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IMPACT OF COVID-19 PANDEMIC CRISIS AND FOOD SAFETY SYSTEM: A Literature Review

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ABSTRACT

The new outbreak as unknown pneumonia that occurred in Wuhan province of China in December 2019, is a new coronavirus from Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), and has been termed Coronavirus Disease 2019 (COVID-19). Coronaviruses are a family of viruses that usually cause respiratory illness. Since food plays an essential role in human health as an integral part of human life, food safety is critical in such cases. It is essential to adopt practical strategies in controlling the COVID-19 crisis. Also, extreme economic consequences and threats to human health were imposed in the COVID-19 pandemic in 2019-2021. Some studies have been published by World Health Organization (WHO), Environmental Protection Agency (EPA), and Food and Drug Administration (FDA); however, there is little information about food safety and COVID-19. Although COVID-19 transmission routes through food are not currently known, contamination through contaminated food and environmental surfaces cannot be ignored, especially in manufacturing companies, restaurants, and communities that are unsanitary. Nevertheless, World Health Organization precautions on good hygiene when preparing food, and recommends effective management of food safety during COVID-19. In food safety, COVID-19 is known as a potential risk through food especially in restaurants and industrial areas. There have been very few studies on the relationship between food safety and COVID-19. Studies have shown that COVID-19 can survive longer than MERS-CoV in food stored at 4 °C. In the current situation, several methods are used to disinfect and control the spread of COVID-19 disease, some of which are not effective and can also have problems and limitations. Heat treatment, pasteurization, UV light-based, and chemical disinfectants can be ways to prevent COVID-19 probable transmission. The temperatures (30 or 40 °C) reduced the survival time of HCoVs on the inanimate surfaces. The cooking processes (70 °C) are effective in inactivating the virus in food. SARS-CoVs were inactivated by exposure to ultraviolet (254 nm) for 1 to 6 min with an increase of up to 400-fold. Also, usage of disinfectants can be effective for inanimate surfaces. This review summarizes the available data related to some topics and methods to inactivate COVID-19 and the role and importance of the food industry and food supply chain during the pandemic.

Key words: COVID-19, SARS-CoV-2, Food, Safety, Security, Good manufacturing practice

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INTRODUCTION

The current coronavirus (COVID-19 or SARS-CoV-2), first reported in the Wuhan province of China by the World Health Organization (WHO), has been a global pandemic [1]. Coronaviruses are a family of viruses that usually cause respiratory illness. They comprise viruses that resemble the common cold and more serious illnesses such as Middle East Respiratory Syndrome (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS-CoV). Prior outbreaks of illness because of MERS-CoV, SARS-CoV, and other respiratory viruses may have originally been transmitted to humans [2]. These viruses are highly homologous that all of which resulted in high mortality. It must be noted that the mortality rate of COVID-19 is lower than SARS but its transmission rate is higher, which can lead to an increased risk of death which might be described by mutation and boosted genetic recombination at the S-protein in the receptor-binding domain (RBD) of COVID-19 [3]. COVID-19 infection occurs in the respiratory and gastrointestinal tract through ACE2 receptors of COVID-19, which play an important role in the expression of some organs such as lung AT2 cells, laryngeal epithelial cells, and endocrine cells of the ileum and colon [4].

Coronaviruses are most commonly spread between animals and humans through person-to-person contact. This virus is commonly transmitted through direct mucous membrane contact with infectious droplets, breathing in airborne virus when someone infected sneezes, or through hand to mouth/nose contact after fingers have touched a contaminated surface [1, 5]. Although COVID-19 transmission routes through food and water are not currently considered, contamination through contaminated food and environmental surfaces cannot be ignored, especially in restaurants, manufacturing companies, and community [1].

Different countries have made decisions on how to fight or slow the spread and prevalence. Currently, the discovery of vaccines and drugs for this disease is one of the most significant objectives of particular organizations involved and countries in general. Yet, prevention is currently the best way to combat it globally. The purpose of this article is to review major studies conducted on food safety issues and presented by various international organizations and researches. It is also meant to provide important tips that can be considered as concern or research topics to investigate more about COVID-19 and food safety.

Food security and COVID-19

Food security is defined as the concept of availability, accessibility, use, and stability of available safe food. The recent COVID-19 crisis and related policies are likely to affect each of these components [6]. COVID-19 is spreading rapidly and is a potential hazard for life and livelihoods [7]. A history of the link between epidemics, migration, and food insecurity in the latest global epidemic of the Spanish flu (1918–1920) and comparisons allow us to understand the main factors influencing how the pandemic spreads and effective political action. Thus, these insights will be important to inform policy makers. Some researchers have argued that poor food quality, famine, and starvation contributed to the spread of the Spanish flu [8]. Famine in Europe Since 1550 increased during the prevalence of epidemics and had a negative effect on health

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and reduces the body's ability to resist viral infections [9]. Population density rises with increasing mobility in people suffering from malnutrition, which increases the likelihood of infection [10]. Famine also raises food prices and leads to widespread unemployment, which increases rural-urban migration, which in turn leads to a pandemic. The food supply and distribution chain will be disrupted during the pandemic because of virus-infected producers, market policy responses, and shipping restrictions to limit the spread of the virus. Measures such as social distance, quarantine, restaurant closure will affect access to and use of food due to lockdown measures. Due to limited access to health services, sanitation facilities and clean water, food storage, processing, and hygiene may be affected [11]. Therefore, behavioral responses such as hoarding are expected to affect food prices and food availability [12]. Policy responses will also have severe consequences, especially in developing countries because people in developing countries rely on informal work, low savings as well as high population density at home. Definitely, closing borders, disrupting trade will restrict people's access to adequate/varied and nutritious food resources [7, 13].

According to FAO, food supply chains are likely to be disrupted [7, 13]. Closing restaurants and buying less food reduces the demand for fresh products and hence affects production and suppliers. Therefore, paying attention to adequate food supply and access to healthy and adequate food to all segments of society, as well as the health and disinfection requirements of the food supply, is an important issue for all countries and their respective governments too. Although, in different countries, charity groups and volunteers donating food due to human approaches can be somewhat helpful in this regard, the main task for the government is to reduce the problems faced by producers. FAO announced recommendations to mitigate the risks of the pandemic, such as countries should meet the immediate food needs of their vulnerable populations, should boost their social protection programs and try to reduce trade-related costs [7].

About the effect of COVID-19 on food security, we can also pay attention to its effect on producers and help to increase food production. The food supply chain is a complex and includes agricultural and animal inputs, production, storage, transporters, marketers, and consumers. In agriculture, animal farms, and fisheries, problems in logistics with transportation restrictions exist [14]. Thus, these are likely to prevent farmers and fishermen from accessing markets, limiting their production capacity and preventing the sale of their products. Therefore, it is necessary to sell the produced ingredients quickly or to process and store them. On the other hand, a decrease in work can disrupt food production and processing. Also, the financial crisis has shown that lower incomes and uncertainty are causing people to lose their purchasing power. In contrast, the need for each person to have a strong immune system in this crisis will make people more willing to buy food products but they will not be able to afford it. Finally, it can be argued that the collaboration between COVID-19 and declining economic activity will lead to amplified food insecurity across countries, which can have negative effects on health, and may act as a pandemic factor.

Food safety and COVID-19

Food safety defines as microbial, chemical, physical and passive defense safety in food [15]. *Hepatitis A* viruses (HAV), *Astrovirus, Noroviruses* (formerly *Norwalk-like* *viruses*, also known as NoV), and *Rotavirus* are associated with foodborne disease [16]. To date, the exact origin of COVID-19 is unknown. The first cases of COVID-19 were reported from the Huanan Seafood Market [17]. Live wild animals such as bats, snakes, and marmots as well as animal limbs are sold there and are suggesting a common transmission route of COVID-19 to humans. However, several studies have identified bats as native hosts of COVID-19 [18]. In fact, the middle host, which is not yet fully understood, was able to help the virus cross the cheek barrier to infect humans [19]. The most well-known and major route of transmission of the virus is human-to-human contact through respiratory droplets, while surfaces can also carry the virus [20]. It is important to note that the WHO and the Centers for Disease Control and Prevention (CDC) have stated that there is no evidence of direct transmission and contamination of COVID-19 through water and food [21, 22], but the spread of the virus should not be ignored by consuming food on contaminated surfaces, packing in an infected room, or by not taking precautions when handling food or sharing food with an infected person [23]. It is reported that physical contact and shared food during a conference resulted in multiple cases of COVID-19 in Singapore in January 2020 [24]. Studies on the persistence of the coronavirus in food are rare. Transmission of MERS-CoV contamination through the drinking of unpasteurized camel milk or semi-cooked camel meat (41.9%) has also been suggested as a transmission route of MERS-CoV disease [25]. Some studies have also assessed the survival rate of MERS-CoV in unpasteurized goat and cow milk after about 48 h [26]. Another study described the stability of COVID-19 on lettuce leaves in refrigerated conditions to investigate the possible transmission of the virus through food and stated that they could be detected for at least 14 days. Therefore, with virus stability at low temperatures and relative humidity and the viral load/concentration, contaminated vegetables can be a potential way to transmit coronavirus to humans [20]. Similar results were reported on lettuce leaves stored at 4 °C for the human coronavirus (HCoV) 229E and showed the virus after two days. They were initially reduced by 0.2 CFU/g and deactivated after 4 days [27]. Long-term survival of COVID-19 in salmon at 4 °C for 8 days and 2 days at 25 °C was reported [28]. Studies have shown that COVID-19 can survive longer than MERS-CoV in food stored at 4 °C [26]. These studies prove the potential sources for transmission that products cannot be heat-treated to inactivate viruses. Thus, COVID-19 can survive through fresh produce for several days at normal storage temperatures in the consumer refrigerator. Moreover, purchasing from shopping centers and their delivery conditions to the home, how to receive and prepare all materials for consumption may be the key points that can be evaluated in food safety. Although transmission of the virus through food has not been established, ensuring proper and consistent personal hygiene, including hand washing and safe waste management practices, can be the best way to prevent the transmission of COVID-19 to humans. Also, a variety of foods, including meat, poultry, and seafood stored at low temperatures, should be inspected to ensure food safety against COVID-19.

Another important point that should be taken into account is the continuation of unconventional hunting activities. There is some information about other viruses in the coronavirus family, including SARS-CoV-1 and MERS-CoV, most of which are of animal origin [7]. Beef, poultry, pork, and wild animals are known to be abundant in heparin sulfate, which is required for COVID-19 to interact with the host tissue

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epithelium [29]. However, to date, there is no evidence of animal-to-human transmission that one research has reported [18]. Burimuah *et al*. [30] determined the prevalence of Bovine Coronavirus (BCOV) in cattle, sheep, and goats in Ghana. This study identified a significant prevalence for BCOV in Ghana and needs more attention to BCOV infection to ruminants in mixed farming and limited species separation. People should not consume animal protein from wild animals or their uncooked products. Any side effects or abnormal death of animals should be reported to animal health authorities. There is misinformation about the possible potential hazards of animals spreading the virus. It is important to prevent livestock disruption due to the widespread prevalence of COVID-19 in humans. Given the points raised, a more accurate understanding of the route of transmission and possible infection through food with scientific evidence, as well as the search for new ways to control the rapid spread of the virus are required and it is also necessary to update international guidelines during a pandemic.

Inactivation in the food and food environmental system

The significance of COVID-19 transmission through contaminated surfaces has in recent times been noticed. It is known that many viruses, including SARS-CoV, MERS-CoV, and SARS-CoV-2, can survive for hours or even months on several intimated subjects [31]. The surfaces of various foods can also be a means of transmitting the virus if they are exposed to unsanitary conditions of contaminated surfaces [20]. One of the main mechanisms of COVID-19 transmission, which is also highly contagious, is the self-inoculation of mucous membranes in the nose, eyes, or mouth from a contaminated dry surface [32]. During the infection, the virus is present in large numbers in the patient's body secretions, including blood, saliva, nasal fluid, urine, and feces. In this way, the infected person may touch surfaces or inanimate objects and the infected virus particles may be transmitted to the mucous membranes of the uninfected person. The durability of COVID-19 in airborne particles and surfaces, including plastics, stainless steel, copper, and cardboard was investigated and the results can demonstrate the presence of human coronavirus per liter of air for 3 h in aerosols and 72 and 48 h on plastic and stainless steel, respectively. Nevertheless, for the virus on copper and cardboard within 4 and 24 h, no causative agent was observed, respectively [33]. No infectious virus was detected through paper towels within 3 h of exposure and for 2 days on wood and fabric. However, COVID-19 survived on glass and banknotes for 4 days and with stainless steel and plastic for 7 days. This study showed that 7 days after inoculation on the outer layer of the surgical mask, the virus survived, thus more caution and more information are needed when wearing masks or throwing them away [34]. Some environmental conditions such as temperature and humidity can affect the survival of viruses. A study by Kampf *et al.* [35], found that higher temperatures (30 or 40 °C) reduced the survival time of HCoVs on the inanimate surfaces while surviving up to 9 days at 4 °C. All this information from the literature indicates that frequent contact with infected surfaces is a potential source of virus transmission [35]. There is currently no antiviral drug, treatment, or vaccination for up to 70% of the population for COVID-19. To this end, personal hygiene, including proper disinfection of food contact environments and surfaces and social distance [36] is the best protection of personal health. Reducing the risk of exposure to COVID-19 by disinfecting is a key point that should be taken into account in the reopening of

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food-producing and supplying businesses and requires careful planning. Methods such as heat inactivation, ultraviolet (UV) treatment, and chemical disinfectants for inactivation are suggested, which will be discussed in this article.

As mentioned, studies have shown that an increase in temperature and a decrease in relative humidity are associated with a decrease in the rate of infection [37]. Many studies have shown that temperature and humidity can be used as general intervention measures. Thus heat inactivation can be considered and successfully used for food safety [38]. MERS-CoV was destroyed from camel, cow, and goat milk during heat treatment at 63 °C for 20 min [26]. Similar results were observed in SARS-CoV after heat treatment at 60 °C for 30 min [39] . Most recent studies on the effect of three heat inactivation protocols (56 °C for 30 min, 60 °C for 60 min, and 92 °C for 15 min) on SARS-CoV-2 were investigated [40]. In another study, 67-56 °C for 60-90 min was sufficient to inactivate SARS-CoV-2 [41]. Regardless of the protocol, results observed a decrease of 4 CFU/g. However, samples containing viral 6> CFU/g loads are still infected after 56 °C in 30 min and 60 °C in 60 min. Therefore, it is suggested to take precautions when eating foods. Using heat treatment was effective at 70 °C for 5 min and 30 and 15 min at 56 and 65 °C in human serum and sputum, respectively [34, 42]. Therefore, all these results of the cooking process that is usually cooked at 70 °C are effective in inactivating the virus, however there is very little information about the association between COVID-19 and food. For example, many studies on inactivation in this way are related to various coronaviruses, or the heat process cannot be applied to many fresh foods.

The World Health Organization outlines strategies including the use of ultraviolet light-based innovations, ultraviolet surface disinfection with control in hospital rooms, and microbial inactivation in food safety applications [43]. The maximum absorption wavelength of DNA molecules is about 260 nm, viruses are sensitive at close wavelengths and are vulnerable to a study at 253.7 nm, which is the UVC range [44]. The mechanism of inactivation is based on the structural similarity of SARS-CoV and SARS-CoV-2, thus there is the same UV inactivation effect. UV inactivation is due to the greater intensity of UVC light and proximity to the light source. SARS-CoV was inactivated by exposure to ultraviolet (254 nm) and the inactivation rate increased from 1 to 6 min with an increase of up to 400-fold [31]. The effects of UVC irradiation on SARS-CoV-2 in water at different virus concentrations (1000, 5, and 0.5 M) have been evaluated. At 254 nm and a dose of 3.7 mJ cm^2 SARS-CoV-2 with 3 log_{10} in water and a dose of 16.9 mJ cm^2 completely inactivated all viruses [45]. Most UV-based inactivation studies have been performed on water-suspended target viruses because doses of inactivation in water are higher than on solid surfaces. Relative humidity and temperature can also affect the inactivation rate of UV dose, thus UV can be considered as suitable for food and water-based samples [46]. Limitations of this method is that important details about dosage for quantitative and exposure time as well as robust validation have to be established before large-scale use of UV-based inactivation methods. Therefore, effective alternative method approaches such as the use of nanoparticles such as copper can be an attractive target for future research due to its effect on the virus.

Since the beginning of the COVID-19 pandemic, significant efforts have been made to remove COVID-19 from environmental surfaces, but very little information is available on the removal of the virus from food surfaces [31]. Although no current evidence exists that the COVID-19 virus is transmitted via food or food packaging, people may become infected by touching a surface or object infected with the virus and then touching the mouth, nose and eyes [47]. Disinfection is probably the best way to reduce the incidence of COVID-19. A wide range of disinfectants are available that are generally cost-effective, easy to use, and have a wide range of applications on commonly touched surfaces. Reducing the risk of exposure to COVID-19 by disinfecting is an important part of the reopening of food manufacturers and requires careful planning. Standard disinfectants have been introduced by CDC and WHO that can be effective against COVID-19 because these compounds are resistant to viruses that are harder to kill than viruses such as the COVID-19 virus [14, 48]. A regular cleaning with disinfectants reduces the amount of virus on surfaces and objects, and this reduces the risk of exposure [35, 49]. To inactivate coronaviruses in humans and animals with agents such as chlorine and its derivatives, 62-71% ethanol, and 0.5% hydrogen peroxide or 0.1% sodium hypochlorite showed that surface disinfection was achievable within 1 min [9]. About 2.0–4.0 $\log_{10}$ reduction of SARS-CoV-2 was shown by ethanol (62–71%) for 1 min, whereas sodium hypochlorite (0.1–0.5%) or glutardialdehyde (2%) was also in effect for >3.0 $\log_{10}$ reduction for 1 min [35]. In another study using household bleaching agents, ethanol (70%), povidone-iodine, chloroxylenol (0.05%), chlorhexidine (0.05%) no virus was observed after 5 min, or benzalkonium chloride (0.1%) but hand soap took 15 min to completely disable SARS-CoV-2 [34]. The inactivation effect of acetic acid and vinegar SARS-CoV-2 was evaluated for food safety, which reduced the virus by more than 4 $\log_{10}$ by 4% and 6%, respectively, after 5 min. Disinfectants and UV treatment that are studied by international organizations and available on the market are listed in Table 1. WHO (2020d) has declared the effectiveness of bleaching and disinfecting agents in reducing COVID-19 (for example: a 1:100 dilutions from 5% sodium hypochlorite to a final concentration of 0.05% or 0.5% hydrogen peroxide). The World Health Organization also recommended a concentration of 70% ethanol to inactivate viruses at small levels [9, 50]. Besides, frequent disinfection of surfaces and objects touched by many people is important [14, 22, 51-54].

One of the important points when using disinfectants is, they should be stored and used according to the label. In the case of bleach, it should not be mixed with food and other cleaning agents because it can cause vapors that are very dangerous when inhaled [54]. Also, disinfectant compounds are not always safe for the environment and human health, and, therefore, the inactivating effect is essential for any chemical disinfectant for safe use. Therefore, it is necessary to search for suitable disinfectants for direct use on the surface, appropriate doses and methods to reduce the risk of COVID-19 infection.

Food industry during COVID-19

The food industry looks at high insecurity about the presence of COVID-19 in food production and distribution. During the COVID-19 pandemic, the food industry must strictly adhere to food safety management systems (FSMS) based on the HACCP

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principles at every stage of food processing, production, packaging, and marketing. Good manufacturing practices (GMPs) refer to the methods, equipment, facilities, and control of processed food production [62]. Good manufacturing practices are an important part of regulatory control over food safety. In an outbreak, every food industry needs to follow a set of standards and follow safety precautions. One of the major challenges in crisis planning is creating flexible food systems. Planning, staff training, staff attendance, catering oversupply, catering infrastructure, location, service providers, insurance, and post-event learning are factors that create organizational flexibility in food supply chains. Implementing any change in food safety requires that key stakeholders, including industry, policymakers, governments, and consumers, play an active role. In the global COVID-19 pandemic, it is more important that companies comply with GMPs by the highest production standards. Despite announcements from the food and drug administration (FDA) to postpone further inspections of foreign facilities and domestic monitoring facilities, the global manufacturing industry must be prepared for close government oversight and the organization of food and medicine [62]. In the COVID-19 pandemic, companies have to develop and put certain guidelines in place. These include conducting internal audits following GMPs and increasing surveillance in specific areas that may be related to COVID-19. For example, companies need to train their employees to prevent the spread of disease and provide regular updates on COVID-19 improvements. It may also be necessary to develop more accurate protocols for employee hygiene, equipment hygiene, and even employee quarantine. Reducing the number of employees in factories can also be effective. Good manufacturing practices regulations on personal hygiene responsibilities such as wearing clean clothing and protective clothing, exercise and health habits, creating rules for limited access to certain facilities, deprivation of any employee who has an apparent illness and is considered unsafe or negatively affect the quality of products via direct contact with parts, utensils, and materials in the process. Temporary policies on packaging and labeling are also required in the event of an emergency public health COVID-19 pandemic. Working remotely may be an ideal option for most individuals [16]. Maintaining GMP in surface installations reduces the potential for surface contamination and also eliminates contamination in the event of an outbreak. Considering coronavirus in asymptomatic individuals and studies on the survival of coronavirus on surfaces for a short time, as an additional precaution, food manufacturers should consider frequent cleaning and disinfection programs for human contact surfaces.

Guidance for food industry

Food and Drug Administration (FDA) and World Health Organization (WHO) have set up a temporary emergency health policy for COVID-19 due to eligible exemptions from growth, harvesting, packaging, and storage standards for human consumption. It had better register the announcement of any production plan with the FDA in each country [63]. During the pandemic, FDA in each country reported faster and more specific information about some food manufacturers (factories, food retail sellers), thus improving the current state of the food supply and the challenges facing production. Here are some tips to help food manufacturers: determine what needs to be disinfected, to implement the disinfecting plan, to maintain and revise the disinfecting plan, people should be 2 m apart when working and talking, and body temperature checks before entering the factory gate (use an IR scanning thermometer that does not require touching the skin or ear temperature with alcohol). It must be noted that there are legal consequences if anyone with a temperature above 38°C is allowed to enter. All workers should wear a mask and observe personal protective equipment (PPE) throughout the factory. The surfaces should be separated, and doors opened or automatic door use to eliminate contact with the handle. Ventilation and the percentage of outdoor air circulation inside the system should be increased. It can be useful to identify areas that require restricted access during and immediately following enhanced cleaning and all administrative teams work remotely (sales team, marketing, and asset teams as well as accounting). The shifts must be completely isolated to protect each shift. Also, the plan should be set up to prevent employees from entering into areas where they do not need to work. The personnel should separate those who are unable to work from others to prevent them from getting sick. Congestion should be minimized during start or stop time, rest time and lunchtime. If it is confirmed that an employee has COVID-19, employers must notify other employees of their possible exposure to COVID-19 at work. Also, include how to handle suspect cases. The patient must follow the WHO guidelines, and employers must consult with the FDA of the local Health Department for further guidance. Common areas like canteens, common utilities like, desk, door handles, and telephones must be regularly sanitized. The final Food Safety Modernization Act (FSMA) regulation could be effective in controlling preventive measures. It is necessary to prepare the necessary disinfectant products registered by EPA for use against the list of SARS-CoV-2, which is available under the Viral Pathogen Viral EPA program for use against SARS-CoV [48]. It is a good idea to check the product label instructions as to whether these disinfectant products are safe and recommended for use in manufacturing areas. Manufacturers should thoroughly review policies for symptoms, COVID-19 infections, sterilization, and related reports.

CONCLUSION

Even though food is not the main route of transmission of COVID-19, more effort is needed to research on transmission from the respiratory tract to food packaging or food and also to manage the risks when handling raw foods. The potential impact of the virus on food safety is an important issue for governments, the food industry, and consumers around the world. Food producers and consumers should follow hygiene tips to prevent transmission of COVID-19 and to observe maximum food safety guidelines. Consumers must follow the guidelines when buying food, moving food, and preparing food. Strategies to inactivate COVID-19 are required through international guidelines to ensure food safety and control the COVID-19. Also, intensive research should be conducted to discover safe food packaging materials and ways to prevent cross-contamination.

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Conflict of Interest

The authors declare no competing financial interest.

Table 1: Different types of biocide agents on COVID-19

Biocide agent	Concentration	Exposure time	Reduction of viral infectivity (log10)	Ref.
Ethanol	95%	30 s	>5.5	
	85%	30 s	>5.5	[55]
	80%	30 s	>4.3	
	78%	30 s	>5.0	[39]
	20%	30 s		
	20%	1 min		
	20%	3 min		
	20%	5 min		
	30%	3 min		
	30%	5 min		[56]
	30%	30 s		
	30%	1min, 3min, 5min		
	40, 50, 60, 75%	30s, 1min, 3min, 5min		
Didecyldimethylammonium chloride	0.0025%	3 day	> 4.0	[35]
Sodium hypochlorite	0.02%	10 min	0.3	[57]
	0.21%	30 s	>4.0	[58]
	0.01%	10 min	2.8 -2.3	[57]
	0.1%	1min		
Hydrogen peroxide	0.5%	1 min	> 4.0	[35]
Chlorine	0.5 mg/L	1 min		[49]
chlorine dioxide	2.19 mg/L	1 min		[49]
UV	254 nm 3.7 mJ/cm2	6 days	completely inactivated	
	254 nm 3.7 mJ/cm2	after 24 h	3	[45]
	254 nm ≥16.9 mJ/ cm2		completely inactivated	
UV	BSC's UV lamp 134 µW/cm2	15min UV exposure	1.8 × 102 TCID50/mL (initial titer was 3.8 × 107 TCID50/mL).	[59]
	260 nm >90 µW/cm2	15 min UV exposure	51 to 75% to less	[60]
	365 nm (UV-A)	more than 15min	significant effects	[61]
	254 nm (UV-C)	up to 6min	in a 400-fold decrease in infectious virus). And there was no additional inactivation from 6 to 1 min.	

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