COVID-19 and Food Safety

Risk Management and Future Considerations

Peter Pressman, MD
A. Satyanarayan Naidu, PhD
Roger Clemens, DrPH

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.
Nutr Today. 2020;55(3):125–128

ORIGIN OF CORONAVIRUS 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. Coronaviruses are positive-stranded enveloped RNA viruses belonging to the order Nidovirales, classified into 4 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]

Peter Pressman, MD, is Medical Director at Daedalus Foundation, Mount Vernon, Virginia.

A. Satyanarayan Naidu, PhD, is Director at N-terminus Research Laboratory, Yorba Linda, California.

Roger Clemens, DrPH, is Adjunct Professor, USC School of Pharmacy, Los Angeles, California.

The authors have no conflicts of interest to disclose.

Correspondence: Roger Clemens, DrPH, USC School of Pharmacy, 1540 Alcazar St., CHP 140, Los Angeles, CA 90033 (clemens@usc.edu).

DOI: 10.1097/NT.0000000000000415

CHEMISTRY AND PATHOBIOLOGY OF SARS-COV-2

Viruses facilitate their replication cycle using 3 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 4 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 SARS-CoV-2 recognize angiotensin-converting enzyme 2 as host-binding receptor, which is an exopeptidase involved in blood pressure regulation.[2,8] These 2 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 (Figure).

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

FIGURE. Food safety and health management is a continuum that impacts global health and personal well-being. The image credit belongs to A.S.N.

virus-friendly temperature. Its viability will likely be a few hours to possibly several days. For example, using a bovine coronavirus, 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 World Health Organization emphasizes the importance to control zoonoses, which are often neglected, especially among populations living in poverty and relying 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 labeled as neglected."[16]

Zoonoses 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 an RBD similar to SARS-CoV-2. In that way, a pangolin is 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 a 6-ft (1.8-m) radius of an infected person is at risk. Because 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

Coronavirus 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-CoV-2.

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 virus 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% to 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, and on plastic and stainless steel up to 72 hours.[18]

Also, SARS-CoV could be inactivated by UV 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. Although 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.[21–23] 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 Centers for Disease Control and Prevention, the US Department of Agriculture, and the European Food Safety Authority 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 ensuring that the food supply remains safe. Viral-contaminated oysters and orange juice 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 Hazard Analysis Critical Control Point (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 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.[23]

TABLE Valuable Credible Resources and Updates on COVID-19 and the Food Supply

Organization	URL
World Health Organization	https://www.who.int/emergencies/diseases/novel-coronavirus-2019
US Food and Drug Administration	https://www.fda.gov/emergency-preparedness-and-response/mcm-issues/coronavirus-disease-2019-covid-19
Centers for Disease Control and Prevention	https://www.coronavirus.gov
US Department of Agriculture Animal and Plant Health Inspection Service	https://www.usda.gov/coronavirus
European Food Safety Authority	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

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 Table.

CONCLUSIONS

Understanding virus epidemiology is not a simple matter; confusion seems to have arisen because the coronaviruses typically evolve genetically and spill over 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 and sneezes, must be carefully controlled and monitored. The food supply chain is diverse throughout the United States, and any disruptions in food supply during this crisis should be temporary as distribution catches up with demand. Importantly, as noted by the US Food and Drug Administration, there is no evidence associating food or food packaging with the transmission of SARS-CoV-2.

REFERENCES

1. Wu F, Zhao S, Yu B, Chen Y-M, Wang W, Song ZG. A new coronavirus associated with human respiratory disease in China. *Nature*. 2020;579:265–269. doi:10.1038/s41586-020-2008-3.
2. Zhou P, Yang XL, Wang XG, et al. A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature*. 2020; 579:270–273. doi:10.1038/s41586-020-2012-7.
3. Corman V, Muth D, Niemeyer D, Drosten C. Hosts and sources of endemic human coronaviruses. *Adv Virus Res*. 2018;100:163–188. doi:10.1016/bs.aivir.2018.01.001.
4. Pellett P, Mitra S, Holland T. (2014). Basics of virology. In Tselis A, & Booss J, eds. Handbook of Clinical Neurology (Vol. 123). San Francisco, CA: Elsevier B.V. 45–58. doi:10.1016/B978-0-444-53488-0.00002-X.
5. Wang N, Shang J, Jiang S, Du L. Subunit vaccines against emerging pathogenic human coronaviruses. *Front Microbiol*. 2020;11: 298. doi:10.3389/ fmicb.2020.00298.
6. Du L, He Y, Zhou Y, Liu S, Zheng BJ, Jiang S. The spike protein of SARS-CoV—a target for vaccine and therapeutic development. *Nat Rev Microbiol*. 2009;7:226–236. doi:10.1038/nrmicro2090.
7. Liu S, Xiao G, Chen Y, et al. Interaction between heptad repeat 1 and 2 regions in spike protein of SARS-associated coronavirus: implications for virus fusogenic mechanism and identification of fusion inhibitors. *Lancet*. 2004;363:938–947. doi:10.1016/S0140-6736(04)15788-7.
8. Li W, Moore MJ, Vasiliva N, et al. Angiotensin-converting enzyme 2 is a functional receptor for the SARS coronavirus. *Nature*. 2003; 426:450–454. doi:10.1038/nature02145.
9. Mycroft-West C, Su D, Elli S, et al. The 2019 coronavirus (SARS-CoV-2) surface protein (spike) S1 receptor binding domain undergoes conformational change upon heparin binding. 2020; bioRxiv preprint. doi: 10.1101/2020.02.29.971093.
10. Naidu AS. Microbial blocking agents—a new approach to meat safety. *Food Technol*. 2000;54:112. https://www.ift.org/-/media/food-technology/pdf/2000/02/0200col_backpage.pdf.
11. Lang J, Yang N, Deng J, et al. Inhibition of SARS pseudovirus cell entry by lactoferrin binding to heparan sulfate proteoglycans. *PLoS One*. 2011;6(8):e23710. doi:10.1371/journal.pone.0023710.
12. Bourouiba L. Turbulent gas clouds and respiratory pathogen emissions—potential implications for reducing transmission of COVID-19 [published online March 26, 2020]. *J Am Med Assoc*. 2020;26:E1–E2. doi:10.1001/jama.2020.4756.
13. Mullis L, Saif L, Zhang Y, Zhang X, Azevedo M. Stability of bovine coronavirus on lettuce surfaces under household refrigeration conditions. *Food Microbiol*. 2012;30:180–186. doi:10.1016/j.fm.2011.12.009.
14. Taylor LH, Latham S, Woolhouse M. Risk factors for human disease emergence. *Phil Trans R Soc Lond B*. 2001;356:983–989. doi:10.1098/rstb.2001.0888.
15. World Health Organization. The control of neglected zoonotic diseases: a route to poverty alleviation. Joint WHO/DFID-AHP Meeting, September 2005. Published March 2006. https://www.who.int/neglected_diseases/zoonoses/9789241594301/en/. Accessed April 1, 2020.
16. World Health Organization. Neglected tropical diseases. 2020. Neglected Zoonotic Diseases. https://www.who.int/neglected_diseases/diseases/zoonoses/en/. Accessed April 1, 2020.
17. Duarte E, Clarke D, Moya A, Domingo E, Holland J. Rapid fitness losses in mammalian RNA virus clones due to Muller's ratchet. *Proc Natl Acad Sci U S A*. 1992;89:6015–6019. doi:10.1073/pnas.89.13.6015.
18. van Dormalen N, Bushmaker T, Moris DH, et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *N Engl J Med March*. 2020;17. doi:10.1056/NEJMc2004973.
19. Kampf G, Todt D, Pfaender S, Steinmann E. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *J Hosp Infect*. 2020;104:246–251. doi:10.1016/j.jhin.2020.01.022.
20. Darnell ME, Subbrao K, Feinstone SM, Taylor DR. Inactivation of the coronavirus that induces severe acute respiratory syndrome, SARS-CoV. *J Virol Methods*. 2004;121:85–91. doi:10.1016/j.jviromet.2004.06.006.
21. World Health Organization. 2010. Guide to local production: WHO-recommended handrub formulations. https://www.who.int/gpsc/5may/Guide_to_Local_Production.pdf.
22. US Food and Drug Administration. https://www.fda.gov/consumers/consumer-updates/safely-using-hand-sanitizer. Accessed March 30, 2020.
23. Centers for Disease Control and Prevention. Coronavirus disease 2019 (COVID-19). CDC Statement for Healthcare Personnel on Hand Hygiene during the Response to the International Emergence of COVID-19: https://www.cdc.gov/coronavirus/2019-ncov/infection-control/hcp-hand-sanitizer.htm. Accessed March 14, 2020.
24. US Food and Drug Administration. Food Safety and the coronavirus disease 2019 (COVID-19). https://www.fda.gov/food/food-safety-during-emergencies/food-safety-and-coronavirus-disease-2019-covid-19. Accessed April 1, 2020.
25. Feet GH, Heiskanen P, Reid I, Buckle KA. Foodborne viral illness—status in Australia. *Int J Food Microbiol*. 2000;59:127–136. doi:10.1016/S0168-1605(00)00249-X.