigeria. J Bioanal Biomed 2013; 5(5): 133-7.

[13] S.J. James, C. James. The food cold-chain and climate change. Food Research International 43 (2010), 1944-1956.

[14] Greenpeace (2009). Cool technologies: Working without HFCs. <http://www.greenpeace.org/usa/assets/binaries/cool-technology-report-2009>.

[15] Hall, G. V., D'Souza, R. M., & Kirk, M. D. (2002). Foodborne disease in the new millennium: Out of the frying pan and into the fire? The Medical Journal of Australia, 177, 614-618.

[16] Kovats, R. S., Edwards, S., Hajat, S., Armstrong, B., Ebi, K. L., & Menne, B. (2004). The effect of temperature on food poisoning: A time-series analysis of salmonellosis in ten European countries. Epidemiology & Infection, 132, 443-453.

[17] Le Pierrès, N., Stitou, D., & Mazet, N. (2007). New deep-freezing process using renewable low-grade heat: From the conceptual design to experimental results. Energy, 32, 600-608.

[18] Legett, J. A., Peebles, R. W., Patoch, J. W., & Reinemann, D. J. (1997). USDA DMRY forage research center milking system improvements. Paper no. 973037. Presented at the ASAE annual international meeting, Minneapolis Convention Center Minneapolis. Minnesota August 10-14, 1997.

[19] Zubeldia, B. B., Jiménez, M. N., Claros, M. T. V., Andrés, J. L. M., & Martin-Olmedo, P. Effectiveness of the cold chain control procedure in the retail sector in Southern Spain. Food Control, 2016(59), 614-618.

[20] Amrat lal Basediya & D. V. K. Samuel & Vimala Beera. Evaporative cooling system for storage of fruits and vegetables - a review. J Food Sci Technol (May-June 2013) 50(3): 429-442.

[21] Nodali Ndraha, Hsin-I. Hsiao, Jelena Vlajic, Min-Feng Yang, Hong-Ting Victor Lin. Time-temperature abuse in the food cold chain: Review of issues, challenges, and recommendations. Food Control 2018, 2(13): 157-165.

[22] Abeyratne, S. A., & Monfared, R. P.. Blockchain ready manufacturing supply chain using distributed ledger. International Journal of Research in Engineering and Technology, 2016 (5), 1-6.

[23] Zeng, W., Vorst, K., Brown, W., Marks, B. P., Jeong, S., Pérez-Rodríguez, F., & Ryser, E. T. 666. Growth of Escherichia coli O157:H7 and Listeria monocytogenes in packaged fresh-cut romaine mix at fluctuating temperatures during commercial transport, retail storage, and display. Journal of Food Protection, 2014(77), 197-206.

[24] Accorsi, R., Bortolini, M., Baruffaldi, G., Pilati, F.,& Ferrari, E.. Internet-of-things paradigm in food supply chains control and management. Procedia Manufacturing, 2017(11), 889-895.

[25] Xiao, X.,He, Q., Fu, Z., Xu, M., & Zhang, X. (2016). Applying CS and WSN methods for improving efficiency of frozen and chilled aquatic products monitoring system in cold chain logistics. Food Control, 60, 656-666.

[26] Spring. Singapore. Technical reference for cold chain management of vegetables. TR24: 2007: 13-27.

[27] Zheng, Z., Xie, S., Dai, H.-N., & Wang, H.. Blockchain challenges and opportunities : A survey. International Journal of Web and Grid Services, 2016, 1-24.

[28] Wu, D., Hou, S., Chen, J., Sun, Y., Ye, X., Liu, D., Meng, R., & Wang, Y. (2015). Developmentand characterization of an enzymatic time-temperature indicator (TTI) based on Aspergillus niger lipase. LWT - Food Science and Technology, 60, 1100-1104.

[29] Shimoni, E., & Labuza, T. P. Modeling pathogen growth in meat products: Future challenges. Trends in Food Science and Technology, 2001(11), 394-402.

[30] Moureh, J., Laguerre, O., Flick, D., & Commere, B.. Analysis of use of insulating pallet covers for shipping heat-sensitive foodstuffs in ambient conditions. Computers and Electronics in Agriculture, 2002(34), 89-109.