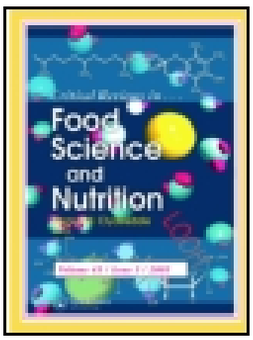

Critical Reviews in Food Science and Nutrition

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/bfsn20

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To cite this article: Carollyne Maragoni-Santos , Thaiza Serrano Pinheiro de Souza , Julia Rabelo Vaz Matheus , Talita Braga de Brito Nogueira , Douglas Xavier-Santos , Roberta Fontanive Miyahira , Adriane Elisabete Costa Antunes & Ana Elizabeth Cavalcante Fai (2021): COVID-19 pandemic sheds light on the importance of food safety practices: risks, global recommendations, and perspectives, Critical Reviews in Food Science and Nutrition, DOI: 10.1080/10408398.2021.1887078

To link to this article: https://doi.org/10.1080/10408398.2021.1887078

Published online: 16 Feb 2021.

CRITICAL REVIEWS IN FOOD SCIENCE AND NUTRITION
https://doi.org/10.1080/10408398.2021.1887078

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REVIEW

COVID-19 pandemic sheds light on the importance of food safety practices: risks, global recommendations, and perspectives

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ABSTRACT

The outbreak of the coronavirus disease (COVID-19) is global health and humanitarian emergency. To respond effectively to this pandemic, it is mandatory to reaffirm science in its different fields of study, including the food safety area. Presently, we review food safety in times of COVID-19, exploring whether the virus can be transmitted by food or water; recommendations from regulatory agencies; perceptions of food hygiene practices during the pandemic; and post-pandemic perspectives. The review was based on papers published in Web of Science, Scopus, Pubmed, and covered recommendations of public health protection and regulatory agencies around the world. The transmission of the severe acute respiratory syndrome (SARS-CoV-2) by food was not confirmed until the present time. In any case, the protocols already established for food safety were reinforced, emphasizing the proper hygiene of hands after shopping, handling food packages, or before manipulating or eating food, adequate social distance, the use of individual protection equipment, the health of employees, and the proper preparation of food. It is hoped, in the post-pandemic scenario, to reach a better understanding of the particularities that led to greater care with food hygiene. Moreover, it is expected that the food system will creatively adapt the way meals are served.

KEYWORDS

Food quality control; foodborne viruses; novel coronavirus; public health; safe food handling; SARS-CoV-2 pandemic

Introduction

In early 2020, many coutries were confronted with COVID-19, a complex, systemic, and emerging infectious disease for which there is no specific treatment. Thus, decision-making processes are based on protocols that change according to the dynamic contours of the pandemic and with scientific knowledge, still incipient, despite the unprecedented efforts of research groups around the world. In the context of uncertainties, non-pharmacological measures such as social distancing and face masks have been proposed (Grisotti 2020; Yang and Wang 2020).

In addition to a pandemic caused by the virus, we are experiencing an infodemic, defined by the World Health Organization (WHO) as an "overabundance of information – some accurate and some not – that makes it hard for people to find trustworthy sources and reliable guidance" (PAHO 2020). Though "fake news" is not new, in critical times like these, fake news machines may put lives at risk and even more pressure on the health system, leading to its collapse (Naeem, Bhatti, and Khan 2020; Ortega and Orsini 2020).

Amid the COVID-19 outbreak, some frequent questions about food safety have been asked, such as: How to receive food and raw materials? What precautions should be taken in preparing food? Can coronavirus spread through food? International organizations, including WHO (2020c), CDC (2019), FDA (2020c), and EFSA (2020), indicated that to date there is no evidence that the COVID-19 virus can be transmitted via food or food packaging. Thus, SARS-CoV-2 is not a foodborne disease (Rizou et al. 2020; Shahidi 2020) and epidemiological evidence has been showing the spread of COVID-19 is mainly from person-to-person by droplets and aerosols (Jayaweera et al. 2020).

Nevertheless, the protocols already established for food safety in food retail establishments were reinforced in several countries in this period of COVID-19 pandemics. As in Brazil, the majority of regulatory agencies around the world follow the guidelines recommended by WHO to ensure that the food consumed is safe and hygienic (WHO 2020b). In addition, FAO (2020) encourages prevention measures at the manipulation or consumption of meat from wild animals.

In any case, there has become an increasing awareness of food hygiene importance which may create a positive impact

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in the control of foodborne diseases (Bosch et al. 2018; ANVISA 2020). Aside from those specific health and safety aspects, food has a social function that brings us together as a society. Food habits and feeding patterns change over time according to social dynamics, and the risk posed by COVID-19 is likely to impact shopping, intake, and food choice, as well as to affect how we share meals both inside and outside the house (Bracale and Vaccaro 2020; Barros et al. 2019; Hobbs 2020). This review aims to discuss food safety in times of COVID-19, according to the current state of knowledge, exploring food- or waterborne-virus mode of transmission; its importance; major recommendations from regulatory agencies around the world; perceptions of good practices in food production during the pandemic outbreak; and post-pandemic perspectives.

Can SARS-CoV-2 affect the safety of food produced?

Virus transmission via food

For a long time, humans have suffered from many health problems caused by bacterial or viral infections. As bacteria are a major cause of foodborne diseases, studies focus more on food pathogenic and spoilage bacteria, with less attention being paid to viruses (Ceylan, Meral, and Cetinkaya 2020).

A wide variety of viruses can be transmitted by food, and the most reported to be involved in foodborne outbreaks are the Norovirus, Rotavirus, and Hepatitis A viruses (Neethirajan et al. 2017). These viruses can be single or double stranded DNA or RNA and have the ability to contaminate water or food as a common feature (Neethirajan et al. 2017). However, other viruses such as hepatitis E, astrovirus, enterovirus, coronavirus, and adenovirus can also be transmitted by food (O'Shea et al. 2019). O'Shea et al. (2019) also mention that coronavirus is associated with food production, preparation, and contamination, but not referring specifically to the genetically mutated SARS-CoV-2.

Over the past few years, foodborne viruses have become a particular concern for the food industry and also to regulatory agencies; however, it should be noted that only recent infections caused by foodborne viruses started to be routinely controlled in surveillance systems (Bosch et al. 2018).

Recent data have shown that, worldwide, about one in five cases of acute gastroenteritis resulting in diarrhea and vomiting is caused by norovirus (CDC 2018). In the United States, Norovirus remains the leading cause of foodborne disease outbreaks (Dewey-Mattia et al. 2018). In Europe, it is estimated that Norovirus is the main agent of foodborne diseases, with approximately 15 million cases and over 400 deaths per year (Velebit et al. 2019). In the Netherlands, Norovirus has been the most common pathogen causing foodborne outbreaks, followed by *Salmonella* and *Campylobacter* (Papapanagiotou 2017). In Brazil, Norovirus was the 5th most identified etiological agent in foodborne disease outbreaks between 2009 and 2018, preceded by *Escherichia coli*, *Salmonella spp*., *Staphylococcus aureus*, and coliforms (Ministério da Saúde 2018).

Considering the requirement for safe food production in any circumstance and the scenario of the COVID-19 pandemic experienced, developing more rapid analysis methods for virus detection in food proves to be important (Rizou et al. 2020). Studies such as these are relevant to understand the similarity of these emerging agents to viruses whose mechanism of action in food is already known. Thus, it is possible to answer whether preexisting food quality control tools are sufficient or whether new measures need to be implemented in new outbreaks or even epidemics/pandemics by viral agents.

It is important to note that the transmission of a virus depends on some factors, such as its interaction with the host and the environment outside the host (Rzezutka and Cook 2004). When outside their hosts, viruses are only inert particles that cannot multiply in food, water, or surfaces, and their associated risk depends greatly on their ability to maintain infectivity (Bosch et al. 2018). Virus survival can be affected by various environmental conditions, such as temperature, humidity, and pH (Rzezutka and Cook 2004).

Food contamination by a virus usually occurs in the following ways: during the production process, which may involve contamination of the water in which shellfish grows or contamination of the water used to wash fruit after harvest; by infected food handlers who have not observed good handling hygiene practices; or by consumption of products of animal origin containing a zoonotic virus (Velebit et al. 2019).

The first and second mean of infections are predominantly transmitted via the fecal-oral route through the ingestion of contaminated food and/or water, or through a secondary route of infection and/or by person-to-person contact, followed by an invasion of the intestinal epithelium cells, and replication at the same site or another site in the body (Bosch, Pinto, and Guix 2016). Zoonotic foodborne infection occurs when products from an infected animal are consumed, such as meat and organs; however, this is a very rare way of virus transmission (Velebit et al. 2019).

Can COVID-19 be considered a foodborne disease?

Past outbreaks related to coronaviruses, particularly MERS-coronavirus (MERS-CoV) and SARS-coronavirus (SARS-CoV), have shown that food is not a relevant transmission route for these viruses and there is no evidence to conclude that SARS-CoV-2 is different in this respect (EFSA 2020). Thus, it is not yet certain that the consumption of food contaminated with SARS-CoV-2 causes infection and transmission (Jin et al. 2020), as, according to U.S. Food and Drug Administration (FDA), there is no scientific evidence to indicate that the virus can be transmitted by food products. However, some authors have reported that SARS coronaviruses can be spread to humans through the consumption and preparation of food for animals or wild animals (Neethirajan et al. 2017; Bosch et al. 2018).

According to the Centers for Disease Control and Prevention (CDC), the transmission of SARS-CoV-2 through food and food packaging has not been identified as a risk factor for the disease. However, it may be possible for a person to acquire COVID-19 by touching a surface or

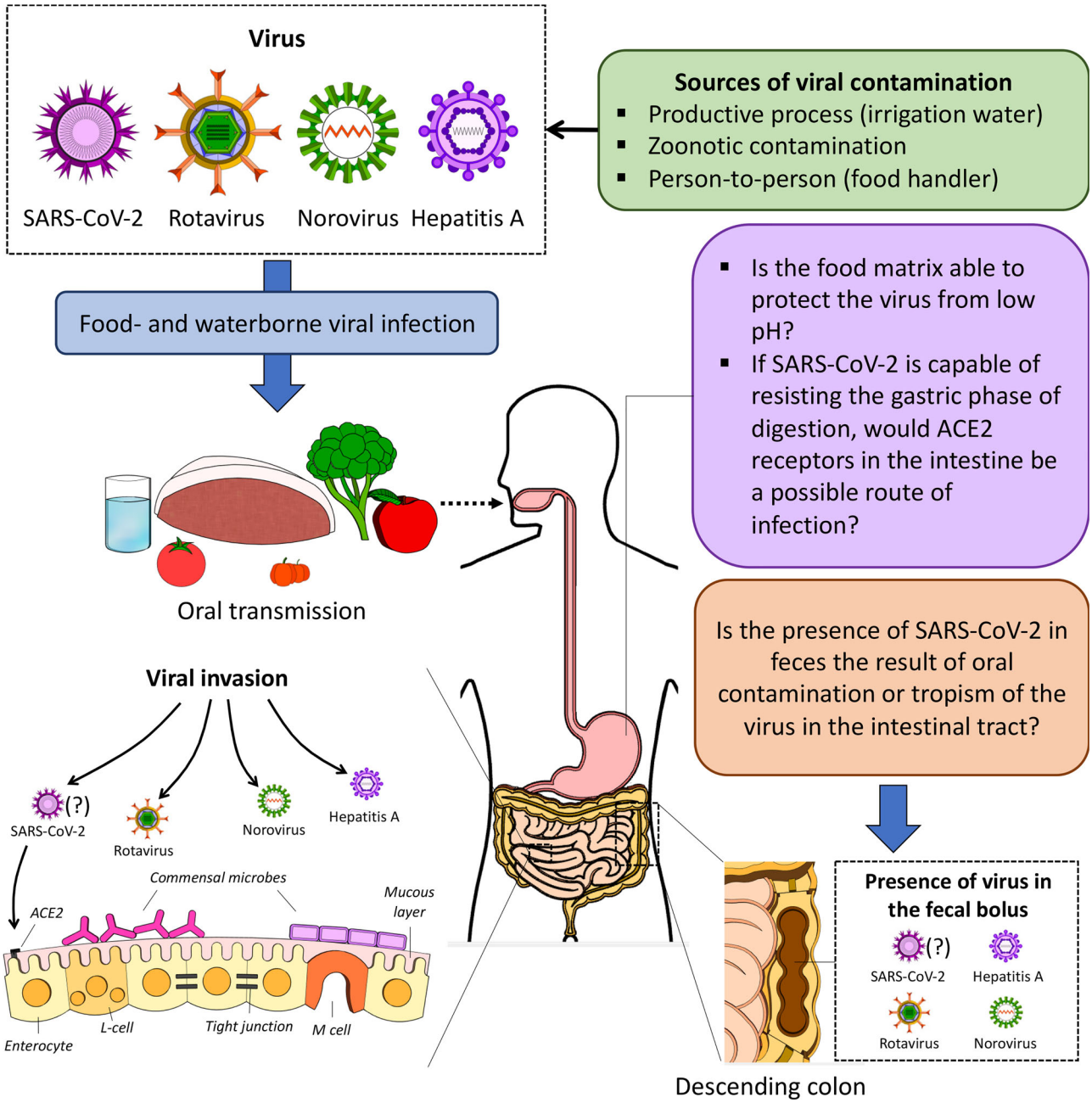

Figure 1. The intestinal mechanism of food and waterborne viruses and uncertainty about SAR-CoV-2. ACE2, angiotensin-converting enzyme 2; SARS-CoV-2, severe acute respiratory syndrome.

object contaminated by the virus and then touching their own mouth, nose, or possibly their eyes (CDC 2019). The WHO recommends that the food industry reinforce the hygiene measures and train food handlers on food hygiene to eliminate or reduce the risk of food and its packaging materials being contaminated with the virus by food workers (WHO 2020c).

This hypothesis can be supported by a recent study that indicated that aerosol and fomite transmission of SARS-CoV-2 is plausible, considering that the virus can remain viable and infectious in aerosols for hours and on surfaces up to days (Doremalen et al. 2020).

Indeed, there are significant ongoing studies to answer for how long SARS-CoV-2 could potentially remain in the air and on different material surfaces, and new knowledge elements arrive daily (Biryukov et al. 2020; Carraturo et al. 2020; Fears et al. 2020; Kampf et al. 2020; Kasloff et al. 2020; Ren et al. 2020). Doremalen et al. (2020) reported that viable SARS-CoV-2 could remain in the air for up to 3 hours, and it was detected up to 72 h on plastic and stainless steel, and there was no viable virus after 24 h and 4 h on cardboard and cooper surfaces, respectively. Other recent data have assessed the stability of SARS-CoV-2 on surfaces and its stability at different temperatures and pH. Chin et al. (2020) stated that COVID-19 was more stable on smooth surfaces, with detection of the virus on stainless steel and plastic on the 4th day but not on the 7th day. Also, the study showed that the virus is highly stable at 4 °C; however, it is sensitive to heat at 70 °C incubation temperature, where the virus was inactivated in 5 min and it is extremely stable at

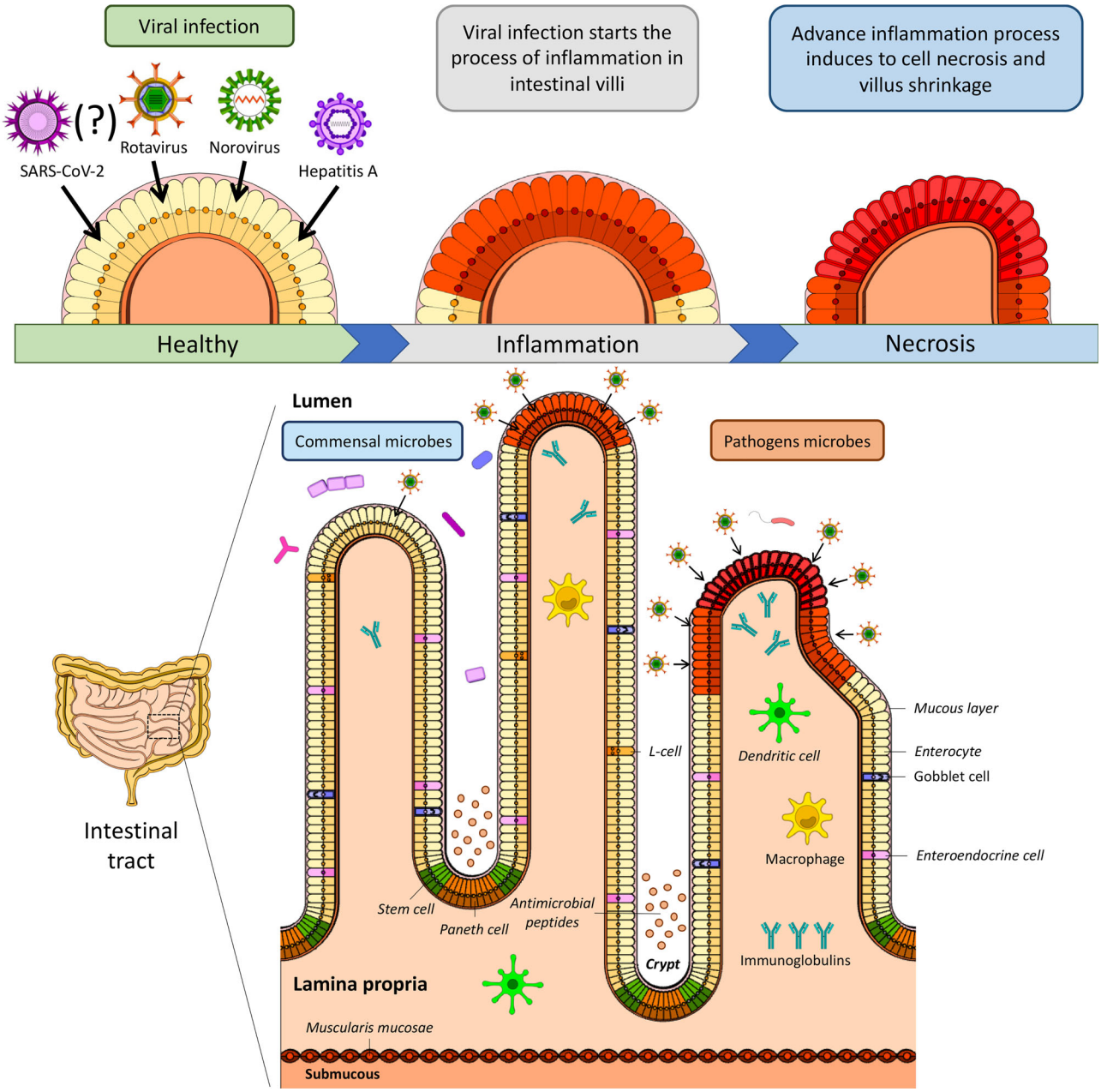

Figure 2. The inflammatory process of the intestinal tract induced by viruses. L-cell, enteroendocrine L-cell; SARS-CoV-2, severe acute respiratory syndrome virus.

room temperature at pH between 3 and 10. Thus, the best way to avoid SARS-CoV-2 is by its inactivation, which can be efficiently reached by surface disinfection procedures, using 0.1% sodium hypochlorite, 0.5% hydrogen peroxide, or 62–71% ethanol within 1 minute (Kampf et al. 2020). Regarding the temperature, it seems that cooking temperature (>70 °C) is enough to inactivate the virus, although, transmission from frozen food might be possible (Rizou et al. 2020). Like the SARS-CoV and MERS coronaviruses, SARS-CoV-2 appears to be stable at 4 °C and is expected to behave similarly at freezing temperatures, which means it can remain infectious at −20 °C for up to 2 years (Rizou et al. 2020). However, it should be noted that even if a food is contaminated with the virus, the possibility of increasing the viral load in this environment to the amount needed to cause disease is negligible, since the virus is not able to replicate in food (Franco, Landgraf, and Pinto 2020). Thus, it is unlikely that food containing the virus on its surface will cause infection through ingestion unless the viral particles are transferred to the hands of food handlers and then to their mucous membranes in the eyes, nose, or mouth (Franco, Landgraf, and Pinto 2020).

Another important aspect to be discussed is that, recently, the prospect of fecal-oral transmission of SARS-CoV-2 has been raised, since the virus has been detected in the feces of COVID-19 patients (Holshue et al. 2020). Walls et al. (2020) reported that SARS-CoV-2 uses angiotensin-converting enzyme 2 (ACE2) as a receiver for entry into humans and can spread effectively, considering the numerous SARS-CoV-2 transmissions from human to human reported to date (Walls et al. 2020). In addition, the viral receptor ACE2 was found to be abundantly expressed in

gastrointestinal epithelial cells (Xiao et al. 2020). These findings indicate that the virus can exist and replicate in the digestive tract, but it is not clear whether eating SARS-CoV-2 contaminated food causes infection (Wong, Lui, and Sung 2020; Mungroo, Khan, and Siddiqui 2020). According to Xiao et al. (2020), fecal-oral transmission could be an additional route for viral spread. Prevention of fecal-oral transmission should be taken into consideration to control the spread of the virus (Xiao et al. 2020). For this, strict precautions must be observed when handling the stool of coronavirus infected patients, as well as proper disinfection of hospital sewage. Another important point is the frequent and adequate hygiene of the hand (Yeo, Kaushal, and Yeo 2020).

Figures 1 and 2 demonstrate the mechanisms of intestinal infection and the inflammatory process of food and waterborne viruses and the uncertainties about SAR-CoV-2. As shown in Figure 1, the body's innate defense is the first line of protection for the human organism and includes physical (e.g., mucous membranes), chemical (e.g., gastric juices), cellular (e.g., phagocytosis), modular defenses (e.g., interferon), and body responses (e.g., inflammation). Furthermore, in relation to protection against potential enteric pathogens, the intestinal tract has an abundant microbiota that competes with the pathogens for space and nutrients (O'Shea et al. 2019).

According to Breban (2016), the gut microbiota is a set of microbes formed mainly by bacteria that colonize the gastrointestinal tract in numbers notably greater than cells of the human body. Besides, it is directly related to the host's health, as well as to the aggravation of diseases influenced by a wide range of microorganisms, which makes it the most important environmental agent (Thakur et al. 2016; Xavier-Santos et al. 2020). On the other hand, studies have demonstrated that a disease variety is associated with the prevalence of pathogen microbes in the gut tract, originating a process known as dysbiosis (Ballan et al. 2020; Bhat, Kapila, and Kapila 2020; Belizário and Faintuch 2018). It is associated with an immuno-intestinal mechanism that influences the growth and translocation of pathogenic microorganisms into the bloodstream (Peterson and Artis 2014; Taddei, Feferbaum, and Sardá 2018).

As shown in Figure 2, Rotavirus, Norovirus, and Hepatitis A infect the cells of the intestinal barrier and initiate an inflammatory process that induces the process of cell necrosis and villus shrinkage. Immune system cells are activated after viral infection and antimicrobial peptides are synthesized in the crypt region to control the inflammatory process that exposes the fragility to secondary infections (Mowat and Agace 2014). Some patients with COVID-19 present diarrhea (Li et al. 2020); however, it is not yet known whether this symptom is related to medication (use of antibiotics, for example) to treat the disease or to some local effect of the virus on the intestinal mucosa.

The presence of SARS-CoV-2 in the feces of infected patients is intriguing and suggests oral infection as a possible route of entry for it. In this case, contamination could occur by binding the viral particles to the cellular receptors of ACE2 present in the enterocytes and colonocytes. However, for this route to be effective, viral particles must remain infectious even after overcoming the hostile environment of stomach acids, bile, and proteolytic enzymes (Goswami and Kulka 2006). According to Infusino et al. (2020), based on intestinal findings, it is possible to assume that viral replication in the intestine determines an exponential increase in the viral load on the digestive mucosa. This mechanism can lead to an alteration of the intestinal microbial flora and an increase of the membrane permeability causing important consequences for the immune system, which could lead to strong production of cytokines. Another possibility of access to the intestine would be due to coronavirus tropism for the small and large intestine of patients affected by COVID-19. Tissue tropism was demonstrated by Leung et al. (2003) for the SARS-CoV, causing the SARS outbreak.

Major recommendations from regulatory agencies around the world for safe food production in pandemic times

The new global panorama regarding the COVID-19 pandemic has made the main regulatory agencies establish guidelines ensuring food safety for consumers (WHO 2020b). Food safety is defined as "the assurance that food will not cause harm to consumers when prepared and/or eaten in accordance with its intended use" (WHO 2009). Its importance regarding good hygiene practices must be emphasized and should reach everyone, involving intermediaries from the food industry to the consumer (Shahidi 2020).

As stated above, the consensus, to date, is that the transmission of COVID-19 from food or food packaging is highly unlikely (WHO 2020c). However, reinforcement in personal and food hygiene practices is necessary. These actions seek to eliminate or reduce the risk of contamination with the virus on food surfaces, countertops, and food handling utensils, as well as in packaging materials (WHO 2009; Kampf et al. 2020). In this sense, several countries have adopted the measures recommended by the WHO.

The protocols established for food security in food retail establishments must be reinforced in this period of COVID-19 pandemics. The main procedures are: follow the processing steps (cleaning, separating, cooking, and cooling); wash, rinse, and sanitize all surfaces in contact with food after use, and frequently disinfect the surfaces most touched by employees or customers, in addition to the entire installation (floors, counters, and other areas); control time-temperature in food distribution and storage; ensure adequate food storage; avoid cross-contamination; encourage frequent proper hand hygiene (use soap and water for at least 20 seconds), especially after using the bathroom, blowing the nose, coughing or sneezing, after touching high-touch surfaces (such as a doorknob) and before eating. It is important to note that if soap and water are not readily available, the use of alcohol-based hand sanitizer (minimum of 60% alcohol) can be used as an alternative (FDA 2020a).

Table 1. Publications from food regulatory agencies in different countries on food security and the COVID-19 pandemic situation.

Countries	Regulatory agency	Type of publication	Publication date	Title	References
WHO	Food and Agriculture Organization of the United Nations (FAO)	Document	April 7, 2020	COVID-19 and food safety: guidance for food businesses	(WHO, 2020c)
European Union	European Commission Directorate-General for Health and Food Safety	Document	April 8, 2020	COVID-19 and food safety Questions and Answers	(European Union 2020)
Brazil	Agência Nacional de Vigilância Sanitária (ANVISA)	Document	June 5, 2020	Documento orientativo para produção segura de alimentos durante a pandemia de Covid-19	(ANVISA, 2020)
United States	Food and Drug Administration (FDA)	Document	April 21, 2020	Best Practices for Retail Food Stores, Restaurants, and Food Pick-Up/ Delivery Services During the COVID-19 Pandemic	(FDA, 2020a)
China	Centre for Food Safety (CFS)	Document	March 22, 2020 May 7, 2020 May 18, 2020	Precautions for Food Delivery Agents on the Prevention of COVID-19. Food Safety and Hygiene Advisory for Food Premises on the Prevention of COVID-19. Food Safety Advice on Prevention of COVID-19 and FAQs	(CFS, 2020a, 2020b, 2020c)
United Kingdom	Food Standards Agency (FSA)	Web page	June 26, 2020	Support for businesses and self-employed people during coronavirus	(FSA, 2020)
Canada	Canadian Food Inspection Agency (CFIA)	Web page	May 11, 2020	Coronavirus disease (COVID-19) and food safety	(CFIA, 2020)
Australia New Zealand	Food Standards Australia New Zealand (FSANZ) Safe Work Australia (SWA)	Web Page Document	April 2020 May 1, 2020 May 26, 2020	Novel Coronavirus and Food Safety Transmission of COVID-19 by food and food packaging Cleaning to prevent the spread of COVID-19	(FSANZ, 2020a, 2020b; SWA, 2020)
India	Food Safety and Standards Authority of India (FSSAI)	Document	June 7, 2020	Food Hygiene and Safety guidelines for Food Businesses during Coronavirus Disease (COVID-19) Pandemic	(FSSAI, 2020)
Nigeria	National Agency for Food and Drug Administration and Control (NAFDAC)	Document	June 5, 2020	Advisory for food businesses on safe food practices during the COVID-19 pandemic	(NAFDAC, 2020)
Argentina	Ministerio de Agricultura, Ganadería y Pesca (MAGyP)	Document	***	Lineamientos de buenas prácticas para la producción agropecuaria para el COVID-19	(MAGyP, 2020)
Portugal	Direção-Geral da Saúde (DGS) Autoridade de Segurança Alimentar e Económica (ASAE)	Document Web page	May 8, 2020 May 2020	COVID-19: Procedimentos em estabelecimentos de restauração e bebidas Pode o novo tipo de coronavírus ser transmissível através da Comida?	(ASAE, 2020; DGS, 2020)

Providing social distance between customers in the food distribution stage is also necessary to reduce the risk of infection. Some measures are interrupting operations in which customers use common utensils or dispensers, encourage spacing between customers in queues according to applicable state or local requirements, discourage customers from entering pet establishments, except service animals (FDA 2020a).

In the case of food pick-up and delivery, other food safety practices should be highlighted, such as cleaning and disinfecting the vehicle, equipment, utensils, and package used in transporting foods; properly transporting hot and cold food, respecting the time-temperature binomial; keeping foods separated (e.g., raw from cooked), avoiding cross-contamination; and maintaining social distance in the areas of food collection and delivery (FDA 2020a).

Personal hygiene for employees is also emphasized by regulatory agencies, where hand hygiene stands out as an important one, as mentioned. Besides that, the recommendation is to use gloves when working with ready-to-eat foods, cover the mouth and nose with a disposable tissue when coughing and sneezing, and avoid touching eyes, nose, and mouth (FDA 2020a).

During the COVID-19 pandemic period, it is important that food workers are in good health and that regular examinations are carried out, especially if there is any suspicion or symptom of COVID-19. If a collaborator is considered a suspicious case, he must inform the company to be removed from his activities and carry out the isolation for at least 14 days and be evaluated again after this period. Besides, people who have contact with this employee at the workplace or home should be advised (WHO 2020c). Some countries are also following the recommendations of the Ministry of Health and the Ministry of Labor, which have some recommendations for the general population and various work segments (DGS 2020). In this way, the population can have as much information about the health of the worker and what measures need to be taken during the pandemic.

Currently, there is a discussion about the high risk of contamination by COVID-19 among workers in food industries, such as meat, poultry, and seafood processing plants. The factors related to a raised risk of exposure to SARS-CoV-2 in meat and seafood processing workers are prolonged closeness to coworkers (e.g., 1.8 m for $\geq$15 minutes), for long periods (8–12 h shifts in meat processing and 8–16 h shifts in seafood processing); shared workspaces; shared transportation; congregate housing, and frequent community contact with fellow workers (CDC 2020b; Waltenburg et al. 2020). According to Waltenburg et al. (2020), there were 16,233 cases and 86 deaths of COVID-19 among workers at 239 meat and poultry processing facilities located in 23 U.S. states from April to May 2020. The major concern is that processing facility workers can rapidly affect large numbers of persons, as CDC and FDA provide guides on how these industries should deal with the COVID-19 (CDC 2020b; Waltenburg et al. 2020).

It is important to emphasize that, as far as it is known, the risk of infection by the virus is not directly related to the contact with food, but rather to working conditions. The processing stations and other areas in busy factories provide greater proximity between workers, with prolonged contact and the performance of activities that increase exposure to the infectious virus. This may happen due to the contact with numerous contaminated surfaces or objects, in addition to the possible presence of droplets and aerosols in the air due to coughing, sneezing, or conversation. There are also seasonal workers in the fish and seafood industry who have an increased risk of infection due to crowding in community housing and onboard vessels (CDC 2020b). Agricultural industry workers are also subjected to these same risks (CDC 2020a). Considering the above, it is evident the need for periodic screening and monitoring of workers, removing those sick or presenting any symptom, testing asymptomatic workers with and without exposure to COVID-19, implementing social distancing, the use of masks, face shields, and other personal protective equipment, proceeding and following good practices of personal hygiene and manufacturing practices, training, and guidance for workers, among other actions (CDC 2020b).

Although some countries still do not have official food safety documents during the COVID-19 pandemic, departments and/or food regulatory agencies have sought to keep the population and food business owners informed. It was made via their websites, where official documents from WHO, FDA, CDC, and others can be accessed. In addition, many recommendations already used in food production remain valid and their use is encouraged with greater rigor.

Table 1 lists documents and recommendations from different countries and major world organizations on food security during the COVID-19 pandemic.

In summary, all countries have adopted the main WHO recommendations, emphasizing the proper hygiene of packaging and surfaces, adequate social distancing (ranging from one to two meters), the use of individual protection equipment, the health of employees, and proper food preparation (WHO 2020c). With the increase in the rigor of hygiene practices that are being adopted during food production due to COVID-19, the risk of contracting several foodborne diseases can decrease considerably (ANVISA 2020).

It is estimated that, annually, there are 600 million cases of foodborne diseases with 420 thousand deaths. The main microorganisms involved in diseases are *Salmonella*, *Campylobacter*, and Enterohaemorrhagic *Escherichia coli*, besides *Listeria monocytogenes* and *Vibrio cholerae* (WHO 2020d). The Public Health England reported that notifications of infections in the February-March period dropped from 930 to 394 for *Campylobacter*; from 93 to 67 for *Salmonella*; and from 204 to 38 for norovirus. Furthermore, England and Wales reported 1700 foodborne infection cases between January and May 2020, while this number was much higher in the same period in previous years: 2674 in 2019 and 3071 in 2018 (Food Safety News 2020). A similar tendency was also present in Ireland, Finland, and Australia (Australian Institute of Food Safety 2020; Canadian Institute

of Food Safety 2020; Food Safety News 2020). Nevertheless, it is noteworthy that apart from the major hygiene care efforts, another possible cause for these reduced notifications might be the focus on COVID-19. The pandemic results in lower laboratory tests and notifications of other diseases, such as foodborne, especially in mild cases of gastroenteritis (Food Safety News 2020). Thus, although these data point to a reduction in the cases of foodborne diseases, it is necessary to evaluate it further in the future.

Amid the WHO recommendations adopted by several countries on food security during the COVID-19 pandemic, regulatory agencies also encourage the use of their Good Manufacturing Practice manuals and the HACCP System (Hazard Analysis and Critical Control Point) through the safety measures already adopted in the manufacture and handling of food, the sanitary and nutritional quality of the food can be guaranteed. Therefore, compliance with Good Practices and the use of Standardized Operating Procedures (SOPs) reduce the risk of spreading COVID-19 among professionals working in the food production chain (ANVISA 2020; FSA 2020; NAFDAC 2020).

Food safety perceptions and practices in times of pandemic – has anything changed?

Emerging trends indicate that viruses play an important role in foodborne diseases. Intrinsic and extrinsic food factors and food processing technologies could be used to control/inactivate enteric food viruses (Bosch et al. 2018). Good food hygiene and personal hygiene, especially hand washing, are essential to help minimize the spread of viruses within the food chain (O'Shea et al. 2019). Since foodborne viruses tend to be more resistant to physical and chemical treatments than bacteria, their control poses a challenge to the food industry (O'Shea et al. 2019). Handling difficulties and technical issues have restricted research to test and detect viruses in several food samples (Shukla et al. 2016). Innovative approaches to the detection of food-borne viruses in food products are being developed, particularly in relation to existing methodologies, which may provide new insights into research and development strategies on the current state of virus research (Shukla et al. 2016). Concerning food services, especially in restaurants, the food will certainly be as tasteful as it was prior to COVID-19; however, the manner in which it will come to you and the way restaurants work will be different (Freitas and Stedefeldt 2020; Hensel and Kuhn 2020; Hobbs 2020).

Digital innovations allowed those businesses to continue operating during the pandemic and some experts say that delivery and takeout will probably grow even after restaurants reopen. They also say that safety and sanitation aspects are going to be much more important from now on. This might include tamper-proof packaging; antimicrobial materials; and more effective store/venue cleaning procedures, as well as safe food handling practices reorientation (Crick and Crick 2020; Hensel and Kuhn 2020; Joglekar, Parker, and Srai 2020; Dannenberg et al. 2020).

It is important to note that good food safety practices are always recommended to minimize the risk of foodborne diseases; however, with the emergence of the COVID-19 pandemic, a new behavior of the food sector and consumers has been developed in relation to these preventive methods. Therefore, some questions raised about those changes are necessary (Rizou et al. 2020). The media played an important part in alert and motivate the consumers to think about possible hazards related to the transmission of SARS-CoV-2, leading to an improvement in the hygiene practices and demand for safe food, which influences changes in the safety practices in food production (Freitas and Stedefeldt 2020).

The changes in food hygiene in the context of COVID-19 can generate a positive impact in the control of foodborne diseases, since, according to Bosch et al. (2018), hand washing and strict compliance of hygienic measures are essential to control and prevent foodborne diseases. Furthermore, good hygiene practices in food are imperative in order to keep food safe. According to Djekic et al. (2021), the food safety systems during the COVID-19 pandemic were implemented in a stricter way, by promoting preventive measures within their operating facilities. For that, the companies applied more restrictive hygiene procedures and also purchased more PPEs. However, regarding emergency plans, less than half of the industries made plans for pandemics and health issues. Even though a better understanding of the particularities that led to greater care with food hygiene is hoped in the post-pandemic scenario, the best way to avoid future outbreaks is through prevention. For that, the use of food safety culture is proposed and should be considered in addition to more traditional risk factors, as it is considered useful as part of outbreak investigation (Griffith, Livesey, and Clayton 2010). When the industry maintains a food safety culture, the operators and staff know the risks associated with the produced products they know why managing the risks is important, which leads to the successful management of those risks (Powell, Jacob, and Chapman 2011).

Companies should rethink their operational priorities and apply what was learned from the pandemic, using the new knowledge and experience as long-term strategies. They also need to create new ways to inform employees or processors about good hygiene practices, aiming to create a food safety culture, with conscious and effective hygiene measures. Some strategies to be developed and implemented as a global approach to modernize the food safety system have been proposed by the FDA (2020b). Among the key aspects of the so-called "blueprint" are the tech-enabled traceability, smarter tools and approaches for prevention and outbreak response, new business models and retail modernization, and food safety culture (FDA 2020b). According to the FDA (2020b), providing a digital, traceable, and safer food system will assist the nations of the world work to keep a resilient and stable food supply for their consumers. Thus, by implementing those modernizations and after learning from the challenges imposed by the virus, it is expected that the improvement of good food production practices, as well as people's attitudes toward hygiene, will remain.

This pandemic strongly exposed the fragilities of the food system, as well as the challenges related to health and agri-food sectors. For example, farmers' access to markets, whether for purchasing inputs or selling their products, has been hampered due to the restrictions imposed by the virus, such as border closures, trade restrictions, and confinement measures. In addition, there was a disruption of the national and international food supply chain, which reduces access to healthy, safe, and diversified diets (ILO et al. 2020). COVID-19 has imposed a real-life experimental laboratory for new ideas to all food sectors, which can accelerate the creation of new tools and innovative strategies like never before. In the coming years, all those changes should be evaluated to understand what works – or not – and why (Hawkes 2020; Nestle 2020; Ranta, Mulrooney, and Ichujo 2020; Gemmill-Herren 2020).

Perspectives

With the course of history, humanity has gained relevant learning from the epidemics and pandemics experienced, which can be used to face the current COVID-19 pandemic. Some examples are the attention given to the need for natural ventilation or at least air renewal through filters in buildings, expansion of sewage networks, improvement of personal hygiene habits, and greater attention to the microbiological safety of drinking water and food. For these gains to be achieved, many lives were lost in major outbreaks of cholera (Reyburn et al. 2011), yellow fever (Romano et al. 2014), Spanish flu (Kilbourne 2006), smallpox (MacIntyre et al. 2018), polio (Gregory et al. 2012), among others, and more recently SARS, MERS, and COVID-19 (Antunes et al. 2020).

Although science has advanced significantly and brought the development of many drugs and vaccines, the phenomenon of globalization has provided a network of connections between citizens across the globe that facilitate the spread of diseases. In this way, diseases that were formerly controlled have spread again, driven, among other factors, by anti-vaccine movements. Among these vaccine-preventable diseases are tetanus, diphtheria, hepatitis B, whooping cough, tuberculosis, and haemophilus influenza type B (Bugvi et al. 2014; Khan et al. 2020), in addition to measles and polio (Sousa et al. 2020). Despite being recognized as one of the most successful public health measures, vaccination started to be perceived by some people as unsafe and unnecessary (Dubé, Vivion, and MacDonald 2015), making it urgent to reeducate the population to raise awareness of the importance of participating in immunization campaigns, including that against SARS-CoV-2.

The selective pressure on microorganisms, facilitated by the indiscriminate use of antibiotics, also as growth promoters in animal husbandry systems, favors the occurrence of natural DNA/RNA mutations in microorganisms. There is a growing concern over the transmission via the food chain of microorganisms resistant to the antimicrobial substances commercially available (Singer et al. 2003). The speed of discovery, safety assessment, and large-scale production of drugs and vaccines is not able to keep up with the speed of transmission of new mutations in viruses, bacteria, or fungi responsible for diseases in humans, including foodborne diseases.

Another activity of great biological risk is the existence of wet markets, which are held in China and some other countries (Aguirre et al. 2020) and which basically market a variety of fresh foods such as, for example, fish, livestock, fruits, vegetables, and, on occasion, wild animals (Roe et al. 2020). In these environments, the poor conditions of hygiene and agglomeration of different native animals facilitate interspecies contamination, which can favor genetic mutations of microorganisms to the point of making them zoonotic. SARS-CoV-2 is 96% identical at the whole-genome level to a bat coronavirus (Zhou et al. 2020), confirming the ability of viral spillage from animals to cause severe diseases in humans (Wu et al. 2020).

COVID-19 imposed profound changes in human activities, such as: i) Social distancing: when crowding cannot be avoided, the WHO recommends a distance of at least 1 meter between the people to reduce the risk of infection when people speak, cough, or sneeze (WHO 2020a); ii) closure of places that may promote agglomerations: the social distance suggested by WHO contributed to the temporary closure of places considered non-essential for groups, such as schools, shops, and restaurants to prevent the propagation of the virus (Qureshi et al. 2021); iii) social isolation: the most adopted method to control the spread of SARS-CoV-2 (Schimit 2020); iv) personal hygiene: the use of soaps and hand sanitizers, in addition to becoming more widespread among the population, play a fundamental role in the maintenance of personal hygiene and combat to COVID-19 (Daverey and Dutta 2020).

In this sense, these changes previously mentioned contributed to a special impact on the out-of-home food business, including restaurants, mall food courts, and meal delivery. Although good production practices in times of the coronavirus pandemic obey the same basic rules already consolidated for other biological risks, it is known that the human factor is the main vector of potential contamination.

Acknowledgements

The authors are grateful to UNIRIO, UERJ, UNICAMP, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for their financial support.

Conflict of interest

The authors declare no conflict of interest.

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