Title: COVID-19 AND FOOD SAFETY: Risk Management and Future Considerations

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Abstract:

COVID-19, also known as the 'novel coronavirus disease 2019', is a respiratory illness and the causative pathogen is officially named as 'SARS-CoV-2'. Infections with SARS-CoV-2 have now been amplified to a global pandemic – as of April 3, 2020, nearly 1,018,000 cases have been confirmed in more than 195 countries, including more than 300,000 cases within the United States. Public safety guidelines are followed worldwide to stop the spread of COVID-19 and stay healthy. Despite COVID-19 is a respiratory illness with mode of invasion through the respiratory tract, not the gastrointestinal tract, an average food consumer is anxious and concerned about the food safety. Could an individual catch the deadly contagious COVID-19 from groceries brought home from the supermarket – or from the next restaurant takeout order? This brief review elucidates the epidemiology and pathobiological mechanism(s) of SARS-CoV-2 and its implications in food-borne infections, transmission via food surfaces, food processing and food handling.

Origin of Coronavirus (CoV) and SARS-CoV-2

Coronavirus (CoV) belongs to a large family of viruses that cause illness ranging from the common cold to more severe diseases. CoVs are positive-stranded enveloped RNA viruses belonging to the order *Nidovirales,* classified into four genera: Alpha, Beta, Delta and Gamma. Two of the Beta-CoVs, the severe acute respiratory syndrome CoV (SARS-CoV) and the Middle East respiratory syndrome CoV (MERS-CoV), have caused serious epidemics worldwide. In December 2019, a novel CoV (SARS-CoV-2) emerged from Wuhan, China, and spread rapidly to a global proportion.[1] Although its original host remains unknown, all available data point to a wild animal source.[2] This novel respiratory pathogen is the seventh CoV known to infect humans – the 3 viruses: SARS-CoV, MERS-CoV and SARS-CoV-2 can cause SARS illness; whereas, the remaining 4 viruses: HKU1, NL63, OC43 and 229E are associated with mild symptoms.[3] .

Chemistry and Pathobiology of SARS-CoV-2

Viruses facilitate their replication cycle using three basic steps, attachment to the host cell, injection of genomic material into the host cell, and replication via the host cell genome mechanisms to form new virions.[4] The virulence of CoV is attributed to four structural proteins: Spike (S), Envelope (E), Membrane (M), and Nucleocapsid (N).[5] Among these, S protein plays the critical role in viral attachment, fusion and entry.[6] S protein is the 'hook' that mediates viral entry into host cells by first attaching to a host receptor through its receptor-binding domain (RBD) and then fusing the viral and host membranes through the S2 subunit.[7] Both SARS-CoV and -CoV-2 recognize angiotensin-converting enzyme 2 (ACE2) as host binding receptor, which is an exopeptidase involved in blood pressure regulation.[8,2] These two key features of the S protein allow the virus to open and enter the host respiratory cells. The RBD in S protein of SARS-CoV-2 is the most likely target for the development of virus attachment inhibitors, neutralizing antibodies, and vaccines.

Mucosal epithelia including in the respiratory tract are coated with a layer of mucin polysaccharides (usually sulfated). Consequently, the polydisperse, natural products of heparan sulfate and the allied polysaccharide, heparin have been found to be involved in the pathobiology of CoV infection.[9] Interestingly, several antimicrobial proteins such as lactoferrin, defensins and lysozyme that are native to the mucosal secretions are potential viral adhesion-blocking agents for providing the first-line defense among mammals, including humans.[10,11] Elucidating the viral attachment/detachment mechanisms is key to understand the interactions of SARS-CoV-2 with different food matrices and to develop nutraceutical interventions to control the pathogen.

Transmission of SARS-CoV-2

The principal mode of transmission of CoV is via droplets in coughs and sneezes, and close person-to-person contact.[12] If a CoV finds its way to a food surface, some data suggest that the virus has a limited survival rate, unless there is optimum moisture, secure porous anchor site, and a virus-friendly temperature. Its viability will likely be a few hours to possibly several days. For example, using a bovine coronavirus (BCoV), which is a distant relative to SARS-CoV, as the infectious agent applied to Romaine lettuce stored at refrigeration temperature (4°C) indicated viral plaques could be recovered after 25 days.[13]

Zoonosis Transmission: Zoonoses or zoonotic diseases are infectious illnesses caused by bacteria, viruses and other pathogens that spread or 'spill' between animals and human. Approximately 75% of such infectious diseases among humans are manifested via animal spillover to humans.[14] The WHO emphasizes the importance to control zoonoses which are often neglected, especially among populations living in poverty and rely on livestock.[15] Except for the emerging zoonoses such as SARS and avian influenza H5N1, "the vast majority are not prioritized by health systems at national and international levels; therefore, are labelled as neglected."[16]

Zoonosis with CoVs are well established – civets (nocturnal mammals native to Asia and Africa) in the case of SARS and camels in the case of MERS. Given the similarity of SARS-CoV-2 with bat-associated SARS-CoV, it is likely that bats serve as the animal reservoir.[2] Some CoVs that originated in pangolins (anteaters) have a receptor binding domain (RBD) similar to SARS-CoV-2. In that way, a pangolin either directly or indirectly involved in spilling its virus onto a human host.

Person-to-person Transmission: Person-to-person spread is the main mode of SARS-CoV-2 transmission, like other respiratory viruses such as influenza. The virus spreads from person-to-person through invisible droplets of water that are suspended in the air after a sick individual sneezes or coughs. Anyone within 6-feet (1.8 meters) radius of an infected person is at risk. Since genetic bottlenecks for RNA viruses often occur during respiratory droplet transmissions, the SARS-CoV-2 is expected to become less virulent through human to human transmissions.[17]

COVID-19: Foodborne Infection and Transmission

CoV infections are known in production animals such as scours and winter dysentery in beef and dairy cattle, respiratory CoVs in swine and avian infectious bronchitis in poultry.

Transmission of animal-CoV to humans was evident during SARS and MERS outbreaks. Similar zoonotic involvement (bats and pangolins) has been suspected with the current COVID-19 pandemic. Therefore, further studies are needed prior to ruling out any potential food safety risk of production animals in the transmission of SAR-CoV2.

Meat foods (beef, pork poultry, seafood, etc.) are rich in heparan sulfate (glycosaminoglycans), which are highly charged anchors for SARS-CoV-2 to interact with host tissue epithelia.[9] Considering the survival of this viral pathogen for days on inanimate surfaces such as cardboard, plastic and stainless steel, it is obvious that animal (meat) tissue surfaces may be critical basements for foodborne transmission of COVID-19.[18] Additional studies are warranted to evaluate the possible foodborne transmission of COVID-19 via meat foods and food processing.

COVID-19: Food Contamination and Pathogen Survival

Food Processing (Inanimate surfaces): In contrast to the respiratory microbes, enteric viruses such as noroviruses and hepatitis-A survive for weeks on surfaces, endure extreme temperatures and spread through contaminated foods. COVID-19 cannot survive for extended time on surfaces. Unlike bacteria, viruses cannot proliferate in food; therefore, the viral load is expected to dwindle over time, rather than increase in numbers. An analysis of 22 studies revealed that human CoV can persist on inanimate surfaces such as metal, glass or plastic for up to 9 days. Surface disinfection with 0.1% sodium hypochlorite (bleach), 0.5% hydrogen peroxide or 62-71% ethanol could significantly reduce CoV infectivity on surfaces within 1 min exposure. A similar effect against the SARS-CoV-2 is expected.[19] A recent study reported that SARS-CoV-2 could remain viable in the air for up to 3 hours, on copper for up to 4 hours, on cardboard up to 24 hours, on plastic and stainless steel up to 72 hours.[18]

Also, SARS-CoV could be inactivated by ultraviolet light, thermal exposure (≥65°C), alkaline pH (> 12) or acidic pH (< 3) milieu.[20] These data support the importance of cooking or processing foods to minimize the risk of SARS-CoV-2 transmission via a potentially contaminated food supply.

Food Handling (Personnel): It is possible that CoV could hitchhike onto hands from contaminated surfaces during food handling. An individual could be exposed to COVID-19 by touching a contaminated surface or object and subsequently self-infect via oral, nasal or optic routes. However, this is no means the common mode of CoV transmission. Though certain individuals may become infected, SARS-CoV-2 is fairly a 'susceptible' virus. In theory, ingested CoV cannot survive the stomach acid. On tissue surfaces including skin, it can be easily removed by handwashing with soap, and eliminated using alcohol-based hand sanitizers.[21,22,23] As a proactive approach, follow the 4 key steps of food safety – *Clean, Separate, Cook, and Chill*, to prevent foodborne illness.

Food Safety Guidelines: Risk Management and Future Considerations

In view of risk management, the CDC, the USDA, and the European Food Safety Authority (EFSA), have stated that there is lack of evidence to support the spread of COVID-19 through food or food packaging.[24] Previous CoV outbreaks likewise showed no evidence of viral spread through food or packaging. However, these results also suggest that the infectious virions are released into the gastrointestinal tract, thereby suggesting the possibility of fecal-oral transmission of SARS-CoV-2. This further emphasizes the importance of personal hygiene and sanitation guidelines to protect against COVID-19 infections.

Viral Testing and Food Protection?

There are many biohazards associated with the food supply. The emergence of COVID-19 represents another challenge in assuring that the food supply remains safe. Viral contaminated oysters and orange juice that impacted Australia more than 20 years ago.[25] The authors noted that few food laboratories were prepared to analyze food products for viruses, and called for implementation of HACCP principles directed to specific risks associated with viruses, such as Norwalk-like viruses, rotavirus, astroviruses, adenoviruses, human caliciviruses, and parvovirus-like particles. A few years later, several investigators called for HACCP plans applied to aquaculture products, such as shrimp facilities. Throughout the United States, the seafood industry established an array of HACCP protocols. Even though these protocols acknowledge viruses as biological hazards, and that all domestic and imported fish and fishery products must comply with provisions of the Hazard Analysis Critical Control Point (HACCP) regulation for

Fish and Fishery Products, the US regulatory agencies have stated that humans do not contract the coronavirus by eating seafood or other animal products.[24]

Current COVID-19 Resources for Food Safety: There are several credible resources at the intersection of COVID-19 and food safety. Some of these are listed in the following Table 1.

Table 1. Valuable Credible Resources and Updates on COVID-19 and the Food Supply

Organization	**URL**
World Health Organization (WHO)	https://www.who.int/emergencies/diseases/novel-coronavirus-2019
U.S. Food and Drug Administration (FDA)	https://www.fda.gov/emergency-preparedness-and-response/mcm-issues/coronavirus-disease-2019-covid-19
Centers for Disease Control and Prevention (CDC)	https://www.coronavirus.gov
USDA Animal and Plant Health Inspection Service (APHIS)	https://www.usda.gov/coronavirus
European Food Safety Authority (EFSA)	https://www.efsa.europa.eu/en/news/novel-coronavirus-where-find-information
Institute of Food Technologists	https://www.ift.org/about-ift/novel-coronavirus-updates

Conclusions

Understanding virus epidemiology is not a simple matter; confusion seems to have arisen because the coronaviruses typically evolve genetically and spillover from animal reservoirs to human hosts. The exact mechanism for this jump between species is not well-understood, but it does appear to occur in very crowded environments in which livestock or wild animals and humans are virtually on top of one another. Emerging data suggest fecal-oral spread, in addition to droplet or gas clouds created by coughs an sneezes, must be carefully controlled and monitored. The food supply chain is diverse throughout the US, and any disruptions in food supply during this crisis should be temporary as distribution catches up with demand. Importantly, as noted by the FDA, there is no evidence associating food or food packaging with the transmission of SARS-CoV-2.

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