



Relevance of SARS-CoV-2 in food safety and food hygiene: potential preventive measures, suggestions and nanotechnological approaches

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Abstract Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is easily transmitted from person to person, which has fueled the ongoing pandemic. Governments in different countries have taken drastic actions such as complete lockdown. However, little attention has been paid to food safety and its potential linkage with the coronavirus disease (COVID-19) pandemic. SARS-CoV-2 spread from staff to food products or food surfaces is conceivable. At least, instead of consuming unpackaged or uncovered foods, consumption of boiled or canned foods processed at high temperatures should be preferred. Before consumption, consumers should clean the surface of canned foods. In addition to recommending or enforcing simple precautions, such as using masks, governments must conduct mandatory SARS-CoV-2 tests regularly and intermittently for personnel who handle food materials or supporting materials (e.g., plastic pouches). Local markets, such as those in Wuhan, which sell live animals and exotic foods for consumption, are a concern. Trade of exotic or wild animals, unhygienic marketplace conditions, and not cooking at high temperatures ought to be prohibited. The consumption of vitamins, minerals, and other food-derived

compounds such as omega fatty acids is a prudent way to improve the performance of the immune system. In addition, nano-encapsulated materials with controlled release properties may be useful in protecting food products and packaging from SARS-CoV-2 contamination.

Keywords SARS-CoV-2 · COVID-19 · Foodborne viruses · Food safety · Food hygiene · Nanotechnology

Introduction

Humans have for millennia faced many health problems caused by bacterial or viral infections. In particular, bacteria are a major cause of foodborne illnesses. Therefore, studies on foodborne illnesses have focused on bacterial spoilage in food and foodborne pathogens, with comparatively less attention given to viruses. Generally, a virus is defined as an infectious agent that is typically 20–300 nm in size, contains RNA or DNA, and requires a living host cell for its replication. The collective host range of viruses is broad and includes animals, humans, plants, and bacteria [26]. Serious diseases caused by viruses include Ebola, acquired immunodeficiency syndrome, and avian influenza. The latter two occur globally. Coronaviruses (CoVs) are members of the subfamily *Orthocoronavirinae* in the family *Coronaviridae*. Illnesses caused by CoVs include the common cold (caused by HCoV-229E and HCoV-OC43), middle east respiratory syndrome (caused by MERS-CoV), severe acute respiratory syndrome (caused by SARS-CoV), and COVID-19, which is caused by SARS-CoV-2 [7, 59]. The latter is the cause of an ongoing pandemic.

The name CoV is derived from the Latin word corona, meaning “crown” or “halo” which refers to the characteristic appearance of the virus particles viewed by electron

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microscopy. CoV is zoonotic, meaning it may pass from animals to humans. This typically occurs when infected animals are slaughtered for consumption. [8, 52, 63]. CoV has been identified in bats, cattle, cats, rats, chickens, turkeys, swine, dogs, rabbits, horses and may cause respiratory tract and gastrointestinal diseases [11, 21, 33, 37, 38, 48]. SARS-CoV-2 is a new strain positive-stranded RNA virus covered by a lipid bilayer. The genome identity of SARS-CoV-2 and SARS-CoV exceeded 70%. Angiotensin-converting enzyme 2 is a cell surface protein that SARS-CoV-2 and SARS-CoV can bind with [45, 65]. The common symptoms of SARS-CoV-2 and SARS-CoV infections are usually pneumonia and fever. However, SARS-CoV-2 has a longer incubation period and is more infectious [45]. SARS-CoV-2, SARS-CoV, and MERS-CoV infections have all been associated with the consumption and trade of wild animals [17, 28, 30, 43, 63]. The ongoing COVID-19 pandemic originated primarily in Wuhan, Hubei Province, China [23, 55]. With regard to food consumption and COVID-19, many initial infections were linked to Wuhan's Huanan Seafood Wholesale market [6, 8, 22, 23, 28], which was closed on 01 January 2020. Whether the market is the actual source of the illness is unclear. In another opinion, the market might have boosted the circulation of the virus more rapidly rather than being the source of the virus [62]. As the outbreak increased in scope and attained pandemic status, information about the virus was disseminated through various organizations. For example, the United States Food and Drug Administration (FDA) released some Frequently Asked Questions related to COVID-19 on its website on 13 March 2020 [13]. Of relevance to this paper, the potential relationship between COVID-19 and food products has received great attention. Some of the examples of questions are: Is food imported to the United States from China and other countries affected by COVID-19 at risk of spreading COVID-19?. Are food products produced in the USA a risk for the spread of COVID-19?. Can COVID-19 be spread by touching SARS-CoV-2-contaminated food, food packaging, or surfaces in contact with food that contact surfaces?. Can SARS-CoV-2 be spread via food that has been handled by someone infected with the virus? Should food facilities (grocery stores, manufacturing facilities, restaurants, etc.) undergo special cleaning or sanitation procedures for SARS-CoV-2?. These questions clearly reveal public worry and anxiety about COVID-19. The responses by the FDA indicate a lack of evidence and reported cases for some of the issues. However, some information is known that can increase consumer awareness.

The main aim of this review is to highlight the potential transmission risk of infection SARS-CoV-2 from food products. The audience includes those with the authority to enact legislation to safeguard food quality and consumers.

Relationship between foods and viruses

Food products play a key role in virus transmission. Viruses may contaminate a wide variety of food products and may remain infective in foods for up to 4 weeks [44]. Norovirus (NoV) and hepatitis A virus (HAV) are two common viruses transmitted by foods [27, 49]. Rotavirus, enterovirus, sapovirus, astrovirus, adenovirus, and hepatitis E virus (HEV) can easily be transmitted to humans via infected food or water [2]. The main foodborne viruses and some of the transmitted food products are summarized in Table 1.

Food contamination can occur in three main ways. The first is during the production process. This can involve contamination of the water in which shellfish grow or contamination of the water used to wash fruits after harvest. The second involves infected food handlers who have not observed good hand hygiene practices, such as hand washing [27]. There are a wide variety of foodborne illnesses associated with viral infections, of which NoV, HAV, and HEV are noteworthy. NoVs have a diameter of 23–40 nm. They belong to the family *Caliciviridae*. Almost 40% of the cases of NoV infections are assumed to result from consumption of contaminated food. Shellfish, berry fruits, and green vegetables are major sources of NoV infection. HAV belongs to the genus *Hepatovirus* within the family *Picornaviridae*. HAV can be maintained on food and in water for a long time. Oysters, clams, mussels, lettuce, green onions, raspberries, and strawberries are susceptible to contamination. HEV (which is 35 nm in diameter) is classified into the unassigned genus *Hepevirus*. Consumption of pork pies, wild boar, undercooked deer, raw pork, home-made sausages, unpasteurized milk, and shellfish pose a risk of HEV infection [49]. The third contamination way is the consumption of animal-based products that contain a zoonotic virus [49]. Ebola is one of the animal-based virus and discovered in 1976 in Africa. Nipah virus is another animal-borne virus that can cause illness in humans [54]. SARS-CoV and MERS-CoV, members of the CoV family, can be also passed from bats [10]. As summarized in Table 2, studies have identified different animals as intermediate hosts of these viruses.

Potential relationship between SARS-CoV-2 and food products

There is currently no scientific evidence to indicate a concern with food products related to SARS-CoV-2, according to the FDA. However, consumption of meat or organs of infected animals can result in zoonotic foodborne infections [9, 49]. China has both a huge population and a

Table 1 Main foodborne viruses

Virus name/illness	Possible contamination source	Transmitted food product
Hepatovirus A/Hepatit A	Water, human stool	Deli meat, raw beef, shellfish, fruit and vegetable
Orthohepevirus A/Hepatitis E	Pig liver	Pork
Noravirus/Gastroenteritis	Contaminated water, food, contact surfaces, human stool	Berry fruit, deli meat, shellfish, oyster

Velebit et al. [49, 50]

Table 2 Comparison of five zoonotic viruses

Virus name	Identification year	Number of countries/territories	Outbreak region/country	Possible primary/intermediate hosts	Cases	Deaths
Ebola	1976	9	Nzara/Sudan	Fruit Bats/-	33,577	13,562
Nipah	1998	2	Sungai Nipah/Malaysia	Bats/pigs	513	398
SARS-CoV	2002	29	Guangdong/China	Bats/civet cat	8096	774
MERS-CoV	2012	28	Arabian Peninsula/Saudi Arabia	Bats/dromedary camels	2494	858
SARS-CoV-2*	2019	213	Wuhan/China	Bats/pig, civets, pangolins, chicken, seafood	5,502,610	346,761

World Health Organization [57, 58]

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history of the consumption of wild or exotic animals [23]. In Chinese food culture, live and slaughtered wild animals are considered to be more nutritious [11, 35]. Live and dead chickens, pheasants, bats, marmots, deer, dogs, pigs, civets, and organs of rabbits are also sold along with wild animals in food markets [28]. When people keep live and dead animals in close proximity, contact or cross-contamination can easily lead to the spread of the virus. Furthermore, it has been suggested that the transmission of SARS-CoV-2 to humans may have been promoted by unhygienic conditions, such as unclean seafood tanks, body fluids of live and dead animals, or insufficient air quality conditions [39].

Precautions and suggestions

Elimination the potential SARS-CoV-2 risk in food

One of the most important issues to address for consumers who are concerned with the food risk posed by SARS-CoV-2 is the possibility that food products or food packaging can be contaminated by the virus. Foodborne transmission of SARS-CoV-2 needs to be studied [11, 38]. Studies on other viruses have revealed their survival on the surfaces of food products or on surfaces that have been in contact with contaminated food [3, 24]. This possibility should also be considered for SARS-CoV-2. Already EU Commission has been highlighted that use of packaging

material contaminated by the staff may increase the risk for the consumers in this pandemic term [12]. Food products prepared from exotic or wild animals should be periodically checked. In particular, animals consumed in undeveloped countries should be tested to eliminate the rapid global spread of SARS-CoV-2. Testing of consumers of these products is prudent, as is the testing of wild or exotic animals consumed widely in suburban or city centers. In addition to the FDA suggestions (clean, separate, cook, and chill), at least in times when the chance of infection is greater, canned or packaged foods could be preferred instead of foods that are not canned or packaged. When the latter are purchased, fruits should be washed and stored in water containing lemon juice and vinegar that decrease the pH value of water [12, 60]. If possible, during an ongoing epidemic or pandemic, products that are not canned or packaged should be boiled, or boiled food products should be consumed. Wang et al. [51] indicated that high humidity and high temperature can reduce the transmission of SARS-CoV-2. Therefore, the risk of contamination of food products by SARS-CoV-2 may decrease when the midpoint temperature of food products increases. Food products that are packaged or canned could be considered safer. Even so, especially canned materials should be washed well using boiled water. In addition, fresh food products that are chilled should be well cooked after purchase (> 100 °C) to eliminate the potential risk of contracting infection, and the midpoint temperature of the products must be checked before being consumed.

Staff hygiene

There is definite concern about food industry workers, who should be tested for SARS-CoV-2 to eliminate the potential risk of contamination of food products. In food processing settings, including settings where food is only slightly processed, infected workers may contaminate food products. In addition, worker-to-worker transmission is a risk in settings where personnel are in close contact with each other. A prudent strategy can be for healthy food industry personnel to wear a mask whenever there is a SARS-CoV-2 risk worldwide [12, 60].

Regular hand washing is crucial [12]. Similar viruses are spread via droplets when an infected person coughs or sneezes [1]. SARS-CoV-2 is also disseminated by coughing, sneezing, breathing, and perhaps even by inhaling the virions [12, 56, 60]. Importantly, avoiding touching the face with hands and avoiding close contact with people may be important to lessen the risk of potential SARS-CoV-2 contamination in the food industry [8, 60]. On 10 February 2020, the WHO released some prevention guidelines on their website [56]. These societal guidelines—frequent hand washing using soap and water or alcohol-based disinfectants, maintaining social distancing, and avoiding hand contact with the eye, nose, and mouth—are applicable to the food industry. In addition to these practices, mobility of food industry personnel such as air travel should be controlled. Regularly (at intervals of at least 14 days), personnel involved in the light preservation of food should be tested for SARS-CoV-2. Personnel who handle packaging that is destined to be used as food containers should also be tested [12, 60].

Nutritional suggestions

Diverse vitamins are important for the immune system. Vitamin A deficiency may impair the immune response [64]. According to one study, patients with chronic diseases, including hypertension, diabetes, coronary heart disease, and tumor-related diseases, are more susceptible to SARS-CoV-2 infection and can have a significantly higher risk of a poor prognosis. This is because these patients can have a less potent immune response [29]. Lack of B vitamins may weaken the immune system. Thus, supplementation with vitamins with the goal of strengthening the immune system is prudent for virus-infected patients. Vitamin B supplementation for patients infected with SARS-CoV-2 might be an option to consider [40]. Vitamin C also supports immune functions and may protect against infections caused by CoVs [19, 20, 41]. SARS-CoV-2 may cause lower respiratory tract infection, and supplementation with a moderate amount of vitamin C might be protective [53]. Treatment that includes

administration of excess vitamin C is being performed at hospitals in New York City, which has been especially affected by the COVID-19 pandemic [34]. Decreased vitamin D and vitamin E levels in adult cattle and calves have also been associated with bovine CoV infection [15, 36]. SARS-CoV and SARS-CoV-2 are both more common in winter when vitamin D status is low in humans [16, 31, 61, 66]. In this respect, increased consumption of fatty fish species in the winter season may help strengthen the immune system. Proper supplementation with vitamin D and vitamin E may also enhance resistance to SARS-CoV-2 [53]. These collective data highlights the important role of vitamins in increasing immune system resistance to CoV infections. Oxidative stress resulting from selenium deficiency can alter the viral genome. Viruses mutate rapidly to survive the oxidative stress that causes inflammation [18]. The combination of pyrithione and zinc at low concentrations might inhibit the replication of SARS-CoV [47]. Shimizu et al. [42] reported that flavonoids from *Pterogyne nitens* can inhibit hepatitis C virus. Jo et al. [25] reported the anti-CoV activity of the flavonoids herbacetin, rhoifolin, and pectolarin, due to the inhibition of 3C-like protease. These findings suggest that until the role of nutrition in SARS-CoV-2 infections is definitively established, the foregoing observations indicate the wisdom of supplementation with vitamins, minerals, and other important compounds [64]. Furthermore, Galanakis [14] has been noted that there is relationship between the human immune system and intake of bioactive component by human diet.

Novel approaches

Nanotechnology applications have received a great deal of attention worldwide. Food safety studies have explored the use of nanofibers [5], nanoparticles [4], nanoemulsions [32], and nanoencapsulated materials [46]. Compared to micro- and macro-sized materials, nanosized materials can come into contact with a larger surface area of materials, such as food products. The average diameter of the nanoscale materials ranges from 60 to 600 nm. It is conceivable (although unproven) that nanoscale materials with a controlled release profile could be useful in preventing SARS-CoV-2 contamination of food products and packaging materials. In this regard, nanoscale materials might have a larger contact area on the 300 nm diameter virus.

Concluding remarks

The potential linkage between SARS-CoV-2 infection and food safety is an important issue for governments worldwide to consider. During times when the risk of infection is

higher, such as during the ongoing pandemic, consumption of boiled or canned foods processed at high temperatures is prudent in addition to following general hygiene rules. Governments should mandate the testing of food industry personnel for SARS-CoV-2. The consumption of exotic or wild animal based food products in countries with large populations, such as China, should be avoided to lessen the chance of a new outbreak. Supplementation of diets with vitamins, minerals, and other compounds can increase immunity and reduce the chances of contracting the infection. Novel approaches in the food industry should be applied instead of conventional practices. In this regard, nanofibers, nanoparticles, and nanoencapsulated bioactive materials could be utilized to bolster food safety. Depending on the release time of the payload from nano-sized materials, food packaging can be labeled to provide information to the consumers. The COVID-19 outbreak has spread worldwide, but precautions related to the food industry must be taken at the international level. The outcomes of these precautions should be disseminated globally.

Compliance with ethical standards

Conflict of interest The authors declare there is no conflict of interest.

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