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CHAPTER 12

An overview of food safety and COVID-19 infection: nanotechnology and cold plasma applications, immune-boosting suggestions, hygienic precautions

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12.1 Introduction

Humankind struggles with many health matters, particularly those caused by bacteria and viruses. Bacteria-based illnesses have gained notoriety globally. Studies have mainly focused on pathogenic bacteria in food. In other words, other potential hazardous effects were mostly ignored. In this respect, today, humans are learning how to fight viruses.1–3

A typical virus has RNA or DNA and is mostly 300 nm in size. Unlike bacteria, viruses may not reproduce in a food environment because viruses are obligate intracellular parasites. In other words, they can only survive by moving their genetic material from one host cell to another. However, water and food may act as vectors for the transmission of viruses to humans via the fecal-oral route.3–6 A virus can spread to food in several ways: (1) contamination during food processing through infected food personnel; (2) direct contamination of human feces without soil or water treatment; (3) ingestion of food animal origin with zoonotic viruses; and (4) inadequate treatment of wastewater.7–11

Ebola, avian influenzas, Nipah, MERS-CoV, SARS-CoV, and currently the most dangerous one, SARS-CoV-2, are the main zoonotic viruses that
affect human health directly.\textsuperscript{12–14} CoVs can easily pass to humans from different sources like animals. According to previous studies, CoVs can transfer by consumption of infected animals.\textsuperscript{15–21} Especially in the case of foods not being heated or cooked, these viruses can cause diseases in humans. Also, it has been observed that some food materials such as chicken or some fish samples are contaminated with SARS-CoV-2.\textsuperscript{22–24} Pneumonia, diarrhea, fever, loss of odor and taste, and organ failures are common symptoms of SARS-CoV-2 and its infection.\textsuperscript{25} Because of its long incubation stage, SARS-CoV-2 can have more infectious effects on society. In terms of food, the aforementioned viruses can be related with the consumption of wild animals. In China, in the first step, as can be seen from various news sources, the main source of spread of SARS-CoV-2 is also associated with some animals such as bats, pangolins, and civets. Furthermore, the relationship between animal-based food consumption and coronavirus disease (COVID-19) infections was associated with Wuhan’s Seafood Wholesale Market, which was immediately closed at the beginning of January 2020.\textsuperscript{8,26,27} A graphical illustration of the possible routes of SARS-CoV-2 transmission from foods to humans is presented in Fig. 12.1. Following the initial stages of COVID-19 spread in China, World Health Organization (WHO) and some leader organizations such as Food and Drug Administration (FDA) and European Food Safety Authority (EFSA) began preparing reports, which consisted of frequently asked questions related to the COVID-19 outbreak and food safety.\textsuperscript{28,29} At that moment, consumers were thinking that foods could be contaminated by COVID-19. Restaurants, markets, and manufacturing facilities were seen as potential areas of risk.\textsuperscript{11,30–34} Consumers have observed a lack of information regarding such risks. After the initial period of the COVID-19 outbreak, new studies related to food safety and COVID-19 have revealed the worry and awareness among consumers.\textsuperscript{8} Also, it has emphasized the Hazard Analysis and Critical Control Point (HACCP) principles for the food industry.\textsuperscript{35}

The International Commission on Microbiological Specifications for Foods (ICMSF) claimed that it is highly improbable that the ingestion of SARS-CoV-2 will result in illness, and there is still no evidence that food is a major source of transmission.\textsuperscript{25} Oral transmission via food consumption has not been reported. One of the ways in which COVID-19 can be spread is through cross-contamination of surfaces. It has been reported that CoV particles may survive for hours to days on surfaces.\textsuperscript{11,34,36,37} However, the possibility of transmission through inanimate surfaces has been observed to be lower.\textsuperscript{25,38}
Figure 12.1 Graphical abstract of emerging SARS-CoV-2 that shows the probable main source, possible intermediate carriers, contamination to food products, infection in humans, and finally, COVID-19 cases, respectively.
Food preservation methods and hygiene practices, already in use for food safety, could be important in eliminating different microbiological risks at the onset of a COVID-19 outbreak. In this respect, to improve consumer safety, recently different certificate systems have been applied. Besides novel approaches like nanotechnology applications or packaging applications, some minor preventions for industrial kitchens and households are gaining importance. On the other hand, consumption of vegetables and dairy products, as well as foods rich in protein such as fish and red meat, will boost the human immune system. In addition, from their harvesting to the plate, food safety should be enhanced.

This study aims to highlight the probable risks based on food material contaminated with potential COVID-19 infection from food surfaces, food packaging materials, food processing equipment, and other items in the food processing industry. With this study, novel perspectives including nanoscience and cold plasma treatment have been presented to society for the elimination or prevention of COVID-19.

12.2 Food safety and COVID-19

Considering risk management, there is currently no evidence that food is a source or route of transmission of SARS-CoV-2 food or food packaging, according to Centers for Disease Control and Prevention (CDC), U.S. Department of Agriculture (USDA), and EFSA. However, there are a few reports that SARS-CoV-2 is found on food packaging materials. These reports show the presence of an RNA virus which may exist as a hazard to human health. As is known, the first case related to food-contact material (a salmon cutting board) with SARS-CoV-2 was determined in the wholesale market in Beijing. Since July 2020, some cases of food contamination have been reported in China, where SARS-CoV-2 was detected on imported frozen food packaging materials such as shrimp. SARS-CoV-2 was also detected in a food shipping container.

Food contamination that occurred with COVID-19 may be observed via the farming activity, processing, storage, transport, and retailing process in which foods might come in contact with staff and atmospheric conditions. Ferretti et al. (2020) emphasized the importance of environmental conditions. In this sense, SAR-CoV-2 can transfer from symptomatic people at a 90% rate. On the other hand, 10% defines the environment, surfaces, and other sources. Therefore, food safety related to COVID-19 should never be ignored.
12.2.1 Vegetables and fruits

According to Mullis et al., a kind of coronavirus called bovine on lettuce samples was stable for 14 days when it was stored at 4°C.52 In addition, another type (CoV 229E) was found on lettuce after two days of storage at 4°C. On the other hand, this virus surprisingly could not survive on the surface because of the acidity in strawberry samples.53

Significant records related to COVID-19 in fruit and vegetables have not been directly detected yet. On the contrary, recently published articles have revealed that indirect contamination can affect vegetables and fruits. For example, irrigation with sewage is able to infect vegetables and fruit with COVID-19.4 Also, if plants or fruit trees are irrigated by sewage constituting SARS-CoV-2, there would be a risk in terms of contamination in vegetables and fruits. In another study, to remove or decline the virus load on the surface of them, a good washing is suggested but the fruit or vegetable’s surface structure would play a key role.1 In this sense, the pH value of the fruit could play a significant role in the elimination of COVID-19.54,55

12.2.2 Animal resources

Breeders play a major role in animal production. With socioeconomic concerns, instead of small-sized family businesses, farms that are formed by the gathering of thousands of animals in closed areas have increased. Diseases transmitted through animal origin have increased because of industrial animal production. CoVs are responsible for respiratory and intestinal infections in animals.56,57 For example, the host animal for MERS-CoV was dromedary camels. Foodborne transmission through consumption of unpasteurized camel milk and raw camel meat was an infection source for humans.38 Like MERS-CoV, SARS-CoV-2 is also a zoonotic virus and has a genome similarity of 96% to a SARS–related bat CoV.56 In fact, a zoonotic transmission from animals to humans has been reported in a Dutch mink farm during the COVID-19 pandemic.56 Around 20 million mink in Europe have been culled in case of further zoonotic transmission possibility.59,60 On November 12, 2020 the Food and Agriculture Organization (FAO) announced guidelines about the exposure of humans or animals to SARS–CoV–2 from wild, livestock, companion, and aquatic animals.56

Determining disease-resistant animal species by epigenetic studies may be beneficial for future applications. Genomic selection applications for animals that have resistance to diseases, will make a significant contribution to
preventing the spread of COVID-19. In this way breeding studies could be carried out for the ones that are resistant to COVID-19.61,62 Animals that are the sources of infection are a concern. To avoid the SARS-CoV-2 that causes disease, while planning animal shelters, attention should be paid to natural ventilation, adequate living space, controlled production and hygiene. All these data show that further investigation is needed for livestock, and precautions need to be taken against COVID-19 on an industrial scale.

12.2.3 Meat and meat products

CoVs can be transmitted from an infected person to meat samples by contaminated hands, or via sneezing or coughing if hygiene rules are not followed. Although the oral/alimentary transmission by consuming meat products does not play a role, according to new research, it was revealed that SARS-CoV-2 lost only a little of its infectivity on frozen meat even after three weeks.63 Also, Liji (2020) has stated that SARS-CoV-2 may survive on frozen or cold storage salmon and meat samples for more than three weeks.64 To the best of our knowledge, on August 12, 2020, the first known case of SARS-CoV-2 was detected on a chicken wing sample that had been imported from Brazil to China.22,23

The CDC requested data related to the number of poultry and meat plants (where beef, bison, lamb, pork, and poultry meats are processing) negatively affected, how many workers were affected in these plants, and the number of deaths based on COVID-19 in these facilities of the United States.65 According to the report, 115 poultry or meat processing facilities, in which 4913 cases and 20 worker deaths were reported between April 9—27, 2020, were affected by this pandemic outbreak. It has been assumed that difficulties at workplaces regarding physical distancing, hygiene, and crowded living and transportation conditions were the factors that potentially affected infection risk. Other data revealed that a slaughterhouse in Germany was shut down on June 18, 2020 because COVID-19 test results of 1550 of 7000 workers were came out positive.66 These data imply that the number of workers who have to work in crowded places in these facilities increased SARS-CoV-2 transmission risk.65 Moreover, salmon from Europe was banned and Ecuadorean shrimp were suspended because of the SARS-CoV-2 outbreak.24,64

European Federation of Food Agriculture and Tourism Trade Unions stated that, according to a report from IUF consultation with Imperial College in London, the meat sector greatly relies on immigrants and cross-border workers in almost all European countries. In some meat factories,
especially the old ones, the spread of the disease is 20 times more likely where there is insufficient ventilation. On the other hand, certain parts of meat processing plants are very cold and the virus spread faster in colder temperatures.66

All these data prove that during meat processing, SARS-CoV-2 transmission risk should be considered. The recognized risk to poultry and meat facility operation requires action plans to decrease risks to workers, preserve facility function, and maintain the food supply. Cleaning and disinfection, screening staff for symptoms, and providing multilingual disinfection training might slow the virus spread among workers in meat and poultry processing plants. Temperature monitoring and symptom screening are important to avoid the introduction of COVID-19 into a facility from infected persons.65 Inactivation of SAR-CoV-2 in artificially contaminated chicken, pork, and salmon samples reveal that three weeks’ storage at 4, −20, and −80°C, respectively, did not decrease infection level.11,24 Above all, precautions in the meat sector should be improved and updated.

12.2.4 Dairy products

Some natural milk preservative components like lactoferrin (LCF), lactadherin and glycomacropeptide in milk serve an antiviral role against some viruses, particularly HIV,67 and may also have antiviral activity for SARS-CoV–2. It is known that LCF can have an interaction with heparin glycosaminoglycan (HSPG) cell receptors. Also, the aforementioned receptors play a significant role in cells of the first term of the virus infection from CoV. These relationships contain the angiotensin-converting enzyme 2 (ACE2) receptor, a metallopeptidase that can bind virus terminals and also facilitate cell entry. All mechanisms mentioned above were revealed in the SARS-CoV epidemic in 2002. In this regard, similar interactions and mechanisms in ACE2 have been observed in SARS-CoV-2.68

Besides SARS-CoV, SARS-CoV-2 and MERS-CoV were determined in 41.9% of camel milk samples.69 In this sense, the experiment indicated that MERS-CoV inoculated to camel milk could survive up to 72 h at 4 and 22°C, respectively. As stated by van Doremalen et al., the virus survived for more than two days in unpasteurized milk samples.70 However, the consumption of milk by pasteurization prevents such foodborne contamination. In order to inactivate a virus like SARS-CoV, it is evaluated as sufficient to heat the milk to \( \sim 60°C \) for 30 min.71 In addition to the heating processes, Ultraviolet (UV) light, alkaline pH (\( >12 \)), or acidic pH (\( <3 \)) are the other tools to inactive SARS-CoV.72,73
They may be recommended for the elimination of dairy products with SARS-CoV-2. Another widely consumed dairy product is yogurt, which is fermented by lactic acid bacteria following heat treatment. The last product possesses about 4.5 pH, but Chin et al. (2020) has reported that SARS-CoV-2 is evaluated as stable from 3 to 10 pH ranges. Contrary to these aforementioned issues, some metabolites such as lactic acid, hydrogen peroxide ($\text{H}_2\text{O}_2$), and bacteriocins shaped by lactic acid bacteria at the end of fermentation possess antiviral properties. So, the last product could provide a good opportunity to support the immune systems of humans in pandemic terms.

Yekta et al. noted that for dairy products, SARS-CoV-2 at $-20^\circ\text{C}$ for 2 years could be found as stable, so ice cream, frozen yogurt, and dairy desserts may be defined to be SARS-CoV-2 carriers. Moreover, many more studies on dairy products should be revealed for potential contamination risk.

### 12.3 Food packaging applications and SARS-CoV-2

Food packaging applications are gaining importance. In the case of outbreaks, all worldwide consumers by time are getting much more worried because of the possible contamination risk of SARS-CoV-2. In this sense, we already know that packaging materials play a key role. Also, if possible, to decrease contamination risks with SARS-CoV-2 on food, different kinds of food products should be processed, preheated, and pasteurized or sterilized. Moreover, following the mentioned applications, food packaging material can be stored. For example, sous vide technology can provide a lower contamination risk for food samples because food material can be placed into the food packaging material then vacuum packaged, sealed, cooked, cooled, and stored (Fig. 12.2). When food products are cooked with sous vide technology, they could be directly consumed or heated, for instance, in a microwave oven. In addition to sous vide technology, intelligent and active packaging enriched with nanosensors could be used with basic food packaging materials used widely in the food industry. The average risk of contamination with food or food packaging is evaluated to be lower.

Zhang et al. revealed that fecal-oral contamination of the virus is an important issue. In the case of handling food packages and containers, SARS-CoV-2 could be transmitted from the food packaging material surface to the eyes, nose, and mouth. But the aforementioned contamination way is not evaluated to be a separate route for this pandemic virus. So, packaged food samples and canned foods may be preferred in this risky period.
Figure 12.2 Main steps of sous vide cooking to lower viral contamination risks for food products.
12.4 Limitation of SARS-CoV-2 spread

12.4.1 Nanotechnological approach

The particle size of SARS-CoV-2 ranges from 50 to 200 nm. Ignatov has reported the exact size as 120 nm. The use of nanomaterials based on antiviral activity provided inactivation of some viruses in chicken embryo models and shrimp samples. These studies have shown that nanotechnological approaches should be considered for the purpose of developing resistance against SARS-CoV-2. Antimicrobial coatings by metal oxide nanostructures and nanopolymers may inhibit the transmission of COVID-19. Silver (Ag) nanoparticles and zinc (Zn) nanomaterials indicated inhibition in viral replication, virus inactivation, viral protein translation, and polyprotein processing. Nanoform of Ag and copper (Cu) cations could affectively damage the nucleotides of some viruses. In this respect, TiO₂, ZnO, and Cu nanoparticles are suggested to control the disease by surface coating and disinfection. In one study, the use of nanosilver colloids was investigated for therapeutic purposes in the early stages of COVID-19. As a result of the study, it was determined that antimicrobial doses of nanosilver colloids also show antiviral effects. In the same study, it was stated that nanosilver colloids can be applied both at home and in the hospital through inhalation. In another study, 2–15 nm size Ag nanoparticles provided a successful inhibition of SARS-CoV-2 at concentrations above 1 ppm. In this regard, a relevance between the intake of SARS-CoV-2 contaminated food and the possibility of infections as well as the advancement of antiviral packaging using nanotechnology ought to be searched. The use of nanomaterial coatings or films (containing Cu, Ag, and ZnO nanoparticles) has a potential against SARS-CoV-2 to avoid contamination of food packaging surfaces, and thus this approach may reduce its rapid transmission. Also, nanosized materials can be integrated with other technologies for obtaining much safer materials, which can be contacted by foods. In this respect, packaging material enriched with nanoparticles in active and intelligent applications could be advised in order to provide food safety against SARS-CoV-2. Moreover, nanoparticles, nanofibers, nanoencapsulation technologies, nanoemulsions, and nanocomposites providing a larger contact area on the surface of the material could be used to increase food safety.

12.4.2 Cold plasma

Cold plasma has demonstrated great potential for inactivation of SARS-CoV-2. Since it does not generate waste or toxic chemicals, this
method is seen as environmentally friendly. This technique also has potential with extensive applications in the disinfection of food surfaces, equipment, and food packages.\textsuperscript{88,91} Furthermore, the in-package plasma treatment can be combined with the bacteriostatic nanophotocatalysts onto food packing films.\textsuperscript{91,92}

The mechanism is attributed to free radicals that diffuse through the capsid to reach and damage the RNA of the virus.\textsuperscript{93} Although Reactive Oxygen Species (ROS) and Reactive Nitrogen Species (RNS) are considered the main contributors to the inactivation of viruses,\textsuperscript{88} plasma does not fully damage the virus but it can delay its ability to infect.\textsuperscript{94} Photons, positive and negative ions, neutral atoms, UV photons, and free radicals could play a key role.\textsuperscript{95,96} The occurrence and role of ozone and UV photons in cold plasma species can affect the protein structure and damage RNA in a virus.\textsuperscript{97} The electrostatic forces related to plasma technology may affect the disruption of cell membranes that lead to cell death. In this respect, gas composition, flow rate, voltage parameters, and food composition are the other main factors to inactivate microbial load in food.\textsuperscript{98,99}

In terms of SARS-CoV-2, cold plasma applications have been discussed to degrade the RNA virus.\textsuperscript{100,101} Cold plasma with Argon gas to deactivate SARS-CoV-2 on various surfaces, including plastic, metal, and cardboard, was also employed. These studies showed that cold plasma could be an effective method to avoid transmission and infections on various surfaces.\textsuperscript{89,101} Also, Verma (2020) has reported that application parameters such as duration should be optimized for the elimination of viruses on the contaminated material.\textsuperscript{94} In terms of food products, inactivation of the Tulane virus on spinach,\textsuperscript{102} murine norovirus-1 and hepatitis A virus on fresh meats,\textsuperscript{95} norovirus surrogates on blueberries\textsuperscript{97} and some other food systems,\textsuperscript{103} Tulane virus on romaine lettuce,\textsuperscript{104} and Newcastle disease virus on poultry\textsuperscript{105} was effectively applied by cold plasma treatment.

Major foodborne viruses on surfaces such as stainless steel\textsuperscript{106} were also studied. These studies demonstrated that cold plasma is effective for reducing microbial load in surface areas such as stainless steel or other industry materials that may have close contact with food products.\textsuperscript{107} For these reasons, cold plasma application can be considered for decontamination of food processing equipment. Furthermore, cold plasma usage can decrease the rapid contamination of COVID-19 in water samples.\textsuperscript{88,108} It is known that most food or food products, such as a different kind of seafood and meat, contain high levels of water. So, in further studies, cold plasma treatment can be combined with food samples that are widely consumed.
12.5 Suggestions for consumers

Suggestions will be evaluated from two perspectives. The main aim is to explain how to decrease the risk in food, food packaging, or kitchen equipment contaminated with SARS-CoV-2. After purchasing foods, packaging materials including food should be washed or cleaned by using different materials having higher acidic pH value. For example, canned sample surfaces should be washed with disinfectants. Cooking temperature or heating processes are highly important to eliminate the potential risk. If possible, as can be seen from the present study, the midpoint temperature of food products such as fish and meat should be controlled before consumption. Also, especially fruits with lower acidity should be washed. Recently, studies reported that freezing or chilling is not meant to eliminate the virus; therefore, it is not thought that they are safer for COVID-19. Moreover, this sort of sample must be well cooked like fresh food samples. Kitchen equipment (knives, cutting board, etc.) must be continually disinfected by using hot water.

CoVs are thermolabile and do not withstand normal cooking temperatures. SARS-CoV was found to be inactivated after 15 min incubation at >75°C. Similarly, SARS-CoV-2 can be inactivated after incubation for 5 min at 70°C. These findings recommend that cooking at >70°C is adequate for virus inactivation, but transmission from frozen food should still be considered; therefore, thorough hand washing after handling raw food is necessary.

Besides the aforementioned hygienic precautions, in order to support the immune system in humans, some recently published articles have presented some suggestions. Ashraf et al. has suggested that consumption of honey (1 g/kg per person/day) will gain a powerful resistance toward COVID-19. Adequate and balanced nutrition is important for boosting the immune system. In this respect, consuming foods rich in vitamins, minerals, and ω-3 fatty acids may have a potential role to help fight COVID-19. Vitamin B plays a role in cell functioning and energy metabolism. Vitamin D decreases rates of infection. The use of vitamin C can help minimize the symptoms caused by COVID-19, while vitamin E and some minerals like selenium may assist in the recovery stage. Also, an increase in immunomodulatory effects can be provided by using ω-3 fatty acids. According to recent studies, polyphenols such as
resveratrol and flavonoids have potential inhibitors. There is also indefinite proof supporting the future use of β-glucan to address COVID-19 due in part to variability in the immune response resulting from heterogeneity in the polysaccharide branch. Nanoencapsulation improves bioavailability through controlled-release properties of substances in food with more health-promoting properties. This contribution summarizes the development of effective antioxidants such as coenzyme Q10, quercetin, curcumin, and probiotics that influences body immune systems in a positive way. In addition to these, micronutrients, functional food ingredients like probiotics, herbs, flavonoids, and carotenoids are also evaluated to be natural immune boosters. As could be seen in several studies, a balanced diet enriched with different vitamins, minerals, and also probiotics may be playing a key role in this fight.

12.6 Conclusion

The potential effect of COVID-19 related to the safety of food is an important issue for the food industry. Further investigation is needed for livestock, and precautions need to be taken against COVID-19 on an industrial scale. Because SARS-CoV-2 is a zoonotic virus, in regards to animal resources, identifying disease-resistant animal genotypes and including them in breeding programs through genetic mapping is necessary. Furthermore, potential viral contamination risks on meat and dairy food products should be further investigated. Novel approaches, such as nanoscience (nanofibers, nanocapsules, and nanocomposites), cold plasma, and ozone applications can be considered as safe and effective methods toward SARS-CoV-2 prevention. The mentioned applications could be combined or integrated with sous vide, active, and intelligent packaging applications to improve food safety against future viral outbreaks. Consumers must take hygienic precautions to decrease the SARS-CoV-2 spread risk for frozen or chilled foods. The heating/cooking process, pH value, and temperature duration for all foods must be controlled. Packaging materials and food-contact surfaces should be cleaned to prevent contamination. Also, a balanced diet with intake of vitamins, minerals, phenolic compounds, and ω-3 fatty acids from various sources, consumption of dairy products, and honey-based products such as bee propolis and other supplementary materials play key roles in supporting the immune system.
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