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RESSIGNIFICAÇÃO DA IMPORTÂNCIA DE PRODUZIR ALIMENTOS SEGUROS E PREVENIR PERDAS PÓS-COLHEITA NA COVID-19: O CAQUI COMO ESTUDO DE CASO PARA ALÉM DA PANDEMIA

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"Se você não sabe aonde quer chegar, qualquer caminho serve."

(Lewis Carroll, Alice no País das Maravilhas.)

RESUMO

A pandemia de COVID-19 é uma emergência sanitária e humanitária, e lança ao mundo o desafio de repensar a dinâmica de produção, conservação e consumo de alimentos. Questões como garantia de produção de alimentos seguros, distribuição, perdas pós-colheita e insegurança alimentar são questões relevantes que se entrelaçam e abrem espaço para reflexões de estratégias que se sustentem no tempo. Neste estudo foi discutida a ressignificação da importância de produzir alimentos seguros e prevenir perdas pós-colheita na COVID-19 utilizando o caqui (*Diospyros kaki*) como estudo de caso para além da pandemia. As evidências científicas apontam que é possível produzir alimentos seguros utilizando as ferramentas de qualidade já preconizadas pré-pandemia e que o SARS-CoV-2 não se configura como um patógeno alimentar. Entretanto, especial atenção é necessária para garantir a distribuição eficiente e o combate ao desperdício de alimentos neste cenário ainda incerto e de aumento de insegurança alimentar (fome). Estas já eram questões inquietantes e que se agravaram na pandemia. O Brasil é o quinto maior produtor mundial de caqui (~171,000 ton/ano) e apresenta em torno de 20% de perda pós-colheita (2014-2019). As perdas médias anuais de produção, valor da produção e terra mal utilizada representam 35,1 mil toneladas, US$12 milhões, e 1673 hectares, respectivamente. Do ponto de vista nutricional, a perda do caqui representa a perda média de 6,6 bilhões de gramas de carboidratos, 1,6 bilhões de gramas de fibras alimentares, 7,2 bilhões de miligramas de vitamina C, 41,8 bilhões de microgramas de vitamina A, 4,5 bilhões de miligramas de cálcio e 54,8 bilhões de miligramas de potássio. Foi calculado o Potencial Nutriente para os nutrientes e o potencial de alimentação do caqui perdido. Vitamina C, vitamina A, cálcio, potássio, carboidrato e fibras têm o potencial para suprir as necessidades nutricionais de cerca de 264 mil, 163 mil, 12 mil, 31 milhões, 138 mil e 175 mil pessoas, respectivamente/ano. Destaca-se que a perda pós-colheita acarreta não só a perda econômica e de nutrientes, mas também em impacto ambiental negativo, uma vez que há desperdício de carbono, de terra e de água consumidos. Portanto, é urgente pensar em novas formas de conservação de caqui e de utilização do mesmo alinhada à agenda 2030. Uma das formas de conservação proposta neste estudo é o congelamento do caqui e concluiu-se que esta é uma estratégia viável para conservar a fração de carboidratos, proteínas e minerais por até um ano, enquanto a fração de voláteis e compostos fenólicos (80.51 para 13.19 mg GAE L^{-1}) e antioxidantes (IC_{50}) (1.39 para 19.01mg mL^{-1}) é reduzida neste tempo. O extrato em autoclave de caqui fresco e congelado apresentou efeito citotóxico (redução de 30-40% de Alamar Blue®) nas linhagens cancerígenas MCF-7 e MDA-MB-231, demonstrando que o potencial antitumoral foi dependente do tipo de extrato utilizado, independente do tempo de conservação do caqui. Como proposta tecnológica, neste estudo foram desenvolvidos e caracterizados molhos picantes à base de caqui (com e sem especiaria). O molho com especiarias se destacou no conteúdo de compostos fenólicos (358.94 μg GAE g^{-1}) e atividade antioxidante ($ABTS_{IC50}$ 2,976.31 μg mL^{-1}; $DPPH_{IC50}$ 1,944.88 μg mL^{-1}). Enquanto o molho sem especiarias se destaca no conteúdo de flavonóides totais (729.63 μg RE g^{-1}). O molho com especiarias apresentou composição volátil mais rica (31 compostos) do que o molho sem especiarias (19 compostos), associada ao aldeído, fenilpropanoide e compostos sesquiterpenos. O molho de caqui elaborado é um produto de baixa sofisticação tecnológica, e pode ser desenvolvido por agricultores familiares de forma a gerar renda e valorizar a produção de caqui.

Palavras-chave: sistema alimentar; perdas pós-colheita; compostos bioativos; pesquisa e desenvolvimento de produtos.

ABSTRACT

The pandemic of COVID-19 is a health and humanitarian emergency and offers the world the challenge of rethinking the dynamics of production, conservation, and food consumption. Issues such as guaranteed safe food production, distribution, post-harvest losses, and food insecurity are relevant questions that intersect and open the possibility of reflecting on strategies that can be sustained over time. This study discussed the resignification of the importance of producing safe food and preventing post-harvest losses in COVID-19 using persimmon (*Diospyros kaki*) as a case study beyond the pandemic. The scientific evidence points out that it is possible to produce safe food using the quality measures recommended pre-pandemic and that SARS-CoV-2 is not a foodborne pathogen. However, special attention is needed to ensure efficient distribution and combat food waste in this uncertain scenario of increasing food insecurity (hunger). These were already issues of concern and have become worse in the pandemic. Brazil is the world's fifth largest producer of persimmon (~171,000 tons/year) and has around 20% post-harvest loss (2014-2019). The average annual losses in production, production value, and land footprint represent 35,100 tons, US$12 million, and 1673 hectares, respectively. From a nutritional perspective, the loss of persimmon represents the average loss of 6.6 billion grams of carbohydrates, 1.6 billion grams of dietary fiber, 7.2 billion milligrams of vitamin C, and 41.8 billion micrograms of vitamin A, 4.5 billion milligrams of calcium, and 54.8 billion milligrams of potassium. Nutrient Potential was calculated for the lost persimmon's nutrients and feeding potential. Vitamin C, vitamin A, calcium, potassium, carbohydrate, and fiber meet the nutritional needs of about 264,000, 163,000, 12,000, 31 million, 138,000, and 175,000 people, respectively/year. Post-harvest loss causes economic and nutrient loss and negative environmental impact since there is a waste of carbon, land, and water consumed. Therefore, it is urgent to think of new ways of persimmon conservation and utilization in line with the 2030 agenda. One form of preservation proposed in this study is the freezing of persimmon, and it was concluded that this is a viable strategy to preserve the fraction of carbohydrates, proteins, and minerals for one year while the fraction of volatiles, phenolic compounds (80.51 to 13.19 mg GAE L-1) and antioxidants (IC50) (1.39 to 19.01mg mL-1) is reduced in this time. The autoclave extract of fresh and frozen persimmon showed a cytotoxic effect (30-40% reduction of Alamar Blue®) on MCF-7 and MDA-MB-231 cancer cell lines, demonstrating that the antitumor potential was dependent on the type of extract used, independent of the persimmon preservation time. As a technical proposal, we developed and characterized persimmon-based spicy sauces (with and without spices) in this study. The sauce with spice stood out in phenolic compound content (358.94 μg GAE g-1) and antioxidant activity (ABTSIC50 2,976.31 μg mL-1; DPPHIC50 1,944.88 μg mL-1). In comparison, the sauce without spices stands out in total flavonoid content (729.63 μg RE g-1). The sauce with spices presented a richer volatile composition (31 compounds) than the sauce without spices (19 compounds), associated with aldehyde, phenylpropanoid and sesquiterpene compounds. The persimmon sauce is a product of low technological sophistication, and can be developed by small farmers in order to generate income and valorize the production of persimmon.

Keywords: food system; post-harvest losses; bioactive compounds; research and development of products.

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1. Introdução

As evidências científicas apontam que é possível produzir alimentos seguros utilizando as ferramentas de qualidade já preconizadas pré-pandemia e que o SARS-CoV-2 não se configura como um patógeno alimentar. No entanto, é interessante mencionar que durante a pandemia foram observadas mudanças positivas na cultura de segurança de alimentos como o reforço na higiene pessoal, do ambiente e dos alimentos. Esta mudança de comportamento pode ter um impacto positivo no controle de doenças de origem alimentar num cenário pós-pandémico devido a uma maior percepção do risco (SHAHIDI, 2020; MARAGONI-SANTOS et al., 2022)

Para além da questão higiênicossanitária e de forma mais ampla, a COVID-19 trouxe à tona pontos críticos do sistema alimentar global, tornando ainda mais visível o desperdício e a perda de alimentos (GALANAKIS, 2020; RIZOU et al., 2020). Obstáculos impostos pela pandemia no setor agrícola, como escassez de mão de obra e maquinário; acesso limitado a à áreas de produção e mercados; interrupções na cadeia de suprimentos; e insuficiente manuseio pós-colheita parecem impactar de forma mais expressiva commodities perecíveis, como vegetais e frutas (KAHRAMANOĞLU et al., 2021; MUSIC et al., 2021). Segundo dados da literatura, a quantidade de frutas, verduras e legumes que nunca chegam aos consumidores finais devido às perdas pós-colheita varia de 10-15% nos países desenvolvidos e de 20-40% nos países em desenvolvimento como o Brasil (KAHRAMANOĞLU et al., 2021). Inserido no cenário de perda pós-colheita, destaca-se o caqui (*Diospyros kaki L.*), fruto com perda pós-colheita no Brasil de aproximadamente 20% (FAO, 2022). A perda pós colheita de caqui pode ser atribuída a uma série de fatores, dentre eles, alta perecibilidade associado ao rápido amolecimento da casca e da polpa; danos no armazenamento e transporte devido ao manejo inadequado; safra curta e intensa; e pouco investimento em desenvolver produtos culinários e tecnológicos à base de caqui de forma a tirar mais proveito dessa fruta (MATHEUS et al., 2020).

Para garantir a diminuição da perda de caqui ao longo da cadeia de produção de alimentos, há de se pensar em aprimoramento das técnicas de armazenamento, assim como no desenvolvimento do sistema de conservação e distribuição pós-colheita. Além disso, o caqui, devido a sua composição química e nutricional possui potencial para ser explorado em novas aplicações e em produtos de valor agregado nos diferentes setores industriais (LUCAS-GONZÁLEZ et al., 2018; MATHEUS et al., 2020, 2021; SANTANA et al., 2022). Importante ressaltar que tais estratégias para o aproveitamento do fruto e residuos do caqui

estão alinhadas com os preceitos da economia circular, focada na geração de valor dos recursos naturais e na redução da geração de resíduos de forma social, ambiental e economicamente sustentável (CONESA et al., 2019; SLORACH et al., 2019).

Os impactos da crise do COVID-19 são um desafio e uma oportunidade de ressignificar a produção de alimentos seguros, e da mesma forma, repensar estratégias que garantam a diminuição dos alimentos perdidos ao longo da cadeia de abastecimento alimentar, como por exemplo a partir do uso de estratégias de valorização de vegetais para geração de produtos de valor agregado. Neste sentido, esta dissertação está estruturada em cinco capítulos, escritos sob forma de artigo científico, que versam sobre produção de alimentos seguros e prevenção de perdas pós-colheita antes e depois da pandemia da COVID-19, utilizando o caqui como estudo de caso.

O primeiro capítulo intitulado: "***COVID-19 pandemic sheds light on the importance of food safety practices: risks, global recommendations and perspectives*** " É uma revisão bibliográfica que aborda a segurança alimentar em tempos de COVID-19, explorando o modo de transmissão de vírus de origem alimentar ou aquática; sua importância; principais recomendações de agências reguladoras em todo o mundo; percepções de boas práticas na produção de alimentos durante o surto pandêmico; e perspectivas pós-pandêmicas. Este artigo foi publicado pela revista **Critical Reviews in Food Science and Nutrition (ISSN: 1040-8398) (DOI: 10.1080/10408398.2021.1887078).**

O segundo capítulo intitulado: "***COVID-19 as a wake-up call to prevent post-harvest losses through the generation of value-added products: persimmon as a case study for before and beyond the pandemic"*** É uma revisão bibliográfica que discute as perdas pós-colheita e a geração de produtos de valor agregado como estratégia de prevenção antes e depois da pandemia da COVID-19, utilizando o caqui como estudo de caso. Além disso, aborda os desafios para estender a vida útil do caqui, reduzir as perdas e gerar produtos de valor agregado como uma oportunidade sustentável. Este artigo será submetido à revista **Trends in Food Science & Technology (ISSN: 0924-2244).**

O terceiro capítulo intitulado: "***Estimating the nutritional, economic, and environmental footprints of persimmon postharvest loss: a Brazilian case study"*** é estimada a quantidade de *land footprint*, nutrientes e valor monetário associado à perda de caqui no Brasil a partir dos dados obtidos na Organização das Nações Unidas para

Alimentação e Agricultura (FAO). Este artigo será submetido à revista **Waste Management (ISSN: 0956-053X).**

O quarto capítulo intitulado: "***Does freezing storage affect chemical components, volatile profile and potential biological activity of persimmon (Diospyros kaki)?"*** é um estudo que avalia o impacto do armazenamento do caqui sob congelamento durante um ano nos componentes químicos, perfil volátil e potencial atividade biológica do caqui (*Diospyros kaki*). Este artigo será submetido à revista **Journal of Food Processing and Preservation (ISSN: 1745-4549)**

Por fim, o quinto capítulo intitulado: "***Innovative spicy persimmon sauces development and characterization: opportunities to reduce post-harvest losses"*** é um artigo sobre o desenvolvimento e caracterização de um produto alimentar inovador, um molho picante à base de caqui. Os molhos foram produzidos em escala laboratorial e caracterizados quanto às suas propriedades microbiológicas, físico-químicas, ópticas, antioxidantes, conteúdo de fenólicos totais, conteúdo de flavonóides totais e perfil de compostos voláteis. Este artigo será submetido à revista **Journal of Culinary Science & Technology (ISSN: 1542-8052).**

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2. Objetivos

2.1. Geral

Discutir a importância de produzir alimentos seguros e prevenir perdas pós-colheita no contexto da COVID-19 utilizando o caqui (*Diospyros kaki*) como estudo de caso.

2.2. Específicos

- Desenvolver uma revisão sobre a produção de alimentos seguros em tempos de COVID-19, abordando doenças de origem alimentar e percepções de boas práticas na produção de alimentos no Brasil e no mundo durante a pandemia e perspectivas pós-pandêmicas;
- Desenvolver uma revisão sobre as perdas pós-colheita e a geração de produtos de valor agregado como uma estratégia de prevenção de perdas para além da pandemia da COVID-19, utilizando o caqui como estudo de caso;
- Estimar, com base em dados oficiais da FAO, o impacto nutricional, econômico e socioambiental da perda pós-colheita de caqui no Brasil;
- Caracterizar as propriedades físico-químicas, composição centesimal e perfil de minerais do caqui fresco e congelado por 12 meses;
- Isolar, identificar e quantificar os compostos voláteis no caqui fresco e congelado por 12 meses;
- Determinar o teor de compostos fenólicos e a capacidade antioxidante do caqui fresco e congelado por 12 meses;
- Investigar o efeito da citotoxicidade do caqui fresco e congelado por 12 meses em células de câncer de mama (MCF-7 e MDA-MB-231);
- Desenvolver um molho picante inovador à base de caqui;
- Avaliar as propriedades microbiológicas, físico-químicas, ópticas, antioxidantes, conteúdo de fenólicos totais, conteúdo de flavonoides totais e perfil de compostos voláteis dos molhos desenvolvidos a base de caqui.

Capítulo 1 – 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 coronavirus disease (COVID-19) is a global health and humanitarian emergency. To respond effectively to this pandemic, it is mandatory to reaffirm science in its different fields of study, including food safety area. Presently, we review food safety in times of COVID-19, exploring if the virus can be transmitted by food or water; recommendations from regulatory agencies around the world; perceptions of food hygiene practices during the pandemic; and post pandemic perspectives. The transmission of severe acute respiratory syndrome (SARS-CoV-2) by food was not confirmed till now. Hence, according to the present epidemiological evidence, SARS-CoV-2 is not a foodborne disease and is thought to spread mainly from person-to-person by droplets and aerosols. In any case, the protocols already established for food safety were reinforced in this period of COVID-19 in several countries based on the World Health Organization's recommendations. It is hoped, in the post-pandemic scenario, 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: Novel coronavirus; SARS-CoV-2 pandemic; food quality control; foodborne viruses; safe food handling; public health.

1. Introduction

In early 2020, we were confronted with COVID-19, a complex, systemic, and emerging infectious disease for which there is no specific treatment. No vaccine or pre-treatment or immunity has been found so far against the causative agent of COVID-19 - SARS-CoV-2. 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 frequently 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 (2020 b), CDC (2020), FDA (2020b), and EFSA (2020), indicated that to date - end of July 2020 - 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 this period of COVID-19 pandemics in several countries. 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 2020a). 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 in the control of foodborne diseases (Bosch 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 (Bracalo and Vaccaro 2020; Barros et al. 2020; 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 viruses 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.

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

2.1. *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 et al. 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 the 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 food 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 recently 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 about 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 2019).

The transmission of a virus depends on some factors, like 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 hand 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 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 et al. 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).

Figure 1 shows the intestinal mechanism of food- and waterborne viruses. 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) (O'Shea et al 2019). 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 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 et al. 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 et al. 2018). Hence, the interruption of this immuno-intestinal mechanism also may represent a possibility of translocation of virus food- and waterborne.

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 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, but 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.

2.2. Can COVID-19 be considered a foodborne disease?

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. In other words, according to the present epidemiological evidence, SARS-CoV-2 is not considered a foodborne disease (Shahidi 2020). 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). However, some authors have reported that SARS coronaviruses can be spread to humans through the consumption and preparation of food animal 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 object contaminated by the virus and then touching their own mouth, nose, or possibly their eyes (CDC 2020).

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 arriving daily (Biryukov et al. 2020; Carraturo et al. 2020; Fears et al. 2020; Kasloff et al. 2020; Ren et al. 2020; Kampf 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 room temperature at pH between 3 to 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. Then to prevent this contamination, hand washing after handling raw food is essential (Rizou et al. 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 et al 2020, Mungroo et al. 2020). According to Xiao et al. (2020), the 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).

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. The presence of this virus 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). 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 SARS outbreak.

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

The new global panorama about the COVID-19 pandemic 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 the consumer 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 transmission of COVID-19 from food or food packaging is highly unlikely (WHO 2020b). However, reinforcement in personal and food hygiene practices are 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).

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).

The 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 2020b). 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 fish, seafood and meat processing plants. 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 with working conditions. Processing stations and other areas in busy factories provide greater proximity between workers, with prolonged contact and performing 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 of periodical screen and monitoring workers, removing those sick or presenting any symptom, testing asymptomatic workers with and without exposure to COVID-19, implementing social distance, the use of masks, face shields, and other personal protective equipment, proceeding following good personal hygiene and manufacturing practices, training and guidance for workers, among other actions (CDC 2020b).

Although some countries do not yet 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 distance (ranging from one to two meters), the use of individual protection equipment, the health of employees and the proper preparation of food (WHO 2020b). 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).

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 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. So, compliance with Good Practices and the use of Standardized Operating Procedures (SOPs) can guarantee that the food produced is safe, reducing the risk of spreading COVID-19 among workers working in the food production chain (ANVISA 2020; FSA 2020; NAFDAC 2020).

4. Food safety perceptions and practices in times of pandemic - has anything changed?

The food sector is being significantly impacted by economic and social aspects due to the pandemics caused by COVID-19. The impacts include supply chains of ingredients, packaging, finished products, and equipment; sourcing, transportation of people, materials, and goods (Crew 2020). Some important safety practices must be taken by the food industry to eliminate any risk of contamination and to avoid the spreading of the virus between producers, vendors and consumers (Galanakis 2020). The food safety measures should be applied in all stages of the food chain, which comprises agricultural production; handling and storage; processing and packaging; distribution, and consumption. The most critical stage is the final one – consumption, which shows more potential sources of infection, as more people are involved (Rizou et al. 2020).

Concerning food services, especially restaurants, the food will certainly be as tasteful as it was prior to COVID-19, but the manner in which it gets to you and how the restaurant works 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, but with the emergence of the COVID-19 pandemic, a new behavior of the food sector and consumers about these preventive methods was developed, 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 the COVID-19 can generate a positive impact in the control of foodborne diseases, since, according to Bosch (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. It is hoped, in the post-pandemic scenario, a better understanding of the particularities that led to greater care with food hygiene and also those creative ways of informing about good hygiene practices are developed, aiming to create a food safety culture, with hygiene measures, conscious, and effective. Companies should rethink their operational priorities and apply what was learned from the pandemic, using the new knowledge and experience as long-term strategies. It is expected that after learning from the challenges imposed by the virus, the improvement in good food production practices, as well as people's attitudes towards hygiene, will remain.

COVID-19 has imposed on all food sectors a real-life experimental laboratory for new ideas. This pandemic strongly exposed food system fragilities as well as challenges to overcome and accelerates innovative tools and strategies like never seen before. In the next years all those changes should be evaluated to understand what is working - or not - and why (Corinna Hawkes, “COVID-19 and the promise of food system innovation”, June 18, 2020, https://www.ifpri.org/blog/covid-19-and-promise-food-system-innovation; Nestle 2020; Ranta, Mulrooney, and Ichujo 2020; Gemmill-Herren 2020)

5. Perspectives

With the course of history, humanity has gained relevant learning from the epidemics and pandemics experienced. Examples of this are attention 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, yellow fever, Spanish flu, smallpox, polio, among others, and more recently SARS, MERS, and COVID-19.

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 that compromise the "herd immunity" necessary to protect especially the most vulnerable people. Despite being recognized as one of the most successful public health measures, vaccination started to be perceived for some people as unsafe and unnecessary (Dubé, Vivion and MacDonald 2015), making it urgent to re-educate the population to raise awareness of the importance of participating in immunization campaigns, including against SARS-CoV-2 when the specific vaccine is available.

Selective pressure on microorganisms, facilitated by the indiscriminate use of antibiotics, including as growth promoters in animal husbandry systems, favors the occurrence of natural DNA/RNA mutations on 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 as well as 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 sell wild animals. 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 zoonoses. SARS-CoV-2 is 96% identical at the whole-

genome level to a bat coronavirus (Zhou et al. 2020), confirming the ability of viral spill-over from animals to cause severe diseases in humans (Wu et al. 2020).

This period of global pandemic promotes other challenges to be overcome, such as the reduced capacity to test food in the laboratories (due to the high demand on COVID-19 clinical tests), the greater risk of food fraud in the food supply chain and the countless questions from government, food industries, consumers and media (WHO, 2020a).

The COVID-19 imposed profound changes in human activities, with 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.

In this context, even though good food handling practices are being strictly followed and employees are periodically tested for COVID-19, customers themselves may be the sources of dissemination of SARS-CoV-2. In this way, restaurants will need to undergo profound readjustments, such as serving meals in open spaces, distancing between tables, and even installing physical barriers between tables and/or customers sharing the same table.

Conflict of interest

The authors declare no conflict of interest.

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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	Date publication	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 2020b)

European Union	European Commission Directorate-General for Health and Food Safety	Document	April 8, 2020	COVID-19 and food safety Questions and Answers	(EU 2020)
Brazil	Agência Nacional de Vigilância Sanitária (ANVISA)	Document	April 6, 2020	COVID-19 e as Boas Práticas de Fabricação e Manipulação de Alimentos	(ANVISA2020)
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)
Canadian	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	(NAFDA 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 Econômica (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)

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.

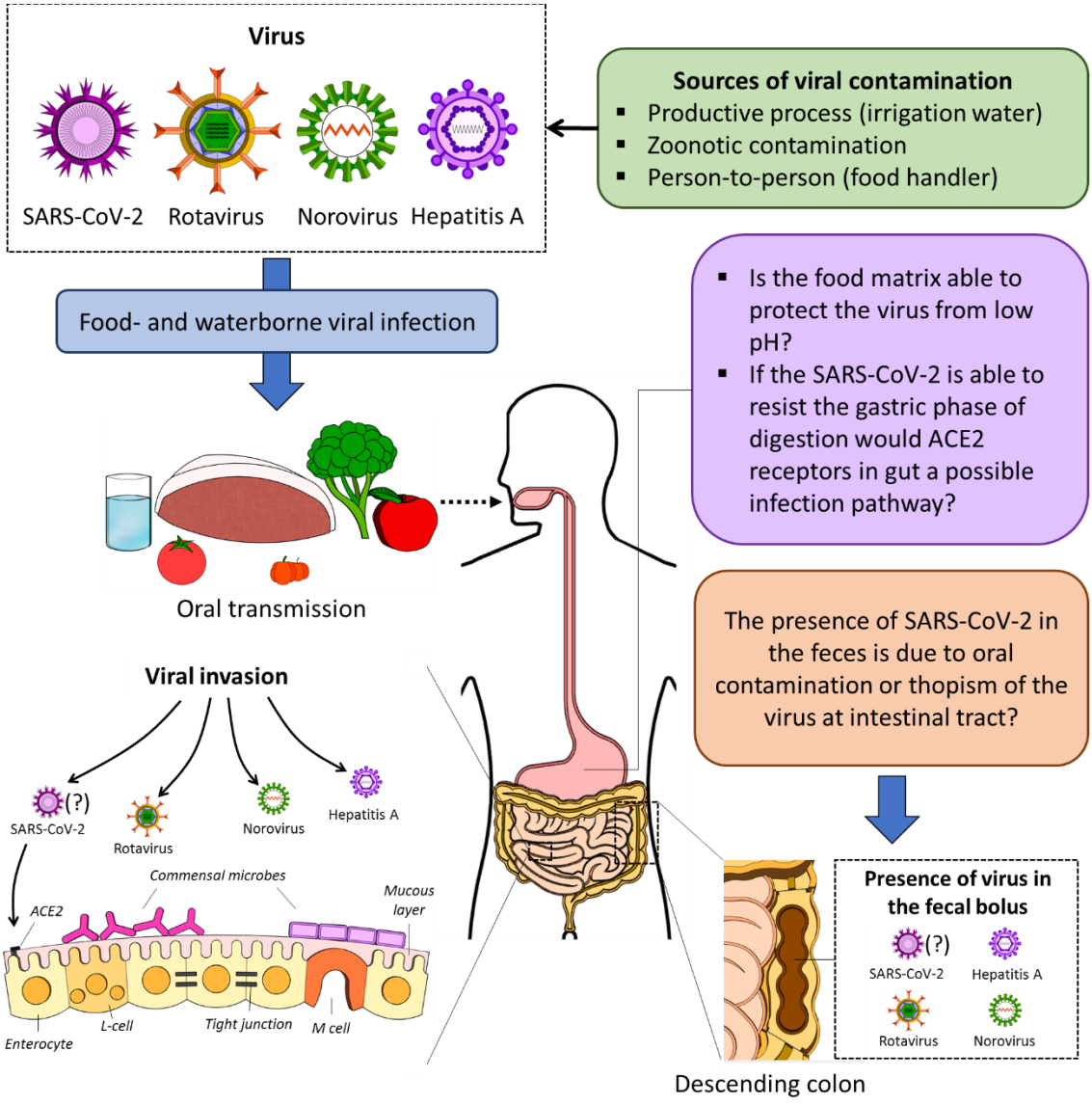
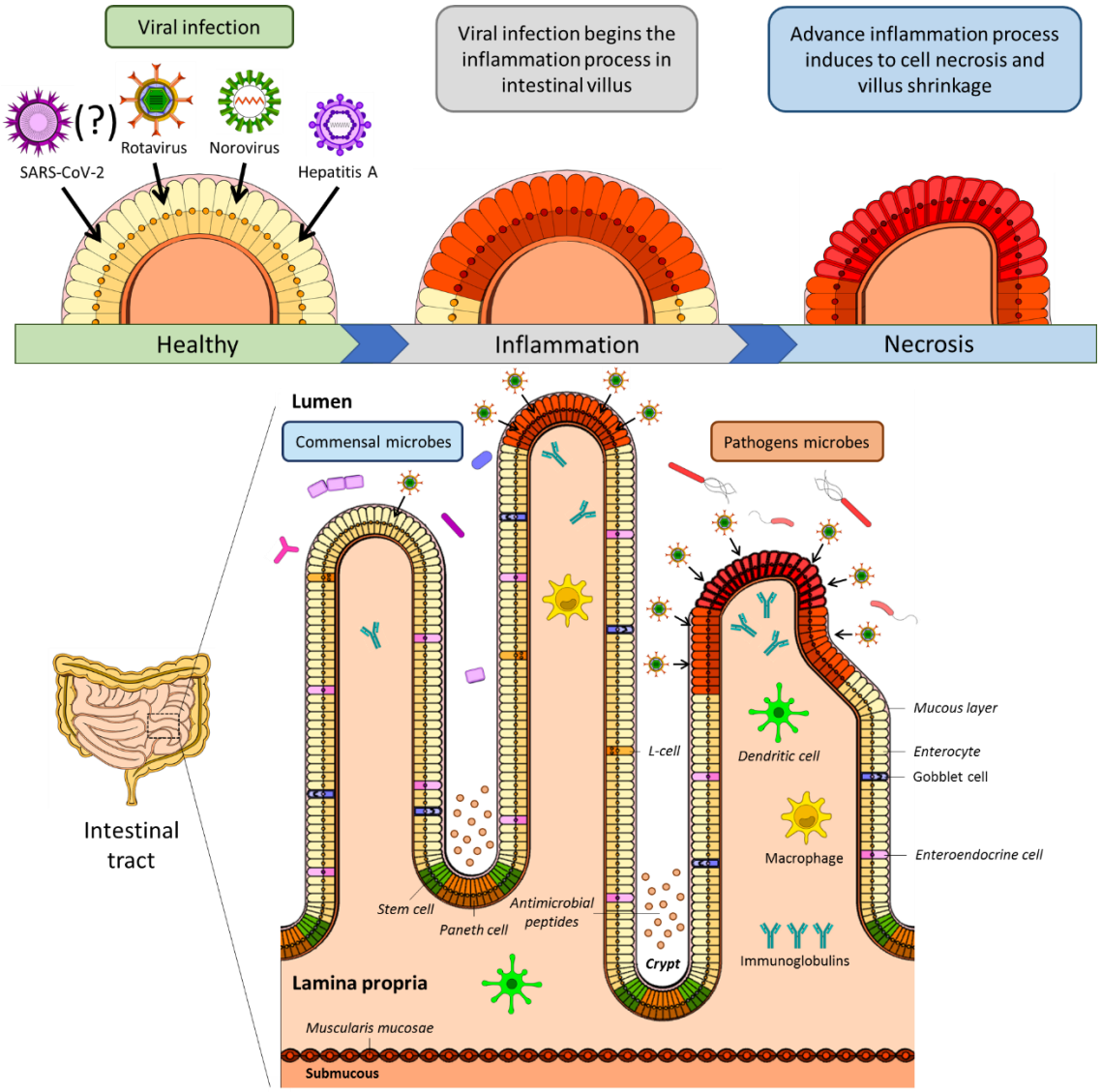


Figure 2. The inflammatory process of the intestinal tract induced by viruses. L-cell, enteroendocrine L-cell; SARS-CoV-2, severe acute respiratory syndrome virus.



Conclusão Geral

A COVID-19 é uma emergência sanitária e humanitária global. Mudanças profundas nas atividades humanas com impacto no sistema alimentar foram impostas pela pandemia, e como resposta, é obrigatório reafirmar a ciência em seus diferentes campos de estudo, incluindo a área de ciência de alimentos. Embora as boas práticas de produção em tempos de pandemia de coronavírus obedeçam às mesmas regras básicas já consolidadas, no cenário pós-pandêmico, espera-se uma diminuição das doenças transmitidas por alimentos como reflexo da mudança positiva de comportamento da população sobre a importância dessas boas práticas.

Vários problemas já existentes foram exacerbados pela COVID-19 no contexto da insegurança alimentar e perda de alimentos. Urge refletir e traçar estratégias alinhadas à agenda 2030 para mitigar esta situação. Existem boas percepções e evidências que mostram o investimento em tecnologia e desenvolvimento de novos produtos, com base na economia circular, como um dos caminhos para criar um cenário diferente.

O caqui é uma importante fonte de nutrientes como vitaminas, minerais e compostos bioativos, que proporcionam muitos benefícios à saúde. No entanto, devido a processos de má gestão pós-colheita (durante a safra curta e intensa), grande quantidade da fruta se perde antes de chegar ao consumidor. A perda do caqui representa a perda de bilhões de gramas de macro e micronutrientes com potencial de suprir parte das necessidades nutricionais de milhares de pessoas. Além disso, a perda de caqui no Brasil também pode ser traduzida como perda econômica média estimada em US$ 12 milhões/ano, além do impacto ambiental negativo ao desperdiçar água, carbono e terra gastos na sua produção. Considerando esses fatores, não resta dúvida de que a redução das perdas pós-colheita é uma forma sustentável de aumentar a segurança alimentar e nutricional, bem como de aumentar a receita dos diferentes atores que compõe sistema alimentar.

O congelamento como sistema de conservação pode ser recomendado, a depender do propósito de aplicação do caqui. Após um ano de armazenamento congelado, o caqui não apresentou diferenças substanciais quanto à composição centesimal, perfil mineral e características físico-químicas. Por outro lado, o armazenamento sob congelamento afetou diretamente os compostos orgânicos voláteis e as propriedades antioxidantes das amostras.

Nossos resultados também demonstraram que a extração aquosa em autoclave de caqui pode ser uma estratégia eficaz para eluir substâncias bioativas com efeito citotóxico nas linhas de células cancerígenas MCF-7 e MDA-MB-23. Não houve diferença na redução da viabilidade celular entre o extrato aquoso em autoclave de caqui fresco ou congelado por um ano.

Produtos de valor agregado desenvolvidos a partir do caqui configuram-se como estratégias interessantes para reduzir as perdas pós-colheita durante a safra e ter produtos à base de caqui disponíveis na entressafra valorizando toda a cadeia de produção de caqui ao longo do ano. Os molhos picantes à base de caqui demostraram propriedades funcionais interessantes como, por exemplo, a atividade antioxidante. A adição de especiarias (noz moscada, cravo e canela) aos molhos à base de caqui pode influenciar as características sensoriais (por exemplo, cor e aroma) e as propriedades funcionais (atividade antioxidante) deste tipo de produto. A produção de molho, dentre outros potenciais produtos gastronômicos e tecnológicos representa uma alternativa promissora para um melhor aproveitamento do caqui pós-colheita e valorização dessa fruta.

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