



# Can imported cold food cause COVID-19 recurrent outbreaks? A review

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## Abstract

The coronavirus disease 2019 (COVID-19) pandemic is still spreading all over the world. Although China quickly brought the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) under control in 2020, sporadic outbreaks have recurred from time to time. Outbreaks since June 2020 have suggested that the imported cold food supply chain is a major cause for the recurrence and spread of COVID-19. Here we review recurrent outbreaks in China from June 2020 to March 2021, and we analyse the main causes for recurrence and transmission by the supply of imported cold food from port to fork. Contaminated cold food or food packaging material can transmit the virus through ‘person-to-thing-to-person’, by contrast with the classical ‘person-to-person’ pathway. We describe safety precautions for the food system, operating environment and people along the cold chain logistics. Surface disinfection and nucleic acid inspection are needed in each stage of the logistics of imported cold food supply.

**Keywords** Imported cold food supply chain · COVID-19 recurrent outbreak · SARS-CoV-2 · Transmission route · Safety precautions · Traceability system

## Introduction

As of July 30, 2021, the global epidemic of coronavirus disease 2019 (COVID-19) has caused over 196 million confirmed cases, including more than 4.2 million deaths (<https://covid19.who.int>), which has brought huge disaster to mankind. The complete control of COVID-19 pandemic is very urgent. Although China quickly brought the virus under control in April 2020, and the local transmission of the epidemic has been basically stopped, sporadic cases and local outbreaks are still at risk. Until March 2021, there have been more than 15 times recurrent outbreaks. All source of the cases can be traced. These localized outbreaks were caused by overseas importation of the COVID-19 virus—including Shandong, Xinjiang, Inner Mongolia, Liaoning, Tianjin, Beijing and other provincial-level administrative divisions.

COVID-19 is a respiratory illness, and the primary transmission route is through person-to-person contact or through

direct contact with respiratory droplets generated by an infected person (Khan et al. 2021; Sun et al. 2021). Although the COVID-19 virus is highly unlikely to cause an epidemic through foodborne transmission, a series of recent incidents have highlighted frozen foods as carriers for the long-range transport of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) during the current pandemic. Before the development of the SARS-CoV-2 detection tools, the possibility of COVID-19 transmission through the food sector was considered negligible, and tracing of SARS-CoV-2 in the food sector and surrounding environments was not considered as a priority by public authorities (Rizou et al. 2020). After the development of the SARS-CoV-2 detection tools, with the spread of the epidemic, the frequent detections of SARS-CoV-2 in frozen foods suggest that these are not random/isolated incidents but rather alerting signs that viral contamination and foodborne transmission may present a systematic risk in the ongoing pandemic.

It is plausible that food contamination may occur via respiratory droplets, contact or other route, during the farming, processing, storage, transport and retailing process where foods may contact with different workers and ambient environments in the “farm-to-table” lifecycle. Furthermore, those who work in these cold, high humidity and congregate locations are at high risk for both the acquisition and

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transmission of respiratory infections. Thus, the food and food packaging materials are likely to become contaminated through droplets expelled from COVID-19 carriers by breathing, coughing, singing, sneezing or even talking. These findings indicated that COVID-19 virus could survive on cold chain food and food packaging during long distance shipping and may cause human infection, in particular to high-risk people (such as dockworkers or stevedores).

Although the likelihood of food-to-human transmission is considered lower than other ways such as respiratory droplets and fomites, it should not be neglected as a risk factor given the large volumes of refrigerated foods being transported across different countries and regions. There is growing evidence in China that the imported cold food supply chain is one of the most important causes for the outbreak and spread of COVID-19. It was confirmed in some studies that COVID-19 outbreak could be caused by fomite transmission in the cold food chain (Han et al. 2021a; Pang et al. 2020). In fact, the cold chain is regarded as one of the six reasons of the breaks in China (the other five reasons are the import cases from outside countries, the long period of case incubation, the loopholes of prevention and control, the failure of self-protection, the improper gathering and dining).

Nevertheless, despite the large scale of the pandemic, there has been no report on transmission of COVID-19 via consumption of food to date (Nakat and Bou-Mitri 2021). None of these scholarly discussions to date has accounted how cold chain food outer packaging can transmit the SARS-CoV-2, and an infected case will spread the virus through person to cold chain food outer packaging and material-to-person transmission not just through person-to-person transmission. Therefore, it is urgent to formulate a comprehensive prevention plan to deal with the localized outbreak epidemic caused by cold food supply chain at any time. Overall we found that there is no research on the COVID-19 recurrent outbreak caused by the imported cold food supply chain so far, studying the recurrence of COVID-19 from the imported cold food supply chain is urgent for China and also meaningful to other countries of the world. In the following, we will summarize the research developments of COVID-19 transmission in cold food supply chain, analyse the cold food supply chain related COVID-19 outbreaks in China and the routes of transmission, and propose safety precautions that should be taken by government and society about cold food supply chain.

## COVID-19 transmission in cold food supply chain

Food safety is among the four pillars of the food systems affected in the era of the coronavirus (COVID-19) pandemic (Galanakis 2020; Rizou et al. 2020). There are a

lot of reports about the COVID-19 and its impact on the food industry since the outbreak in December 2019, mainly including food industry/sector (Ker and Cardwell 2020; Lawley 2020; Richards and Rickard 2020; Rude 2020; Weersink et al. 2020), food security (Deaton and Deaton 2020; Galanakis 2020, 2021; Galanakis et al. 2021; Ma et al. 2021; Rispens et al. 2020; Saupe et al. 2020), supply Chain and Demand (Ali et al. 2021; Cappelli and Cini 2020; Chitrakar et al. 2021; Gray 2020; Hobbs 2020; Ker 2020; Snuggs and McGregor 2021; Weersink et al. 2021), Food safety (Ayseli et al. 2020; Desai and Aronoff 2020; Djekic et al. 2021; Lehberger et al. 2021; Moy 2020) and food system (Coluccia et al. 2021; Duda-Chodak et al. 2020; Galanakis 2020; Rizou et al. 2020), but nearly all reports implied that the main mode of transmission for COVID-19 is from person-to-person, and there is no evidence that COVID-19 can transmit from food/food material to person.

In the early discussions on COVID-19, the possibility of COVID-19 transmission through the food sector is thought to be negligible (Rizou et al. 2020). OSHA (2020) reported that COVID-19 is an issue of occupational safety and protecting employee health rather than food contamination. One can become infected by breathing in the virus if he/she is within 1 m of a person who has COVID-19, or by touching a contaminated surface and then touching one's eyes, nose or mouth before washing ones hands (this is not thought to be the main way the virus spreads however) (WHO 2020). There are also arguments that coronavirus behind the pandemic can linger on doorknobs and other surfaces, but these aren't a major source of infection (Lewis 2021). Nakat and Bou-Mitri (2021) summarized all literatures about COVID-19 and the food industry from the beginning of the crisis to June 5th, 2020, and concluded that it is more likely that an infected food worker will spread the virus through person-to-person transmission rather than from and to contaminated food or food packaging material.

However, more and more researches imply that foodborne transmission especially the risk of cold food supply chain in the global epidemic cannot be ignored. Foodborne transmission was postulated as a potential risk factor (Sharma et al. 2020). Rizou et al. (2020) discussed safety measures needed in the food supply chain during the COVID-19 pandemic, and postulated that transmission may occur via frozen foods or packaging, although the likelihood would be lower after days of shipment. Love et al. (2021) studied COVID-19-related disruptions, impacts and responses to the seafood sector from January through May 2020, and found that COVID-19 has highlighted the vulnerability of certain groups working in- or dependent on the seafood sector. Han et al. (2021b) analyzed the cause of COVID-19 and its impact on the food supply system and food safety, and concluded that although food and water are not currently considered priority transmission routes of SARS-CoV-2,

contaminated food and environmental surfaces cannot be ignored.

Moreover, laboratory studies showed that SARS-CoV-2 remains highly stable under refrigerated, at 4 °C, and freezing conditions, from –10 to –80 °C, on fish, meat, poultry and swine skin, during 14–21 days, which means the contaminated cold-storage foods may present a systematic risk for SARS-CoV-2 transmission between countries and regions (Fisher et al. 2020). van Doremalen et al. (2020) showed that in experimental settings (under controlled relative humidity and temperature), SARS-CoV-2 can persist for up to 24 h on cardboard and up to 72 h on hard surfaces such as steel and plastics. There is research evidence that cold chain transportation in the frozen food industry may have caused a recurrence of COVID-19 cases in destination (González et al. 2021; Liu et al. 2020). In fact, there are also multiple outbreaks of COVID-19 virus linked to imported frozen fruit before (Rispiens et al. 2020; Saupe et al. 2020).

For the first time in the world, Liu et al. (2020) directly isolated SARS-CoV-2 from the cod outer package's surface swab samples in the outbreak of COVID-19 in Qingdao, and put forward that cold chain transportation in the frozen food industry may have caused a recurrence of COVID-19 cases at the destination. Similarly, the material-to-human route that has led to the COVID-19 infection of goods-transport workers participating in cold chain transportation that was reported (Fang et al. 2020; Group et al. 2020; Yuan et al. 2020). There is evidence that SARS-CoV-2 can survive up to 3 weeks in meat and on the surface of cold food packages without losing infectivity (Han et al. 2021a; Liu et al. 2020). Thus, meat from SARS-CoV-2-infected animals or food packaging contaminated by SARS-CoV-2 could be a source of human infection (Zhou and Shi 2021).

Overall, we found that despite a few researches implied the possible transmission mode for COVID-19 from material to human, there is no research on the transmission route of COVID-19 in cold food supply chain. It is urgent to analyse the main causes for recurrences of COVID-19 cases and SARS-CoV-2 transmission routes and formulate safety precautions to prevent the localized outbreak epidemic caused by imported cold food supply chain at any time.

## **Evidence and transmission route analysis of COVID-19 recurrent outbreaks caused by imported cold food supply chain in China**

### **COVID-19 recurrent outbreaks caused by imported cold food supply chain in China**

The earliest COVID-19 outbreak related to cold food supply chain recurred on June 12, 2020 in the Xinfadi agricultural produce wholesale market, Beijing, where SARS-CoV-2

was detected on a cutting board for processing imported salmon. Cold chain food contamination is regarded as the possible origin of this COVID-19 resurgence (Pang et al. 2020). From the beginning of July 2020 to January 26, 2021, China have found 60 positive novel coronavirus nucleic acid cases from the 1369,666 test cases. COVID-19 viral RNA has been detected on the surface of frozen food (salmon, white shrimp, lophiiformes, cod filets, frozen hairtail, frozen beef, frozen pig elbow, frozen chicken wings and frozen pork) from countries with significant COVID-19 epidemics across 18 provincial-level administrative divisions in China (<https://www.jiemian.com/article/5644680.html>).

The COVID-19 outbreak in Qingdao was first found by two infected stevedores. In the investigation of on September 24, 2020, live COVID-19 virus was successfully isolated and cultured from samples taken from imported frozen seafood packaging (Liu et al. 2020; Yuan et al. 2020), which is also the first time in the world that living SARS-CoV-2 virus were isolated from the imported cold chain food and outer packaging (Liu et al. 2020). It can be concluded that the COVID-19 outbreak of Qingdao was caused by SARS-CoV-2 contaminate of cod outer packaging during cold chain food production or transportation by combining with epidemiological data. It was also the first time to realize the possibility of "material-to-human" transmission of the COVID-19 (Yuan et al. 2020), i.e., COVID-19 virus can be transmitted from cold chain food packaging materials to human and from human to human during cold chain transportation. Li et al. (2021) give a COVID-19 transmission controlling summary of contaminated imported frozen food and food packaging. Han et al. (2021a) reviewed the evidence, risk factors, current policy and knowledge gaps, on food contamination and foodborne transmission of SARS-CoV-2.

There is strong evidence that contaminated outer packaging of cold chain food poses a risk to public health in relation to COVID-19. Epidemiological investigation on the source of infection have found that more than half of the outbreaks in different cities of China could be tracked to fomite transmission originating from workers at port cold storage, seafood processing facilities and market sites related to imported cold chain food (Ma et al. 2021a, b; Pang et al. 2020; Zhao et al. 2020). The sporadic epidemic case information of COVID-19 related to the imported cold food supply chain in China is shown in Table 1. We can conclude from Table 1 that all the confirmed cases had direct or indirect contact with the contaminated outer packaging of cold chain food, and they were all cold chain practitioners. The zero patients were all from the stevedores, hotel staff, drivers and factory workers at seafood ports in the outbreaks. Among them, environmental swab samples related to imported cold food were tested nucleic acid positive for SARS-CoV-2 in Xinfadi of Beijing and Dalian outbreak of

**Table 1** Imported cold food supply chain related coronavirus disease 2019 (COVID-19) recurrent outbreaks in China. All the zero patients had contact with the contaminated cold chain food, and they were all cold chain practitioners. All the SARS-CoV-2 sources can be traced from the outer packages or container samples of the cold chain

| Outbreak time | Outbreak city     | Place   | Cases (Tested)     | Zero patient           | SARS-CoV-2 source  |
|---------------|-------------------|---|--------------------|------------------------|--|
| June 11, 2020 | Beijing           | Agricultural products in Xinfadi Wholesale market         | 335 (> 11,000,000) | Employee               | environmental swab samples related to Imported salmon          |
| July 22, 2020 | Dalian, Liaoning  | Kaiyang company (Seafood processing enterprises) Dock     | 92 (> 6,000,000)   | Dockworker             | Outer packaging of imported fish                               |
| Sep. 24, 2020 | Qingdao, Shandong | Qingdao port, Dock  | 2 (5781)           | Stevedores, Dockworker | Outer packaging surface of imported frozen cod                 |
| Oct. 11, 2020 | Qingdao, Shandong | Dagang company of Qingdao port                            | 12 (10,920,000)    | Stevedore Dockworker   | Outer packaging of imported frozen cod                         |
| Oct. 25, 2020 | Kashgar, Xinjiang | Kashgar Airport   | 138 (4,746,500)    | Stevedore              | Container from abroad  |
| Nov. 7, 2020  | Tianjin           | Hailian Frozen Food Co., Ltd Tianjin Hailian cold storage | 12 (1,030,000)     | Stevedore Dockworker   | Outer packaging of imported pig Food packaging of frozen pork  |
| Nov. 9, 2020  | Shanghai          | Pudong Airport  | 4 (> 14,000)       | Stevedore              | Airborne container from North America                          |
| Dec. 15, 2020 | Dalian, Liaoning  | Dalian Port Yidu cold chain Co., Ltd                      | 83 (6,379,000)     | Stevedore              | Environmental swab samples related to imported cold chain food |

Sources: Health Times ([www.jksb.com.cn](http://www.jksb.com.cn)); Chinese Center for Disease Control and Prevention ([www.chinacdc.cn](http://www.chinacdc.cn))

COVID-19 in June and July 2020, respectively (Liu et al. 2020).

Overall we found that the imported cold food supply chain can cause COVID-19 recurrent outbreak. Frozen food and outer packaging can be contaminated with SARS-CoV-2 during processing and packaging. When the cold chain food reached the destination, SARS-CoV-2 virus may infect stevedores or other staff working in the port through direct contact with the goods, and then infect peddlers or other people.

### Analysis of COVID-19 transmission routes in the supply chain of imported cold food

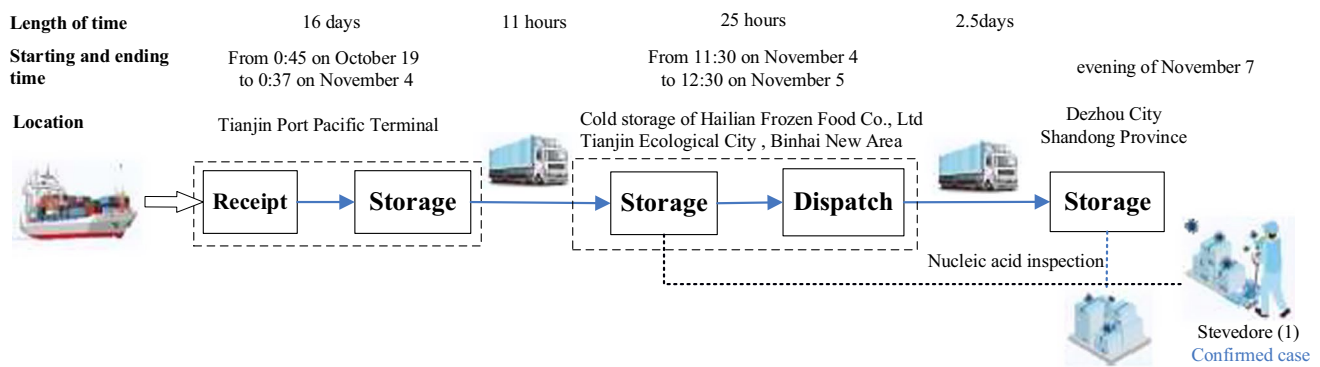
Next, two COVID-19 outbreak cases of Table 1 recurred in Tianjin on Nov. 7 and Dalian on Dec. 15 will be traced, respectively.

We trace the recurrence of COVID-19 cases in Tianjin on November 7, 2020, and the SARS-CoV-2 transmission route along the cold chain logistics after the imported frozen pig elbows arrived at Tianjin Port Taiping International Container Terminal. At 0:45 on October 19, 2020, the cold chain containers with frozen pig elbows imported from Bremen port in Germany arrived at Tianjin Port Taiping International Container Terminal. After receipt, transportation, storage, dispatch and other logistics links, these imported frozen pig elbows were transshipped to Dezhou, Shandong Province on the evening of November 7, 2020. The nucleic acid tests of the outer packaging samples of these imported frozen pig fore-elbow were positive by Dezhou Center for

Disease Control and Prevention. At the same time, one environmental sample from Tianjin Hailian cold storage where these frozen pig elbows had been stored was positive for nucleic acid too, and a stevedore was infected with the SARS-CoV-2. In the period of frozen pig elbows transshipped to inland from Tianjin Port Taiping International Container Terminal, SARS-CoV-2 had survived in the cold chain for about 20 days, which confirms the laboratory studies (Fisher et al. 2020; van Doremalen et al. 2020) in practice. The epidemic transmission chain is shown in Fig. 1.

We trace the recurrence of COVID-19 cases in Dalian in mid-December. On December 15, 2020, during the routine and regular nucleic acid inspection for the employees engaged in the imported cold food supply chain at Dalian port, four stevedores and one worker were found to be SARS-CoV-2 positive and were identified as asymptomatic infection. As of 24:00 on January 2, 2021, there were 83 cases of infection in Dalian, including 48 confirmed cases and 30 asymptomatic cases. The Dalian Center for Disease Control and Prevention conducted an extensive epidemiological investigation and molecular epidemiological analysis to identify the virus transmission chain. It is reasonable to assume that the epidemic in Dalian was caused by the personal activities of a dockworker (stevedore) who was infected through close contact with the above four stevedores infected with SARS-CoV-2 virus. The epidemic transmission chain is shown in Fig. 2.

Through the investigation and analysis of the epidemic transmission chain in Table 1, we can establish the



**Fig. 1** Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission route along the imported cold chain logistics from Tianjin Port to Dezhou City, Shandong Province between October 19 and November 7, 2020. The contaminated cold chain containers with frozen pig elbows imported from Germany arrived in Dezhou, Shandong Province from Tianjin Port through logistics links

such as receipt, storage, transportation, storage, dispatch, transportation and storage. On November 7, 2020, the nucleic acid tests of samples were positive in both Dezhou and Tianjin, and a stevedore was infected with the SARS-CoV-2 in Tianjin. From Tianjin Port to Dezhou City, SARS-CoV-2 had survived in the cold chain for about 20 days

transmission route of SARS-CoV-2 along the cold chain logistics after the imported cold food with the contaminated outer packaging arrives at domestic airport, port or station (see Fig. 3).

Overall we found that SARS-CoV-2 virus can survive 20 days through cold chain transportation with low temperature, and the contaminated cold food or food packaging material can transmit the SARS-CoV-2 virus along the cold chain logistics through “person-to-thing -to-person” transmission not just through “person-to-person”.

## Safety precautions

Critical safety precautions are needed at all stages of the imported cold chain logistics from port to fork including receipt, storage, dispatch, delivery, sales and consumption. Taking safety precautions to prevent the contamination of the imported cold food packaging by SARS-CoV-2, responsible for COVID-19, will aim at preventing SARS-CoV-2 transmission along the cold chain logistics from causing the virus to spread from employees to other people.

The precautions can be grouped in government regulation, nucleic acid inspection, personal protection, disinfection of surfaces, clean working environments, workers’ medical condition (e.g., stay home if sick), personal hygiene (e.g., wash hands) and social distancing.

Since a lot of literatures have put forward the safety precautions about workers’ medical condition, personal hygiene and environmental conditions (Dai et al. 2021; Lu et al. 2020; Nakat and Bou-Mitri 2021; Rizou et al. 2020), the “Make Protection”, “Work Environment”, “Be Healthy”, “Wash Hands” and “Social distance” will not be covered here. Many countries/ regions do not have the conditions

of analyzing and tracing the local outbreaks caused by imported cold food chain, the safety precautions like detection and disinfection proposed (Choi et al. 2021; Singh et al. 2021; Wang et al. 2020; Zucker et al. 2021) are lack of pertinence and specific guidance. The feasibility and effectiveness need to be further verified.

While the imported epidemic cases in China caused by the cold food supply chain were stopped within two to four weeks and were limited in scope to less than ten cases or a few hundred cases for each event. Therefore, based on the experiences of prevention and control of COVID-19 epidemic in China, this paper will concentrate on the three specific precautions that are government regulation, nucleic acid inspection and disinfection.

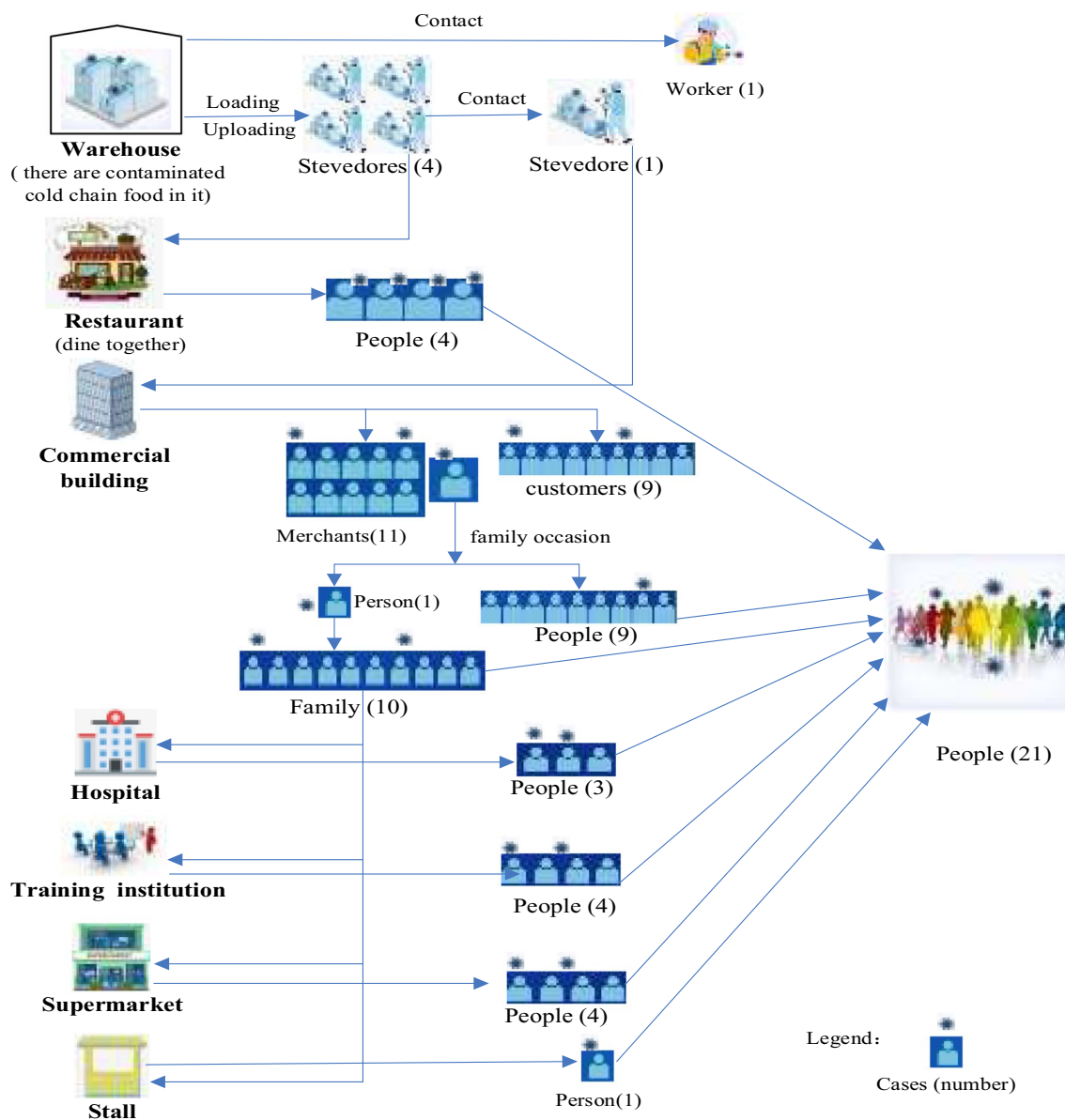
## Government regulation

In order to prevent the outbreak and control the spread of the epidemic, it is imperative for the relevant government departments to formulate the epidemic regulatory system, regulatory process and traceability system. It has been proved to be highly efficient by the practice of COVID-19 epidemic control in China.

The traceability system is an important characteristic of Chinese government regulation, so it is given especially in the next.

The cold chain traceability management system composes of national, provincial and enterprise platforms to trace SARS-CoV-2 virus in the cold food supply chain. Quick-response cold chain food traceability provided strong support for the prevention and control of COVID-19 outbreaks in Dalian, Qingdao, and Tianjin.

The main strategies include:

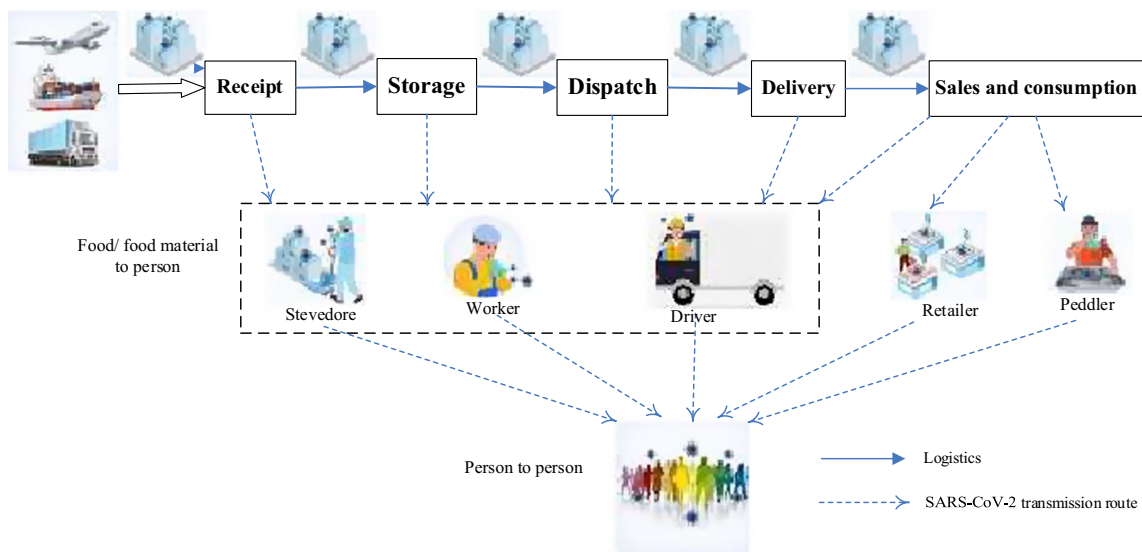


**Fig. 2** Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission chain from contaminated cold chain foods in warehouse to human in Dalian between December 15, 2020 and January 2, 2021. Four stevedores and one worker were found to be SARS-CoV-2 positive and were identified as asymptomatic infection in Dalian port on December 15, 2020. The extensive epidemiological

investigation and molecular epidemiological analysis identified the virus transmission chain across Dalian City. The epidemic in Dalian was mainly caused by the personal activities of a dockworker (stevedore) who was infected through close contact with the above four stevedores infected with SARS-CoV-2 virus. In 18 days, there were 83 cases of infection in Dalian

- (1) Build the national command platform. The national-level platform is developed and constructed by the General Administration of Market Supervision for command and early warning. Through the "heterogeneous identification" mechanism, the inter-provincial mutual recognition and exchange of traceability information can be realized.
- (2) Optimize and improve the provincial platform. The provincial-level platform is positioned for traceabil-

- ity information management and public services. It can help key cold chain food producers and operators achieve informative traceability and data docking. Each province can access to the national platform in accordance with the unified data docking regulations.
- (3) Realize enterprise data docking. In accordance with the principle of territorial management, the market supervision departments of all provinces formulate and publish provincial-level platform interface standards and



**Fig. 3** Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission route along the cold chain logistics after the imported cold food with the contaminated outer packaging arrives at domestic airport, port or station. Frozen food and outer packaging can be contaminated with SARS-CoV-2 during processing and packaging through “person-to-thing”. Through cold chain logistics with low temperature, SARS-CoV-2 can survive and then infect stevedores,

peddlers, drivers, retailers or other staff working in the logistics nodes through “thing (cold chain food outer packaging and material) to person”. These infected cases can infect other close contacts again through “person-to-person”. SARS-CoV-2 virus can be transmitted along the cold chain logistics process, mainly include receipt, storage, dispatch, delivery, sales and consumption

- regulations, guide and urge key cold chain food supply chain enterprises to connect provincial-level platforms.
- (4) Strengthen information management. Customs should connect with the market supervision departments related to the import of cold chain foods to realize information sharing and verification. The specific implementation method is determined by the General Administration of Customs and the General Administration of Market Supervision.
  - (5) Realize traceability. On receiving a positive notification of SARS-CoV-2 virus test for key cold chain foods, local market supervision departments should immediately trace the flow of the same batch of food using the provincial platform and report key food information using the national platform.

The traceability system can help companies report cold chain food information in real time and achieve positive and reverse traceability. The causes of COVID-19 recurrent outbreaks can be identified, and the risks can be controlled.

### Nucleic acid inspection

In order to effectively prevent the risk of the imported COVID-19 epidemic in China, the “four early” (early detection, early report, early isolation and early treatment) strategy to strength epidemic prevention and control is implemented. The General Administration of Customs has

further strengthened communication and consultation with the competent authorities of exporting countries, required them to follow the regulatory guidelines issued by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO). The food and its packaging exported to China are strictly prevented from being contaminated in all aspects of production, processing, storage and transportation process.

For public health surveillance, nucleic acid inspection is used as an important bioanalytical tool to screen populations and monitor foods, surfaces and surrounding environments. The epidemic source control with nucleic acid inspection are strengthened in all stages of logistics. The General Administration of Customs conduct nucleic acid sampling inspection on the imported cold food, including outer packaging, inner packaging, containers, air pallets, land vehicles, bulk carriers, etc.

The main strategies include:

- (1) Source control. The customs department is responsible for the sampling and inspection of imported containerized goods at the port. Imported items can be put into storage, processing and sales only after obtaining a negative nucleic acid test and a disinfection certificate. The production and business enterprises should establish a full traceability system for imported goods so that the source can be checked and whereabouts can be traced.

- (2) Nucleic acid screening for items. All stages of cold chain logistics and operating environment should conduct nucleic acid inspection regularly. Imported items should be strictly done "five inspections" (the customs declaration procedures, the inspection certificate, the origin place specifications, the nucleic acid test report and the disinfection record). As long as frozen meat products and aquatic products enter the storage, sales and processing stages, they must be put into the centralized supervision warehouse for nucleic acid inspection. Only after passing the test can they be moved out of the warehouse.
- (3) Nucleic acid screening for persons. The employees should conduct nucleic acid screening regularly. The industry employees who often have close contact with cold chain products with high possibility of COVID-19 contamination, such as handling, processing and marketing of cold chain products, should be conducted nucleic acid screening regularly. The infected persons should be tracked and inspected systematically. The zero patients should be found in the first time by the sensitive fever clinic network system. The close contacts should be tracked, and if necessary, the contacts of the close contacts need to be further tracked by expanding the detection with the close contacts as center.
- (4) Emergency handling for positive nucleic acid samples. Once there is a positive sample of nucleic acid test, the relative enterprise should promptly activate emergency response plan, seal items and treat them in a harmless manner according to local requirements. Then enterprise should organize traceability investigations of the imported goods involved in the epidemic across provinces in a timely manner, strengthen the traceability management and minimize the risk of epidemic spread.
- (2) In the process of cold chain transportation and storage. When the imported cold food is unloaded from the container and transferred to the domestic transportation equipment, the owner should disinfect the packaging of the goods. In the transportation process of imported cold food, the logistics enterprise should not be allowed to open the box. In the domestic transportation section, the transportation management department should supervise and guide the cold chain logistics enterprises to check the customs clearance documents and implement the disinfection measures for transport vehicles, ships and other transportation equipment.
- (3) In the circulation link. For the imported cold food that has achieved clearance from the port, the relevant enterprises shall make sure the disinfection certificate attached to the goods available before unloading them into the cold storage. Otherwise, the outer packaging and the inner wall of the loading container shall be disinfected when unloading and the certificate of goods disinfection is issued. While the inner packaging of the goods shall be disinfected at all times.
- (4) In the process of distribution. In order to avoid the contamination of cold chain food, the surfaces of objects frequently contacted by human hands and the vehicles should be disinfected regularly. Drivers should ensure that the transport vehicles, handling tools and containers are cleaned and disinfected regularly. The surfaces of objects such as steering wheel, door handle and mobile equipment, should also be disinfected regularly as they are most likely to be contaminated by the virus.
- (5) In consumer terminals. Three certificates including import quarantine certificate, nucleic acid test report and traceability information are indispensable for inspection in large supermarkets, farmers' markets and other consumer terminals. The imported cold food packaging shall be disinfected again after they have been unloaded to the dedicated trolley. Then they will be sent to the dedicated storage area, and finally be moved out of the warehouse for sale.

### Disinfect surfaces

In order to effectively prevent the virus from spreading into domestic areas through international logistics, it is necessary to strengthen the sanitation and disinfection of all stages in the cold food supply chain logistics, as well as the regular cleaning and sanitizing of the cold chain environment.

- (1) In the port link. The inner wall of the container and the outer packaging of the imported cold food should be disinfected by on-site operators or import enterprises under the organization and supervision of the Customs Department. After the completion of disinfection, the disinfection unit should issue the disinfection certificate. The imported cold chain food that was not disinfected at the port must be disinfected in the subsequent cold chain logistics process after the customs clearance.
- (6) In addition, employees engaged in the handling, loading and unloading, transportation, wholesale, processing and sales of cold chain food at ports must follow the relevant national laws and regulations and food safety standards, strictly implement the operation process, work specifications and epidemic prevention and control guidelines and carry out health monitoring. To reduce the spread of COVID-19, employees in the food cold chain logistics industry should also take personal protection, try to use "no touch" deliveries instead of working with hands directly and avoid touching face, hands, mouth and nose etc. Moreover, protective equipment should be replaced in time, and work clothes should be disinfected regularly.



Overall we found that in order to prevent the recurrent outbreak of COVID-19 and control the spread of the epidemic, it is imperative for the relevant government departments to formulate the epidemic regulatory documents, operation process and traceability system, which has been proved to be highly efficient in China.

## Conclusion

By analyzing the recurrent outbreaks in China from June 2020 to March 2021, it is shown that the imported cold food supply chain is one of the important causes for the recurrence of COVID-19. By analyzing and tracing the outbreaks, the transmission route of COVID-19 in the imported cold food supply chain is obtained. Combining with the experience of preventing and controlling the recurrent outbreaks of COVID-19 in China, the most critical safety precautions are put forward for imported cold food system, operation environment and people in the cold chain. They include that government departments formulate epidemic regulatory and traceability system, enterprises strengthen nucleic acid detection and disinfection for goods/people in all stages of cold chain logistics, the working environment is cleaned and sanitized regularly and others.

The COVID-19 pandemic is still spreading around the world. Many countries are still in the hardest hit areas of the COVID-19 pandemic including the United States, India, Brazil, Russia, Britain, France and other European countries. Moreover, more than 60 countries have found mutated SARS-CoV-2, and the second wave of the COVID-19 become spread in many countries. Recurrent outbreaks in China have proved that the imported cold food supply chain is one of the most important ways for the outbreak and spread of COVID-19. The contaminated cold food or food packaging material can transmit the virus, and an infected worker will spread the virus through “person-to-thing-to-person” transmission not just through “person-to-person”, which is different from the previous reports (Nakat and Bou-Mitri 2021). Therefore, formulating a comprehensive prevention plan to deal with the localized outbreak epidemic at any time should be considered as a priority for public authorities.

The COVID-19 pandemic has urged world nations enforced rapid and sometimes very contradictory policies to limit the virus spread, with results ranging widely from total failure to moderate success (Ufnalska and Lichtfouse 2021). The international community should pay close attention to SARS-CoV-2 transmission mode through cold chain, build international cooperative efforts in response, share relevant data, and call on all countries to take effective prevention and control measures to prevent virus contamination in cold

chain food production, marine fishing and processing, transportation and other operations (Huilai et al. 2021b).

Overall, no country can be locked down for a long time and independent from the rest of world. As long as it has economic exchanges with other countries, it will face the safety risk of imported epidemic. This study will be helpful for other countries to control the spread of COVID-19, open up economy and return to normal life as soon as possible.

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## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest in this work.

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