Abstract. – OBJECTIVE: The outbreak of SARS-CoV-2 in 2020 has become the world’s largest public health event, causing global attention and concern. Despite national efforts to control this emerging infectious disease, it still cannot be contained. China, which reported the disease early, was able to control the outbreak quickly, but there is the problem of imported infections abroad. This review aims to summarize SARS-CoV-2 detected on the outer packaging of imported cold chain food and lead to the transmission of novel coronavirus.

MATERIALS AND METHODS: We reviewed information on SARS-CoV-2 detected on the outer packaging of imported cold chain food and relevant literature. We searched the following databases: PubMed, Web of Science, EMBASE and CNKI. search terms were “2019 nCoV”, “SARS-CoV-2”, “COVID-19”, “cold-chain”, “item surface”, “spread”, “people”.

RESULTS: We found that SARS-CoV-2 survives on the surface of cold-chain food for a long period of time and these active viruses can be transmitted to humans.

CONCLUSIONS: We believe that while strictly preventing and controlling the importation of infected patients, we should strengthen the management of imported cold-chain food and its workers to prevent the transmission of SARS-CoV-2 to humans on the surface of cold-chain food objects.

Key Words: COVID-19, SARS-CoV-2, Cold-chain food, Surface, Transmission.

Introduction

The outbreak of novel coronavirus pneumonia in 2020 was caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which is highly contagious and spreads rapidly, quickly spreading around the world1-3. Paradoxically, unlike other respiratory infections, Coronavirus Disease 2019 (COVID-19) also breaks out in hot summer weather, as it does in tropical countries4. Surprisingly countries with robust health care delivery systems and advanced medical technologies also experience outbreaks of COVID-19. SARS-CoV-2, in December 2019, began to be detected in Wuhan, China, and spread rapidly in a short period of time4,5. China adopted an aggressive and effective strategy of rigorous prevention and control and brought the outbreak under control within a few months. As a result of outbreaks in many countries, China faced the difficult task of importing infected patients abroad for transmission. With China’s strict prevention and control measures, imported cases were fully contained. However, in the second half of 2020, several cases of COVID-19 were detected on the outer packaging of imported cold-chain foods in China and resulted in the transmission of the disease6. To explore the presence and transmission of the virus on the surface of cold-chain foods, we searched relevant literature and departmental circulars and reviewed to propose countermeasures for the management of imported cold-chain foods to eliminate the transmission of novel coronaviruses from the surface of articles to humans. Imported cases and the novel coronavirus on the surface of objects are detected and dealt with early, so that the virus can be fully controlled on a continuous basis.

Presence and Spread of SARS-CoV-2 on the Surface of Objects

In December 2019, several cases of unexplained pneumonia were reported in Wuhan, China, and
were soon found to be infectious. On January 7, 2020, experts from the Chinese CDC isolated the pathogen as a novel coronavirus. On January 12, 2020, the World Health Organization officially named this virus as SARS-CoV-2.

SARS-CoV-2 is highly contagious, and the population is generally susceptible. SARS-CoV-2 is transmitted mainly through respiratory droplets and close contact. COVID-19 patients emit the virus from their bodies into the air and surfaces of objects by talking, coughing and sneezing. The surfaces of objects in areas at high risk of respiratory infections such as hospital fever clinics, infectious disease clinics, respiratory clinics and emergency departments are where SARS-CoV-2 is most prevalent. The surfaces of objects in confined and crowded buses, airplane cabins, subways, supermarkets, restaurants, airports and train stations are also frequently exposed to SARS-CoV-2. People in these places are susceptible to infections when they are not well protected19. Hospitals and aircraft cabins are the most common accelerators of SARS-CoV-2.

Viral stability and infectivity under environmental conditions are influenced by viral biology (type), environmental (temperature, light, relative humidity) and surface physicochemical properties, as well as local environmental factors, including vector fluid properties (saliva/mucus), virulence agents, pH, etc9. SARS-CoV-2 spike protein has a 10-to-20-fold increased affinity for the ACE2 receptor compared to SARS-CoV-1, which may contribute to efficient replication in the upper respiratory tract and allow for more efficient transmission in humans10. Chin et al11 reported prolonged survival of SARS-CoV-2 on plastic surfaces, where it was released at room temperature and 65% relative humidity for 7 days. Fisher et al12 found no decrease in the titer of infectious SARS-CoV-2 at low temperatures and was able to survive in inoculated chicken, pork and salmon fillets stored at -20°C for 3 weeks. This would suggest that SARS-CoV-2 may survive and spread on the surface of cold objects for extended periods of time.

Long-Term Presence of SARS-CoV-2 on the Surface of Cold-Chain Foods

Cold-chain food is at a specific low temperature throughout the entire process from processing, storage, transportation, distribution and retailing in order to maintain the quality of the food. The temperature of cold-chain items generally needs to be controlled at around -18°C. During this cold chain process, microorganisms such as viruses do not freeze to death or grow and multiply and remain viable. Frozen seafood products are usually stored at low temperatures, the lower temperature of the environment, the longer the virus can survive, making it easy to find novel coronavirus viruses in frozen seafood products or on their packaging. Incubation periods of SARS-CoV-2 and asymptomatic infections can also spread the disease. In these areas with high levels of SARS-CoV-2, contamination can occur from latent and asymptomatic cases infected individuals participating in the processing, packaging, handling, and transportation of cold chain food.

Since July 2020, the presence of SARS-CoV-2 has been detected in imported cold-chain foods from South America and Europe in Xiamen, Dalian, Chongqing, Yantai, Qingdao and Shenzhen, China, and some have been transported to other locations for wholesale distribution13-26 (Table I). Interestingly, the samples that tested positive for the novel coronavirus were all from the outer packaging of frozen seafood products and were not detected within the frozen seafood food, suggesting that the chances of the food itself being contaminated with the virus are very small, which means that the chances of the virus being transmitted through food are relatively small. We consider that the reason for this may be related to the fact that masks must be worn in specific places when processing cold-chain foods. During transport of these cold-chain foods, latent and asymptomatic cases may not wear masks and could easily excrete SARS-CoV-2 or contaminate the outer packaging of cold-chain foods.

A shipment of frozen pork from Bremerhaven, Germany arrived at Tianjin port after a long journey on 19 October 2020. On November 4, the shipment was transported from the Pacific Ocean Terminal to the Haitian Cold Storage, and on November 5, the shipment was shipped in its entirety to Dezhou, Shandong Province. On November 7, a weakly positive test for SARS-CoV-2 was detected on the surface of the cold-chain pork package in Dezhou. The virus survived in the cold-chain for nearly 20 days from the time of entry to the time of detection17. Cold-chain food products usually travel by sea and take more than 20 days to reach China from South American countries. The high detection of SARS-CoV-2 on the packaging surface of cold-chain seafood from Ecuador, South America also indicates that SARS-CoV-2 survives for at least 20 days on the packaging surface of cold-chain seafood.

As relevant government departments and the public pay attention to the problem of SARS-CoV-2...
detection on the surface of imported cold-chain food, the detection of SARS-CoV-2 on the surface of imported cold chain food has increased, which has led to an increase in the detection of SARS-CoV-2 on the surface of cold-chain food. However, do not be overly concerned, as SARS-CoV-2 has been detected on the surface of imported cold-chain foods at only 0.48 parts per million through sampling and monitoring to date. We should not only pay attention to the problem of SARS-CoV-2 detected on the surface of imported cold chain food, but also be rational and do a good job of initial disinfection and hygienic cleaning of the distribution chain to prevent the problem before it happens.

Table 1. Detection of imported cold-chain foods and their packaging surfaces.

<table>
<thead>
<tr>
<th>Time</th>
<th>Location</th>
<th>Category</th>
<th>Location of detection</th>
<th>Importing countries</th>
<th>Source/Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul 16, 2020</td>
<td>Yunnan</td>
<td>South American White Shrimp</td>
<td>Outer surface of the box</td>
<td>Ecuador</td>
<td>Yunnan Provincial Health Committee, 2020[16]</td>
</tr>
<tr>
<td>Jul 23, 2020</td>
<td>Dalian, Liaoning</td>
<td>A variety of seafood</td>
<td>Cold storage food, processing workshop, dormitory, canteen, horse yard, communal toilets, administrative offices</td>
<td>N/A</td>
<td>Dalian Municipal Health Committee, 2020[17]</td>
</tr>
<tr>
<td>Aug 11, 2020</td>
<td>Yantai, Shandong</td>
<td>Frozen Seafood Products</td>
<td>Outer packaging</td>
<td>N/A</td>
<td>Zhou, 2020[18]</td>
</tr>
<tr>
<td>Aug 12, 2020</td>
<td>Longgang, Shenzhen</td>
<td>Frozen Chicken Wings</td>
<td>Frozen chicken wing surface</td>
<td>Brazil</td>
<td>Xuan, 2020[19]</td>
</tr>
<tr>
<td>Aug 12, 2020</td>
<td>Xian, Shanxi</td>
<td>Frozen white shrimp</td>
<td>Outer packaging</td>
<td>Ecuador</td>
<td>Shenzhen Provincial Health and Wellness Committee, 2020[20]</td>
</tr>
<tr>
<td>Oct 17, 2020</td>
<td>Qingdao, Shandong</td>
<td>Frozen Cod</td>
<td>Outer packaging</td>
<td>N/A</td>
<td>Chinese Centre for Disease Control and Prevention, 2020[21]</td>
</tr>
<tr>
<td>Oct 31, 2020</td>
<td>Weihai, Shandong</td>
<td>Frozen Pork</td>
<td>Outer packaging</td>
<td>Brazil</td>
<td>Zhang et al, 2020[22]</td>
</tr>
<tr>
<td>Nov 07, 2020</td>
<td>Dezhou, Shandong</td>
<td>Frozen Pork Fore Knuckle</td>
<td>Outer packaging</td>
<td>Bremen, Germany</td>
<td>Cheng, 2020[23]</td>
</tr>
<tr>
<td>Nov 07, 2020</td>
<td>Tianjin</td>
<td>N/A</td>
<td>Outer packaging, Door handles</td>
<td>N/A</td>
<td>Tianjin Municipal Health and Wellness Commission, 2020[25]</td>
</tr>
<tr>
<td>Nov 18, 2020</td>
<td>Fuzhou, Fujian</td>
<td>Frozen Pomfret</td>
<td>Outer packaging</td>
<td>India</td>
<td>Zhao, 2020[26]</td>
</tr>
</tbody>
</table>
Transmission of SARS-COV-2 from Cold-Chain Food Surfaces to Humans

Earlier this year, it was reported that interpersonal transmission occurs mainly in households in China29. This household transmission suggests that close contact transmission between individuals may be one of the most important modes of transmission30. Family members infected with SARS-COV-2 readily emit SARS-COV-2 on the surfaces of room objects; however, direct research evidence of SARS-COV-2 transmission from the surfaces of these objects alone has not been seen.

Although the presence of SARS-COV-2 on the surface of cold-chain food products was detected in several cases from imported food, it is not clear how active SARS-COV-2 is on the surface of these objects and whether they transmit to humans. Previously, the viral nucleic acid load on the packaging surface of imported cold-chain foods was low and no live virus had been isolated. On October 17 2020, China Center for Disease Control and Prevention issued an official release, confirming for the first time outside the laboratory that novel coronavirus could survive for a longer period of time on the outer packaging of items under special conditions of cold chain transport, suggesting that the novel coronavirus could infect people in contact with the items under specific conditions and circumstances, using cold-chain items as carriers. The cold-chain food has the potential to be used as a vehicle for cross-border importation of novel coronaviruses. Cold-chain foods have the potential to import SARS-COV-2 across borders over long distances21.

On September 19, 2020, two workers from Qingdao Port Dagang Company loaded and unloaded this shipment of frozen seafood imported from abroad during the night shift. On September 24, 2020, during regular routine SARS-COV-2 testing of personnel in contact with the imported products, two stevedores were found to be infected with the novel coronavirus and were asymptomatic. As there were no novel coronavirus patients in Qingdao at that time, and they had no history of travel outside the city. Combining these epidemiological histories with the fact that both workers had a history of contact with cold-chain food overpacks, it was considered that SARS-COV-2 transmission from cold-chain food overpacks may have been the cause. 2 workers were sent to the sentinel hospital for treatment, and 1 patient later developed clinical symptoms and changes in the chest CT and was diagnosed with COVID-19 common type. Meanwhile, 132 and 228 close contacts of the 2 patients were all put under intensive isolation. All 360 close contacts and 4341 general contacts were negative for SARS-COV-221.

Coincidentally, the incident did not end there and involved a SARS-COV-2 sentinel hospital. The 2 patients with SARS-COV-2 who left the closed ward for examination in the CT room during isolation and observation at the designated hospital, were not properly protected, resulting in the CT room being contaminated with the virus, which in turn infected the TB inpatients and their companions who went to the same CT room for examination the following morning, and brought the virus into the TB ward, leading to the spread of this outbreak in the hospital.

This infection event successively involved 7 TB patients admitted to the hospital, 3 were daily companions of TB patients at the hospital and 2 were family members of patients or caregivers at the hospital. No health care workers were infected. The whole gene sequence sequencing and matching were carried out and confirmed that the infected individuals were highly homologous to the viral gene sequences of the specimens of the two loaders12. Fortunately, no community transmission occurred, and the outbreak of this SARS-COV-2 was quickly contained through the efforts of various departments.

What impressed the world was that, in response to this SARS-COV-2 transmission on the surface of objects, nucleic acid testing was conducted around the clock in Qingdao for a full 120 hours from November 12, 2020, and on October 17, nucleic acid testing was almost complete for the entire population of Qingdao, with the results of all 10899145 nucleic acid negative samples, except for the previously announced confirmed cases33.

Later, on November 7, the outer packaging of a batch of German frozen pork samples imported through the Tianjin port was tested positive for SARS-COV-2, and in the early hours of 8 November, the first nucleic acid test results showed a positive test at the door handle of a cold storage at the site, while a handler from a frozen food company was also tested positive26. Another asymptomatic infection was added to Tianjin on November 9 for a Binhai New Area Dongjiang port cold-chain handler. Although it is not certain that these patients are infected by cold-chain food surface SARS-COV-2, they have no history of exposure or epidemiological history of SARS-COV-2.
SARS-CoV-2 is a respiratory virus and there is no evidence that SARS-CoV-2 poses a food safety risk. Although the probability of human transmission of SARS-CoV-2 from contaminated food packaging surfaces is small and concentrated in the outer packaging of food, we need to pay attention to it. This is because SARS-CoV-2 on the surface of cold-chain foods can be transported over long distances, allowing the spread of COVID-19 infection from areas of high prevalence to areas of low risk of COVID-19 or areas free of COVID-19 outbreaks.

Although different countries and regions implement their own food safety management systems during the preparation and packaging of cold chain items, they are all based on good hygiene practices. For example, hygienic practices such as wearing clean clothing, washing hands before handling, wearing hats and masks, etc. prevent any potential microbial contamination from spreading to the food. It has been reported that approximately 90% of SARS-CoV-2 transmission is from symptomatic and asymptomatic patients, with the remaining 10% coming from the environment, including surfaces. Food contact surfaces include all areas that come into contact with food during preparation (e.g., cutting boards, tables, utensils), production, processing and packaging, and typically include stainless steel, plastic materials, wood, rubber, ceramics or glass. These surfaces can be contaminated with pathogenic bacteria and viruses that can infect the food and/or the person handling it, so the greatest risk in the food environment remains human-to-human transfer. The wearing of masks, hats and gloves during cold-chain food processing greatly reduces contamination during cold-chain food processing. During the handling and transport of these cold chain foods, the environment in which they are handled and transported has low hygiene requirements, which can lead to contamination of the cold-chain food outer packaging.

Introduction of Relevant Policies Based on the Detection of SARS-COV-2 on the Surface of Imported Cold-Chain Foods

With the increase in the detection of SARS-CoV-2 on the surface of imported cold-chain food and the occurrence of its transmission to people, the relevant departments in China attached great importance to it. A series of measures were introduced within a short period of time. On July 10, 2020, the General Administration of Customs announced the suspension of the registration of three Ecuadorian producers in China. On August 14, 2020, the General Administration of Customs announced the issuance of an announcement on the inspection and quarantine requirements for imported Ecuadorian frozen South American white shrimp. On November 13, 2020, the Ministry of Transport issued the COVID-19 for (Imported Cold Chain Food Logistics by Road and Waterway Technical Guidelines on Prevention, Control and Disinfection of Viruses) and the [[Guidelines on Prevention and Control of Novel Crown Pneumonia Outbreak for Ports and their Frontline Person nel (Fourth Edition)].

Strengthen the Management of Imported Cold-Chain Foods and Their Practitioners

Strengthen source control and strictly require imported cold-chain food companies to reduce or eliminate SARS-COV-2 contamination on the surface of imported cold-chain food during production and transportation. For companies with SARS-COV-2 contamination on the surface of cold-chain food, reduce or temporarily suspend their trading qualification. Domestic personnel engaged in the importation of cold-chain food establish awareness of the risk of SARS-COV-2 infection, remember the importance of wearing appropriate personal protective equipment and practicing proper hand hygiene, and strictly implement national policies on cold-chain food prevention and control of the COVID-19. Loaders and unloaders should wear work clothes and hats, use disposable medical masks and gloves, etc., avoid goods close to their faces, touch their hands to their mouths and noses, and prevent contact with frozen aquatic products that may be contaminated with the Novel Coronavirus, etc. They do a good job of cleanliness and hygiene before leaving the cold-chain food workplace. Personnel working in the imported cold-chain food do a good health registration system and abnormal health reporting procedures and do SARS-COV-2 nucleic acid tests once a week.

Strengthening the Management of SARS-COV-2 Detection on the Surface of Imported Cold-Chain Food

During the transportation of imported cold-chain food, the carrier shall not open the container. If the test result is positive upon arrival, the cold-chain food operator shall promptly activate the
emergency plan of the unit, take timely emergency disposal of the relevant items and environment under the guidance of professionals according to local requirements, return the relevant items, temporarily seal them or dispose of them harmlessly, disinfect the work area, and carry out timely nucleic acid testing and health screening as well as isolation and observation measures for personnel who may come into contact with them. Personnel involved in the removal of relevant items should be properly protected personally and isolated for observation in the workplace. Even if the SARS-COV-2 test results for imported cold-chain food are negative, the customs department should organize guidance to urge the operators of the inspection sites or the importing enterprises to implement disinfection of the inside of the containers and the outer packaging of the goods for imported cold-chain food. Only timely detection and disposal of contamination by SARS-COV-2 can effectively stop the cold-chain from reaching the market. Consumers who purchase cold-chain food can avoid the risk of SARS-COV-2 infection by taking good personal precautions (avoiding direct contact with cold chain food with their hands).

**Enhance Comprehensive Prevention and Control of SARS-COV-2 Transmission to Humans on the Surface of Imported Cold-Chain Food Products**

When SARS-COV-2 is detected on the outer packaging of imported cold-chain food, all staff in contact with these items should be isolated and observed for their health status and SARS-COV-2 nucleic acid screening. Once they are positive for viral nucleic acid, they should be seen at a designated hospital regardless of whether they have symptoms such as fever, cough or fatigue. A survey of their movement trajectory is also conducted, and close contacts and general contacts are identified and placed under fixed-site isolation and home isolation observation for 2 weeks respectively. Early detection, diagnosis and treatment, combined with timely traceability, comprehensive contact investigation and integrated prevention and control, will maximize the possibility of controlling the SARS-COV-2 outbreak.

**Conclusions**

The transmission of SARS-COV-2 to humans from imported cold chain food surfaces is only an isolated occurrence. However, we also need to be alert to this mode of long-range transmission and carry out early and comprehensive prevention and control to avoid large community spread.

**Conflict of Interest**

The Authors declare that they have no conflict of interests.

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How to deal with the transmission of SARS-COV-2 on the surface of Cold-chain foods to people