Trends in Food Science & Technology 116 (2021) 415–433

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: www.elsevier.com/locate/tifs

Korean traditional foods as antiviral and respiratory disease prevention and treatments: A detailed review

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ARTICLE INFO

Keywords:
Antiviral
Pathogens
Coronavirus
COVID-19
SARS-CoV-2
Functional foods
Plant extracts
Respiratory infections
Viruses
Korean traditional diet

ABSTRACT

Background: Korean traditional food (KTF), originated from ancestral agriculture and the nomadic traditions of the Korean peninsula and southern Manchuria, is based on healthy food that balances disease prevention and treatment. Fermented foods that include grains, herbs, fruits, and mushrooms are also an important practice in KTF, providing high levels of *Lactobacilli*, which confer relevant health benefits, including antiviral properties. Some of these probiotics may also protect against the Influenza virus through the modulation of innate immunity.
Scope and approach: The emerging of the COVID-19 pandemic, in addition to other diseases of viral origin, and the problems associated with other respiratory disorders, highlight how essential is a healthy eating pattern to strengthen our immune system.
Key Findings and Conclusions: The present review covers the information available on edible plants, herbs, mushrooms, and preparations used in KTF to outline their multiple medicinal effects (e.g., antidiabetic, chemopreventive, antioxidative, anti-inflammatory, antibacterial), emphasizing their role and effects on the immune system with an emphasis on modulating properties of the gut microbiota that further support strong respiratory immunity. Potential functional foods commonly used in Korean cuisine such as Kimchi (a mixture of fermented vegetables), Meju, Doenjang, Jeotgal, and Mekgeolli and fermented sauces, among others, are highlighted for their great potential to improve gut-lung immunity. The traditional Korean diet and dietary mechanisms that may target viruses ACE-2 receptors or affect any step of a virus infection pathway that can determine a patient's prognosis are also highlighted. The regular oral intake of bioactive ingredients used in Korean foods can offer protection for some viral diseases, through protective and immunomodulatory effects, as evidenced in preclinical and clinical studies.

1. Introduction

The positive health effects of several beverages and foodstuffs have been recorded and studied during the last decades. These effects are due to the presence of specific naturally-occurring compounds, whose particular levels and proportions influence the observed health benefits (Visioli et al., 2011). In this context, several traditional Korean foodstuffs are currently recognized for their beneficial properties (Im Kim, Sim, & Choi, 2010). This fact is rationalized since, for Koreans, the low risk of diseases and feeding starts from the same root, based on the philosophy called "*Yaksikdongwon,*" which defends that good health is part of an appropriate diet, in order to keep the human body in balance

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https://doi.org/10.1016/j.tifs.2021.07.037
Received 7 January 2021; Received in revised form 26 July 2021; Accepted 27 July 2021
Available online 30 July 2021
0924-2244/

(Oktay & Ekinci, 2019). According to this philosophy, medicinal therapy would only be required if a positive evolution of the disease is not observed after 'treatment' with food, since health starts with diet (Oh, Park, Daily III, & Lee, 2014). Therefore, in the same concept, medicine and food converge (Leem & Park, 2007). In other words, Korean traditional food (KTF) is based on a notion of healthy foods, and these healthy properties cover food materials and their preparation (Park & Kim, 2014; Park, Jeong, Lee, & Daily, 2014). Such features have specialized over centuries owing to geographical, social, and political factors (Oh, Park, Daily, & Lee, 2014).

Originating in ancient agriculture and nomadic traditions of the Korean peninsula and southern Manchuria, KTF has evolved through complex interactions between the environment and different cultural trends, developing a distinct ethnicity and a matchless culture (e.g., language and food) (Hyun Kim, Song, & Potter, 2006). In order to resist long winters within a land isolated by rugged mountains and rocky ocean fronts, KTF developed out of the obligation to preserve good food by fermentation (e.g., fish, seaweed, vegetables, and salted beans, among others) in clay pots (Dharaneedharan & Heo, 2016; Patra, Das, Paramithiotis, & Shin, 2016).

Apart from the fact that Koreans have learned a reasonable balance between nutrition and disease prevention/treatment, an increasing interest in South Korea opened up a market that includes dietary supplements and health products of natural origin (namely, functional health foods (FHF)) (Kim, Kim, & Lee, 2008; Yoon et al., 2012). Thus, a regulatory venue for such products in South Korea (one of the largest Asian markets for FHF) was introduced and regulated by the Korea Food and Drug Administration (KFDA) (Zawistowski, 2014).

Some herbs and fruits (such as ginseng, cinnamon, wormwood, ginger, pomegranate, and adlay) are actually used as food, but their therapeutic effects are also exploited. Therefore, KTF usually includes some herbs/fruits for their medicinal properties and, correspondingly, health benefits in KTF are attributed to various common ingredients (Kim et al., 2006; Park & Kim, 2014). Based on this fact, KTFs are a subject of growing interest worldwide (Baeg & So, 2013; Kim, 2013). Particular KTF ingredients (broadly consumed in Korea) are currently being placed on global FHF markets, owing to the increasing interest beyond the characteristic examples (e.g., ginseng preparations, mushrooms, fermented sauces and mixed rice). Such attention comes from increasing research supporting their several health benefits (Park & Kim, 2014), including antiviral properties (Kang et al., 2011; Lee, Lee, Lee, & Choi, 2013).

Antivirals are the only drugs traditionally used to treat infectious diseases of viral origin (Gonçalves et al., 2020). However, like other drugs, they also have associated risks or harmful health effects, such as phlebitis, hematuria, hypocalcemia, creatininemia, and, in the worst cases, mutagenesis, and teratogenesis. Additionally, they develop resistance due to the change and decreased affinity of viral enzymes, especially polymerases and reverse transcriptases (Goldhill et al., 2018; Gonçalves et al., 2020). Therefore, the antiviral capacity of phytochemicals present in extracts of certain medicinal and edible plants and mushrooms (in common/dietary use) is a good choice, since they have been shown to be active *in vitro* and *in vivo* against many different types of viruses, including those that cause respiratory diseases (Nugraha, Ridwansyah, Ghozali, Khairani, & Atik, 2020; Verma et al., 2020).

In this regard, acute respiratory infections present morbidity and mortality of approximately 4 million children annually. These infections are considered a major cause of early childhood mortality, including diarrhea and malnutrition (Rodríguez, Cervantes, & Ortiz, 2011). In fact, a shocking surprise in the scientific and global community was caused by the epidemiological situation initiated by the influenza A subtype H1N1. It is a swine-origin influenzavirus strain producing critical respiratory infection in some places, which was identified for the first time in April 2009 (Phaswana-Mafuya et al., 2020). However, the current situation (i.e., 2021) is even worse due to the pandemic generated by COVID-19, an emerging disease triggered by SARS-COV-2 (severe acute respiratory syndrome coronavirus 2) (Rajaiah, Abhilasha, Shekar, Vogel, & Vishwanath, 2020). This disease has caused 3.03 million deaths worldwide as of this writing (i.e., 18/04/2021).

Therefore, without a cure or well-proven vaccine until now against SARS-COV-2 and the problems associated with other respiratory infections, a healthy eating pattern is essential to strengthen our body's defenses and improve response to these respiratory disease-causing agents (BourBour et al., 2020; Lin et al., 2016). Faced with the restrictions that we are currently experiencing, it is crucial to take care of our diet to maintain our health and ensure the strengthening of our immune system, that is, our body's natural defense against respiratory infections (Jawhara, 2020; Junaid et al., 2020; Roy et al., 2020). Therefore, it is easy comprehensible that a well-balanced diet is key to body homeostasis and in to preventing respiratory infections. Various nutrients in the diet on a regular basis can help strengthening the respiratory system. Moreover, more recently, studies have also highlighted the role of probiotics in promoting a healthy gut microbiota and how that can affect general health, reducing inflammation and strengthening the immune system. Adding to this, many people have to live with chronic conditions such as asthma, chronic obstructive pulmonary diseases (COPD) and pulmonary fibrosis that affect their quality of life. Lifestyle modification can help to protect the respiratory system and even reduce lung damage and disease's symptoms. Specific nutrients and foods have been identified to be particularly beneficial for lung function. Clinical studies have recommended that zinc, curcumin, and zinc-ionophores have significant antiviral potentials. And thus, intake of these food supplements can be helpful in the treatment of COVID-19 in the form of considerable immunity support, inhibition of replication of RNA of the SARS-COV-2 virus and by prevention of the virus entry into the cell (Celik, Gencay, & Ocsoy, 2021; Ghati et al., 2021; Roy et al., 2020). Moreover, KTF offers good edible alternatives to help us in this purpose through prophylactic and direct actions (Park & Kim, 2014). Accordingly, the present narrative review covers the information available on edible plants, herbs, and preparations used in KTF to outline the potential of KFTs and their ingredients based on their antiviral and anti-respiratory effects.

2. Korean traditional foods in brief and their beneficial effects

Korean traditional foods (KTF) are known worldwide for being spicy, tasty, and delicious, but KTF are also able to promote wellbeing and a balanced health. This KTF characteristic is often linked with the obesity percentage of South Koreans (i.e., 3.5%), which differs substantially from other countries such as the United States, the United Kingdom, Brazil, Mexico or New Zealand (25–34%) (Gupta et al., 2012; Groneberg et al., 2015). This is a good starting point since such a low obesity rate can be attributed to the genetic factors of Asians compared to Caucasians since the latter are greater than the former, but this is also not entirely true. Nutritional habits of Koreans make them healthier than other people since the fat content of Korean food is generally 13% lower compared to American and European diets (Lee, Sobal, & Frongillo, 1999). This condition can be justified as Korean food culture has evolved from very ancient times and adheres to a significant classification of various philosophical actions. The recognition that consuming healthy food can prevent and cure diseases is deep-rooted Korean thinking (Oh et al., 2014).

In this sense, edible plants and mushrooms in KTF are exploited for their medicinal properties that support their health benefits. However, each KTF exhibits particular benefits on health due to certain active principles and the use of special preparation/cooking procedures and practices (Patra et al., 2016). In addition, some KTF-used ingredients are also employed in traditional medicine to treat different health events. For instance, stomach problems are treated with chives or raw potato juice, whereas garlic is used for digestive purposes and blood cleansing. Bellflower roots and hazelnut are good for coughing/cold and skin/-pregnant women, respectively, while patients are strengthened with pine nuts or rice porridge (Oktay & Ekinci, 2019).

The facts mentioned above supported several of the informed benefits of KTF and their ingredients (e.g., red ginseng, aloe, zedoary, turmeric, red sage, astragalus, among others), which comprise several effects, such as lower risks of cardiovascular diseases (Jovanovski et al., 2014), as well as neurological diseases (Leem & Park, 2007), reduced probabilities of developing some cancer types due to anticancer properties (Yoon, Jeong, Kim, & Aggarwal, 2013), more efficient and stronger internal organs (mainly liver and kidneys) (Choi, 2008), healthier digestion due to enhanced inclination for more digestible foods (Kim, Song, & Potter, 2006a), stronger bones by consuming isoflavones occurred in mushrooms/beans (Youn et al., 2008), and healthier skin (Pazyar, Omidian, & Jamshydian, 2012).

A previous review categorized the impact of the ingredients of Korean edible herbs involving properties such as antidiabetic, chemopreventive, and antioxidative and effects on the immune system (Park & Kim, 2014). In the case of mushrooms (e.g., *Agaricus blazei*, *A. bisporus, Flammulina velutipes*, *Ganoderma lucidum, Hericium erinaceus*, *Inonotus obliquus*, *Lentinus edodes*, *Phellinus linteus*, *Pleurotus eryngii*, *P. ostreatus*, *Sparassis crispa*, among several others), they were traditionally used in Korea for their health benefits (i.e., digestive effects, risk of cancer, lowering cholesterol, losing weight, improving the immune system, preventing diabetes and anemia) (Thu et al., 2020), but also as food due to the good content of digestible carbohydrates and proteins and lower fat (Fu, Shieh, & Ho, 2002; Kim, Song, Kwon, Kim, & Heo, 2008). Indeed, the antiviral effects of *I. obliquus* have been recognized, even against SARS-CoV-2 (Shahzad, Anderson, & Najafzadeh, 2020).

Apart from using medicinal ingredients in KTFs within the healthy philosophy, the preparation is also important for them. In such preparations, preservation by fermentation is also an important practice in KTF, despite the country's different traditions (Han, Lucas, & Kunz, 1993). As one of the cheapest methods to increase the shelf-life of several highly-perishable foods (e.g., vegetables, fruits, fish, and meat), fermentation is a microorganism-mediated transformation process of organic compounds (Lee, Jang, Lee, Park, & Choi, 2015). The importance of this process in KTF is the action of particular microorganisms (such as bacteria and yeasts), not only for transform organic compounds (particularly carbohydrates) but also for the role as probiotics, conferring important health benefits to feeders, and regular consumption is recommended (Park, Jeong, et al., 2014).

The most recognized Korean fermented probiotic food is *Kimchi* (a Korean mixture of Fermented Vegetables), which has more than 3000 years of history (Chang, 2018). It is widely consumed in South Korea and, together with Indian lentils, Spanish olive oil, Greek yogurt, Japanese soybeans, it is considered one of the five healthiest foods in the world (Dharaneedharan & Heo, 2016). In fact, a strain of *Lactiplantibacillus plantarum* isolated from *Kimchi* can modulate innate immunity and protect against IV (influenza virus) (Park et al., 2013) and produces cyclic dipeptides that inhibit IV proliferation (Kwak et al., 2013). However, other traditional Korean fermented foods can be highlighted, such as *Meju*, *Doenjang*, *Jeotgal,* and *Mekgeolli*, which exhibit several medicinal effects (e.g., anticancer, antiobesity, antioxidant, anti-inflammatory, antidiabetes, among others) and involve different beneficial microorganisms, such as *Leuconostoc mesenteroides*, *L. plantarum*, *Aspergillus* sp., *Bacillus* sp., *Bacillus siamensis, Halomonas* sp., *Kocuria* sp., *Saccharomyces cerevisiae*, among others (Dharaneedharan & Heo, 2016).

3. Korean traditional foods with effects against the respiratory diseases

Fermented foods have been widely studied, and their benefits for human health have been elucidated. In this sense, it has been shown that fermented foods can affect the modulation of the immune system; therefore, fermented foods may improve the immunitary response to certain diseases or infections, such as those caused by viruses.

Table 1
Potential beneficial effect of Korean foods against respiratory diseases.

Korean food	Respiratory and antiviral models	Inhibitory effect	Reference
Chongkukjang extract	Influenza A virus	Neuroaminidase inhibitory effect of 4565.9 to 28,242.4 by IC_{50} (μg/mL).	Wei et al. (2015)
Ethanol extract from Cheonggukjang	Allergic asthma in a murine model	70% ethanol extract (100 mg/kg/day) decreased degranulation and histamine release from mast cells	Bae et al. (2014a)
L. plantarum[a] (YML009) strain isolated from *Kimchi*	Influenza H1N1 virus	Antiviral activity at concentrations of 2[a] - 2[c] 10x cell-free supernatant.	Rather et al. (2015)
L. plantarum[a] DK119 isolated from *Kimchi*	Influenza H1N1 virus	A 10^9 CFU/mouse diary dose prevented weight loss of mice and maintained 100% survival.	(Park et al., 2013)
Lactobacillus strains isolated from Korean fermented foods	Mice model	Mice were fed a lyophilized powder (dose of 2.5×10^{10} CFU day^{-1}) and induced the T-lymphocytes proliferation and IFN-γ production	Won et al. (2011)
L. citreum[b] HJ-P4 isolated from *kimchi*	Allergic mice model	A dose of 2×10^8 CFU/mL enhanced the secretion of IFN-γ and decreased IL-4 and IL-5	(Kang et al., 2009)
L. citreum[b] EFEL2061 isolated from *kimchi*	Allergic mice model	A dose of 1×10^{10} UFC was given daily and reduced the bystander B cell activation	(Kang, Moon, Lee, & Han, 2016)
S. succinu[c] 14BME20 isolated from *doenjang*	Allergic asthma in a murine model	A dose of 5×10^7 UFC reduced cytokines and induced the accumulation of anti-inflammatory cells	(Song et al., 2019)

[a] *Lactiplantibacillus plantarum.*
[b] *Leuconostoc citreum.*
[c] *Staphylococcus succinus.*

Fermented food by lactic acid bacteria has been described to produce metabolites with antiviral effects (Table 1). Some of the antiviral mechanisms of lactic acid bacteria are the stimulation of the immune system and the production of antiviral metabolites. This type of fermented foods has shown an antagonist effect on respiratory viruses, such as influenza virus by stimulating the immune response, such as increased levels of interferon (INF-α and INF-β) and interleukin (IL-6), as well as the high secretion of cytokines IL-2, IL-12, and IFN-γ (Özel & Öztürk, 2020).

Kimchi is a well-known fermented traditional Korean food rich in vitamins, minerals and dietary fiber, containing lactic acid bacteria and other compounds. *Kimchi's* effects on health, extend to anti-obesity, anti-aging, anti-mutagenic, anti-cancer, antioxidant, and anti-diabetic roles (Kim, Ha, Choi, & Ju, 2016; Kwon, Park, Chang, & Ju, 2016; Park, Jeong, et al., 2014). Likewise, *Kimchi* contains lactic acid bacteria, which are related to the content of beneficial compounds to health, as well as probiotic effects, decreased lipid peroxidation, and enhanced immune system response, reported *in vitro* and *in vivo* (Jang, Yu, Lee, & Paik, 2020; Lee, Shim, Park, Heo , Kim, & Ham, 2016; Yang et al., 2019). Similarly, Rather et al., 2015 demonstrated that a strain of *Lactiplantibacillus plantarum* (YML009) isolated from Kimchi has antiviral activity against the influenza virus H1N1 is hypothesized to be more effective than Tamiflu. Also, Park et al. (2013) found that *Lactiplantibacillus plantarum* DK119 (DK119) isolated from Kimchi improves protection for mice against the H1N1influenza virus by intranasal and oral administration. Jang et al. have reported the immune-stimulating potential of the *Lactobacillus plantarum* Ln1 strains isolated from the Kimchi (Jang, Yu, Lee, & Paik, 2020).

On the other hand, Kwon et al. (2016) reported that *Kimchi* intake might be associated with rhinitis prevention because Korean adults who consume *Kimchi* are less prone to asthma (Kim et al., 2014). These effects may be related to vegetables and lactic acid composition of *Kimchi*, since the consumption of this food provides a significant amount of vitamins, such as ascorbic acid, which is associated with the improvement of the immune system and prevents allergenic diseases such as rhinitis and asthma (Kim, Ha, Choi, & Ju, 2016; Kim et al., 2014). In this sense, Kang et al. (2009) demonstrated that bacteria presented in Kimchi could be responsible for the reduction of allergenic diseases (such as rhinitis and asthma) in a murine model, as they have found that *Leuconostoc citreum* HJ-P4 (KACC 91035) isolated from *Kimchi* improves the immune system by decreasing serum levels and enhancing the secretion of antigen-specific IFN-γ. Likewise, Kang et al. (2016) have found that the bacteriium *Leuconostoc citreum* EFEL2061, isolated from Kimchi, induced cytokines and decreased the serum IgE in an allergic mice model. They reported that this could be due to the enhance in innate immune cells and reduced the bystander B cell activation. Also, Won et al. (2011) reported that strains of *Lactobacillus* isolated from Korean fermented foods (*Kimchi* and *Deodoek Muchim*) have a positive effect on improving the immune system in the murine model; they found that this effect could be due to the increased secretion of IL-2 which could induce T-lymphocytes proliferation and IFN-γ production; therefore these bacteria can affect diseases like asthma (Ya et al., 2008).

On the other hand, fermented Korean food, such as "*doenjang*" has been studied for the prevention of asthma; in this sense, Song et al. (2019) demonstrated that a bacterium isolated from the fermented Korean food "*doenjang*" has a protective effect against allergic asthma in a murine model. They found that the administration of *Staphylococcus succinus* strain 14BME20 significantly reduced cytokines and induced the accumulation of anti-inflammatory cells, enhancing the immune response to allergens. Likewise, Bae, Shin, See, Chai, and Shon (2014a) reported that an ethanol extract from the traditional Korean fermented soybean food, namely "*Cheonggukjang*" decreased the symptoms of allergic asthma in a murine model; they found that this extract decreased Ca^{2+} input to mast cells and decreased degranulation and histamine release from mast cells. Wei et al. (2015) also reported the antiviral effect of extracts of *chongkukjang* against the influenza A virus. They found that ethyl acetate extract from chongkukjang showed inhibitory activity of neuraminidase *in vitro*. Also, chongkukjang extracts maintained higher body weight and decreased the mortality of influenza in infected mice. Besides, Kim and Ju (2019) found that the consumption of seaweed and fish could be related to the prevention of asthma in Korean adults because these foods have a great content of polyunsaturated fatty acids and vitamins, related to anti-inflammatory precursors and pro-inflammatory mediators, such as protectins, resolvins, prostaglandins, and leukotrienes.

Besides, the Korean Red Ginseng which is obtained by the processing of the ginseng using repeated steaming and drying has shown nemorous potential activity against the human pathogenic viruses such as human immunodeficiency virus, human herpes virus, influenza virus, respiratory syncytial virus, hepatitis virus, norovirus, enterovirus, rhinovirus, coxsackievirus and rotavirus (Im, Kim, & Min, 2016). It is stated that the ginseng could possibly exert a direct antiviral potential by a number of mechanism of action such as inhibiting the attachment of the virus, penetration and replication, and also through the enhancement of the host immunity (Im et al., 2016). In another study it has been reported that the major compound in ginseng called the ginsenosides are highly effective against the H1N1, H3N2, H5N1 and H9N2 influenza viruses by the stimulation of the antiviral cytokines (Chan et al., 2011; Dae-Goon; Yoo et al., 2012; Park, Jeong, et al., 2014; Ratan et al., 2020). A clinical study has also reported that the Korean red ginseng have reduced the depletion of CD4 T-cells and have weakened the serum soluble CD8 antigen level in patients infected with the HIV type-1 viruses (Cho & Kim, 2017; Ratan et al., 2020). Another herb, *Geranii Herba* (*Geranium thunbergii* Siebold et Zuccarini), which is has been included in the Korean traditional foods, have been reported to possesses antiviral effects against the influenza viruses through the mechanism of neuraminidase enzyme inhibition (Choi, Kim, Kim, & Chung, 2019). In another study, the authors have reported that Platycodin D, a natural bioactive compound found in *Platycodon grandiflorum*, are helpful in preventing both the lysosome- and TMPRSS2-driven COVID-19 infection by obstructing the membrane fusion mechanism and or by briefly disrupting the distribution of membrane cholesterol (Kim et al., 2021). Similarly another herbal formulation, *Qingfei Paidu* decoction included in both Korean and Chinese Pharmacopea, are helpful in the treatment of COVID-19, as it could inhibit and alleviate the excessive immune responses and eliminate the inflammation by regulating the immune-related pathways and cytokine action–related pathways (Wu et al., 2020; Zhao, Tian, Yang, Liu, & Zhang, 2020). This herbal formulation increases the immunity and reduces inflammation by targeting the lung and spleen in COVID-19 patients (Wu et al., 2020; Zhao et al., 2020).

3.1. Korean traditional foods and beneficial effects on the COVID-19

Korean meals are rich in grains and vegetables, and many publications have arisen describing their pharmacological properties. A number of traditional foods have been reported to possess beneficial antiviral effects against the COVID-19 virus and these foods and herbs could be taken as dietary supplements and thus could be helpful in preventing the infection and strengthening the immunity against these viruses (Panyod, Ho, & Sheen, 2020). Besides, a number of research has been reported on the numerous medicinal plants and their potential active components which are highly effective against the COVID-19 viruses by possibly blocking the life-cycle related proteins, such as the cellular receptor ACE2, papain-like or chymotrypsin-like proteinases or by other possible mode of actions (Ang, Lee, Kim, Choi, & Lee, 2021; Benarba & Pandiella, 2020). Cabbage and fermented vegetables, for instance, fall under the scope of anti-viral properties (and severe anti-COVID-19 symptoms) (Bousquet et al., 2020). In the case of COVID-19 (SARS-CoV-2 infections), there is a correlation with lower mortality rates due to the high consumption of fermented vegetables, common in East Asia, Central Europe, and the Balkans.

These foods contain many *Lactobacilli,* which are also effective activators of nuclear factor (erythroid-derived 2)-like 2 (Nrf2). Additionally, *Lactobacilli*, present in large amounts in the fermented foods with strong probiotic properties are effective against the foodborne pathogenic microfloras (Behera, Ray, & Zdolec, 2018). Previously, heat-killed *Lactobacilli* have already been reported to effectively protect against influenza A and prevent secondary infections by stimulating immunity (Jung et al., 2017). A number of recent publications already exist, establishing a relationship between diet, gut microbiota, and viral and respiratory infections (Alkhatib, 2020; Chaari, Bendriss, Zakaria, & McVeigh, 2020). This literature attempts to draw correlations and make practical recommendations for the use of antiviral functional foods and lifestyle approaches to tackle the ongoing COVID-19 pandemic. They based their reports on the latest knowledge on the immunology of COVID-19 (Vabret et al., 2020) and the reported effects of the gut microbiome on health and disease.

However, before the pandemic of COVID-19 eruption, there were already comprehensive reports on the value of foods for their nutritional, antioxidant activity, and phenolic composition, including beans, which are widely used by Koreans (Carbas et al., 2020). Moreover, many publications have also highlighted the role of microbiota on viral infections (Dominguez-Diaz, Garcia-Orozco, Riera-Leal, Padilla-Arellano, & Fafutis-Morris, 2019; Planès & Goujon, 2020; Roth, Grau, & Karst, 2019; Wilks & Golovkina, 2012). Indeed, much has been postulated about how the gut microbiome can influence the severity of COVID-19. The greatest risk is often associated with pre-existing conditions as

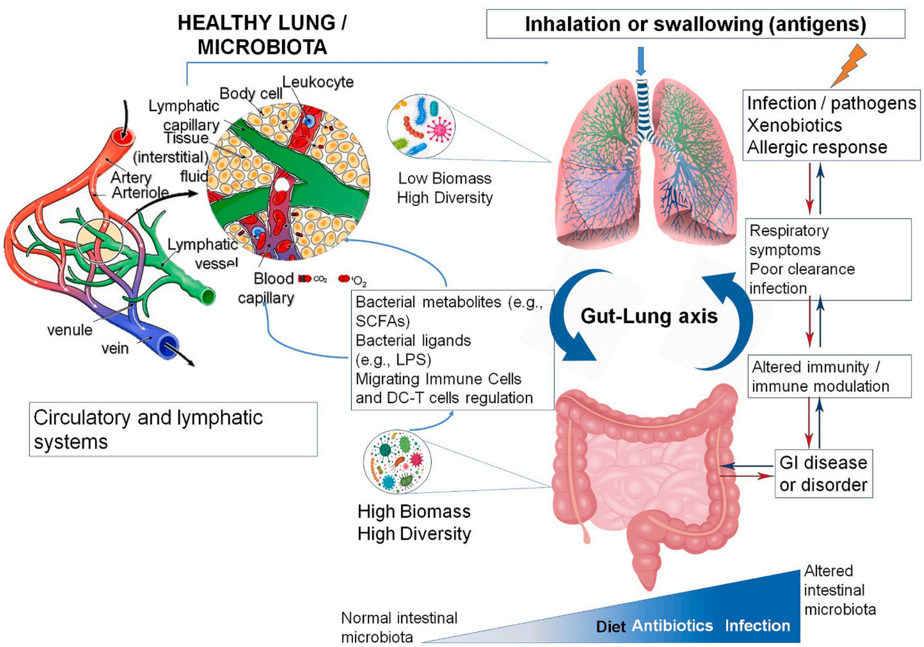

Fig. 1. - Potential connection between the gut-lung axis and nutrition related to the host-defense by the intestinal microbiota and lung immunity. Adapted from Samuelson et al. (Samuelson et al., 2015). The gastrointestinal tract (GI) or gut and lungs influence their homeostasis reciprocally. The unbalanced gut microbiota is correlated with lung disorders and infections. For example, antibiotic abuse can cause changes in the structure of the microbial intestinal community structure, which can result in altered immunity and changes in microbial growth conditions and, in turn, cause respiratory responses; or in the other way, a viral infection or inhalation of antigens/pathogens can alter immunity and microbial communities, resulting in changes in the gut. SCFAs, short-chain fatty acids; LPS, lipopolysaccharide; DC-T cells, Dendritic cell-T cell. Some of the intervenient immunity cells include: IL-6 (interleukin-6), IFN γ (interferon-gamma) and TNF-α (Tumour Necrosis Factor alpha), as well as migrating immune and DC-T cells, CCR 4/6 (Chemokine Receptor 4/6), $CD4^+$ (Cluster of Differentiation antigen 4) and Th1 (T-Helper Cell type 1) that are carried in the circulatory vessels.

hypertension, diabetes, and obesity (Richardson et al., 2020), as already recognized by official health organizations such as the Centers for Disease Control and Prevention, CDC, U.S.A. (https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-with-medical-conditions.html accessed Dec 29th, 2020). A relationship between all of these conditions and alterations in the gut microbiome composition was reported (Aoun, Darwish, & Hamod, 2020; Gurung et al., 2020; Jose & Raj, 2015). The robustness of these associations raise the possibility that the mechanisms underlying hypertension, diabetes, and obesity may be responsible for developing severe respiratory infections associated with COVID-19; the gut microbiome at the time of infection may be determinant for patients outcome.

COVID-19 disease is caused by the new beta-coronavirus, now designated SARS-CoV-2 (Severe Acute Respiratory Syndrome coronavirus 2). The global COVID-19 pandemic has started an unprecedented race to find therapeutic targets and treatments for this disease and related serious pulmonary infections; thus, everything about SARS-CoV-2 has been under tight scrutiny. SARS-CoV-2 shares 79% sequence identity with SARS-CoV. This virus provoked a previous outbreak in early 2000, and with MERS-CoV, the Middle East Respiratory Syndrome Coronavirus (~50%) that appeared in 2012 (Lake, 2020; Lu et al., 2020). In common, all of these pathogens use the angiotensin-converting enzyme II (ACE-2) receptor to enter into the cell and have distinctive spike proteins. ACE-2 receptors are also expressed in cardiovascular tissues and kidneys, and gastrointestinal (GI) tracts, besides the airways (Harmer, Gilbert, Borman, & Clark, 2002; Leung et al., 2020). Thus, the expression of receptors for this peptidase is decisive for COVID-19 patient outcomes and has been pinpointed as a high-potential target for an effective vaccine. Moreover, it has been reported that SARS-CoV2 RNA can be detected in the stool of some patients with COVID-19 long after the live virus can be cultured from patients' secretions and feces. Together with the fact that many patients develop diarrhea as a symptom of COVID-19, this suggests a distinct gut-lung link that may encompass gut microbiota (Dhar & Mohanty, 2020; Zuo et al., 2020).

The gut-lung or axis connection was reported long before the COVID-19 outbreak (Anand & Mande, 2018). A recent review points to the role of gut-lung axis in modulating the immune response and its implication in respiratory pathologies (Enaud et al., 2020). The gut microbiota may likely predict the patient's prognosis for SARS-CoV-2 infection, particularly when considering reports of gut symptoms (such as diarrhea and nausea) in patients with worse outcomes (Shang et al., 2020). Therefore, a healthy gut microbiome may support a better immune response to viral infections, thus inducing an effective protective response to COVID-19. Moreover, the state of this immune system-microbiota partnership may justify people's susceptibility to infections and inflammations, which in turn can be associated with a regular diet (Belkaid & Hand, 2014). A healthy gut or intestinal microbiome is known to be associated with a diet rich in fibers and a variety of fruits, vegetables, whole grains, legumes, nuts and seeds, and herbs and spices, as well as a few fermented foods (such as Kefir, *kimchi* and *sauerkraut*) (Heinen, Ahnen, & Slavin, 2020; Singh et al., 2017). Thus, the diet can also assist patients impaired with COVID-19 to recover and improve clinical outcomes, in addition to being behind lower infection rates or better disease prognosis (associated with lower mortality and morbidity rates) in certain regions of the planet or regions with characteristic cuisines or diets.

A scheme of the gut-lung connection is depicted in Fig. 1. Succinctly, antigens or microbes in the intestine are 'scrutinized' by Dendritic cells (DC) directly from the lumen or after translocation through M cells to the GALT (Gut-associated lymphoid tissue). A combination of microbial cues leads to phenotypic changes in dendritic cells and migration to the draining lymph node. Dendritic cells then induce the activation of several T cells subsets within the MLN (mesenteric lymph nodes) and the production of several regulatory cytokines, such as IL-10, TGF-β, INFγ and IL-6. T cells then gain immune homing molecules (CCR9, CCR4). As a consequence of the immune challenge in the respiratory tract, cells activated in the GALT and MLN travel to the respiratory mucosa via CCR4/6 and induced protective and anti-inflammatory responses. Additionally, bacterial-derived products (e.g., LPS) can bind to TLR (Toll-like Receptors) in both intestinal epithelium and macrophages, which results in the production of several cytokines and chemokines. TLR activation can also encompass the expression of NF-kB in macrophages. The formation of several bacterial metabolites (as SCFAs) also affects the gut-lung connection. These products are conducted to the lung, where they modulate inflammation levels (Samuelson, Welsh, & Shellito, 2015).

The diet-intestinal microbiota and the gut-lung connection have been extensively reviewed (e.g. (Anand & Mande, 2018; Nurmatov, Devereux, & Sheikh, 2011). It is now widely accepted that food intake affects the intestinal flora (or microbiota), resulting in bacterial metabolites that modulate immunity, namely by stimulating immune cells

Table 2
Some functional foods used in Korean traditional cuisine and their potential health benefits. Results from a literature survey reporting antiviral properties in the food are also indicated.

Elements used in Korean traditional cuisine	Potential Effects	References	Direct Antiviral evidence
Beet and beet greens	Anti-inflammatory Cholesterol modulation Improve cardiovascular health Immunomodulatory	(Asgary et al., 2016; Gomes et al., 2019; Shepherd et al., 2019; Wylie et al., 2013)	No
Peppers (genus Capsicum)	Improved fat metabolism/lipemia	(Hobbs, Caso, McMahon, & Nymark, 2014; Lee, Cha, et al., 2017; McCrea et al., 2015)	No
Anchovies	Improve cardiovascular health	Ferretti, Judd, Taylor, Nair, and Flanagan (1993)	No
Apples	Improve cardiovascular health Improve fat metabolism	(Bondonno et al., 2018; Cicero et al., 2017; Tenore et al., 2019; Trošt et al., 2018)	No
Cruciferous vegetables	Antioxidant Anti-inflammatory Modulate GI microbiota	(Kaczmarek et al., 2019; Kellingray et al., 2017; López-Chillón et al., 2019)	Yes (Müller et al., 2016; Noah et al., 2014)
Beans, seeds and nuts	Antioxidant Anti-inflammatory	(Hermsdorff, Zulet, Abete, & Martínez, 2011; Nilsson, Johansson, Ekström, & Björck, 2013; Relja et al., 2017; Reverri et al., 2015); revised in (Bolling, McKay, & Blumberg, 2010; Ganesan & Xu, 2017a; Lorenzon Dos Santos, Quadros, Weschenfelder, Garofallo, & Marcadenti, 2020)	No
Carrots	Antioxidant Cholesterol modulation Modulate GI microbiota Anti-diabetic	(Hu et al., 2019; Nicolle et al., 2003)	Yes (Torky, 2013)
Cocoa	Antioxidant Anti-inflammatory Improved fat metabolism Modulate GI microbiota Immunomodulatory	(Cavarretta et al., 2018; Gu, Yu, & Lambert, 2014; Jang, Shin, et al., 2017; Massot-Cladera, Franch, Castell, & Perez-Cano, 2017; Massot-Cladera, Perez-Berezo, Franch, Castell, & Perez-Cano, 2012; Sarria et al., 2020)	No
Coffee	Antioxidant Improved fat metabolism Anti-inflammatory Immunomodulatory	(Kuang et al., 2018; Loftfield et al., 2015; Poole et al., 2017; Rao & Fuller, 2018; Vitaglione et al., 2019)	Yes (Tsujimoto et al., 2010; Tsutomu et al., 2009; Utsunomiya et al., 2008); reviewed in (Valentina, 2017)
Garlic and onions	Antioxidant Anti-inflammatory Improved fat metabolism Immunomodulatory	(González-Peña, Checa, de Ancos, Wheelock, & Sánchez-Moreno, 2017; Gonzalez-Pena et al., 2017; Seo et al., 2019; Yang et al., 2018); Reviewed in (Corzo-Martínez, Corzo, & Villamiel, 2007; Bisen, P, & Emerald, 2016)	Yes (Lee et al., 2012; P. Mehrbod, E. Amini, & M. Tavassoti-Kheiri, 2009; Tsai et al., 1985; Weber et al., 1992)
Ginger	Antioxidant Anti-inflammatory Immunomodulatory	(Akhtar, Jantan, Arshad, & Haque, 2019; Jo et al., 2016; Kim, Kwak, & Kim, 2018; Motawi, Hamed, Shabana, Hashem, & Aboul Naser, 2011; Tian et al., 2020); Revised in (Anh et al., 2020)	Yes (Aboubakr et al., 2016; Chang, Wang, Yeh, Shieh, & Chiang, 2013)
Green tea	Antioxidant Anti-inflammatory Improved fat metabolism Immunomodulatory	(Gennaro et al., 2015; Han et al., 2016; Newsome et al., 2014; Yamashita et al., 2018)	Yes (Cheng, Lin, & Lin, 2002; Song, Lee, & Seong, 2005; Weber, Ruzindana-Umunyana, Imbeault, & Sircar, 2003)
Lentils	Antioxidant Anti-inflammatory Improve cardiovascular health Modulate GI microbiota Improved fat metabolism	(Graf et al., 2019); Reviewed in (Ganesan & Xu, 2017b)	No
Pumpkin	Antioxidant Anti-inflammatory Improved fat metabolism	(Alshammari & Balakrishnan, 2019; Bardaa et al., 2020; Hossain et al., 2018)	Yes (Elkholy, Hamza, Masoud, Badr, & El Safty, 2009; Sener et al., 2007)
Tomato	Antioxidant Anti-inflammatory Improve fat metabolism Immunomodulatory	(Schwager, Richard, Mussler, & Raederstorff, 2016; Valderas-Martinez et al., 2016)	No
Turmeric/curcumin	Antioxidant Anti-inflammatory Improve fat metabolism Modulate GI microbiota	(Lee, Kim, Lee, Choi, Chung, & Lee, 2017; Lee, Kim, Lee, Choi, Jung, & Kim, 2016; Peterson et al., 2018); Reviewed in (Labban, 2014; Lobo, Prabhu, Shirwaikar, & Shirwaikar, 2009)	Yes (Anantikulchai, Emprom, Pringproa, & Yamsakul, 2017; Anggakusuma et al., 2014; Praditya et al., 2019); Revised in (Mathew & Hsu, 2018; Moghadamtousi et al., 2014)
Yogurt	Antioxidant Anti-inflammatory Improve fat metabolism Modulate GI microbiota Immunomodulatory	(Buendia et al., 2018; Gonzalez et al., 2019; Lasker et al., 2019; Pimentel et al., 2018; Poutahidis et al., 2013; Rettedal, Altermann, Roy, & Dalziel, 2019)	Yes (Choi, Song, Ahn, Baek, & Kwon, 2009; Choi et al., 2010)

*Properties reported in pasteurized carrot juice; No-lack of information.

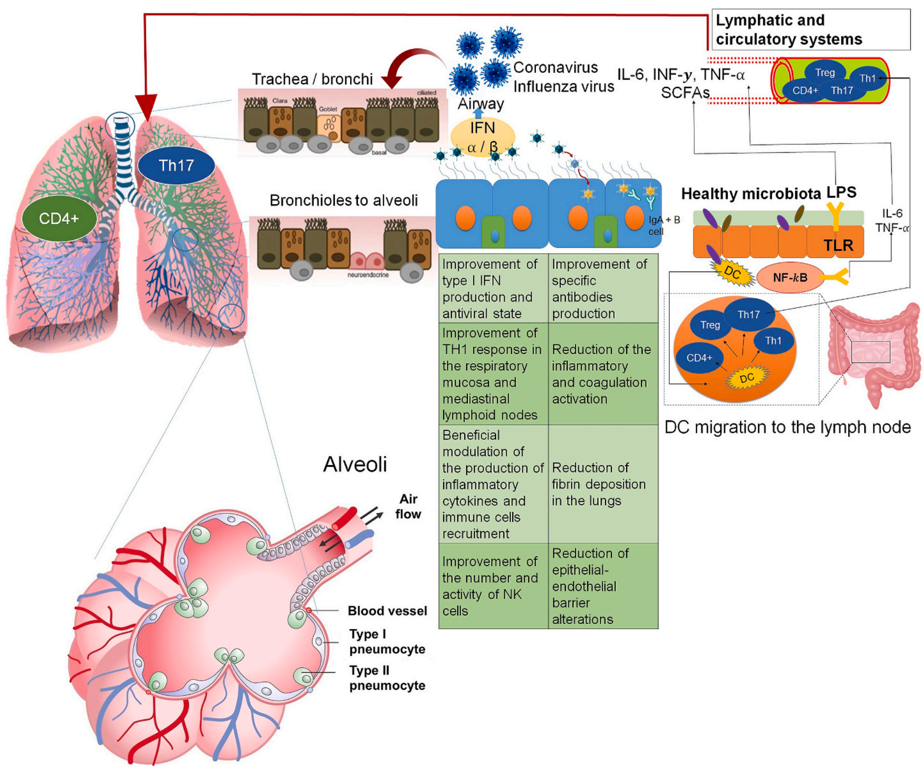

Fig. 2. – Focused effects of gut or gastrointestinal microbiome in lung immunity. Adapted from Camelo et al. (2014) and Zelaya et al. (2016a).

and the movement of sensitized immune cells or metabolites through the circulatory and lymphatic systems, can reach various distal organs, like the lungs or the brain. Therefore, unsurprisingly literature on nutrition, respiratory health, and gut flora increased substantially during the COVID-19 pandemic (Chaari et al., 2020; Dhar & Mohanty, 2020). Additional relationships have been established between dietary-related pre-conditions, such as obesity and severity of COVID-19 infection (Aoun et al., 2020). However, the opposite is why some regions or countries have not been as affected by the COVID-19 pandemic as Western countries like Spain or U.S.A. remain underexplored. Here, we will now focus on the traditional Korean diet and dietary mechanisms that may target viruses ACE-2 receptors or affect any step of a virus infection pathway, determining the patient's prognosis. Potential functional foods commonly used in Korean cuisine will be highlighted for their potential to improve gut-lung immunity (Table 2).

As mentioned above, traditional Korean food is rich in fermented fruits and vegetables as cabbage. This has already been reported to help mitigate the COVID-19 severity (Bousquet et al., 2020). It may also be associated with the richness of phenolic compounds and antioxidants in these foods, as well as with the high levels of *Lactobacilli* present and ingested upon consumption (Bousquet et al., 2020; Park et al., 2013). Therefore, the Korean diet has various fronts on which it can offer better outcomes for patients with COVID-19: high content of important bacteria for a healthy gut, high levels of antioxidants and phenolic compounds that can act as an anti-inflammatory and nutritionally rich in whole grains, fibers, and vitamins that further support a healthy balance for immunity and gut microbiota. In fact, antiviral properties have already been highlighted in these functional foods, particularly for their immune-promoting nutraceutical properties, through antioxidation and anti-inflammation features as summarized by Alkhatib (Alkhatib, 2020).

The lung epithelium in the adult is arranged in different types of cells. The tracheo-bronchial epithelium is a pseudo-stratified layer with ciliated cells and secretory epithelial cells (Clara), and goblet cells. Human basal cells (potential epithelial progenitor cells) appear in high numbers below this layer, decreasing as the lung proceeds into the alveolar space. Neuroendocrine cells may also occur and be innervated by ganglion cells, which are described to regulate cell proliferation and differentiation. Respiratory bronchioles' structure is not very well described, and these lead to the alveoli, which are known to be linked mainly by type I and type II alveolar cells (Camelo, Dunmore, Sleeman, & Clarke, 2014). Therefore, lungs epithelia may differentiate into different cell types, including types I and II pneumocytes (Fig. 2). Type II pneumocytes make important proteins that reduce the surface tension of the alveoli, preventing them from collapsing. While type I pneumocytes are thin, flat cells that grant gas exchange between the alveolus and the surrounding blood capillaries.

The SARS-CoV-2 virus can attach and infect alveolar pneumocytes. These primary human epithelial cells are their ACE-2 receptor, the gateway portal for SARS-CoV-2, and a different histological structure that may respond differently to virus infection. Therefore, a potential antiviral that can reduce the virus titter, an improvement in the survival rate, and a reduction in the rate of symptoms accumulated from the moment of contagion will be considered beneficial for future medical applications. This can occur via different pathways or mechanisms, as suggested in Fig. 2. An innate immune response against a virus in the respiratory tract is mediated by recognizing molecular patterns associated with viruses by specific receptors expressed in epithelial cells.

Intake of immunobiotics as yogurts or fermented/preserved foods can induce resistance and effective immune responses against viruses infection in the respiratory tract (Zelaya, Alvarez, Kitazawa, & Villena, 2016). Moreover, the respiratory tract also has significant remodeling capacity that can originate in an aberrant epithelial cell (genetic mutations) or exposure to external irritants and viruses or cigarette smoke, and this follows similar pathways to those that describe the benefits of

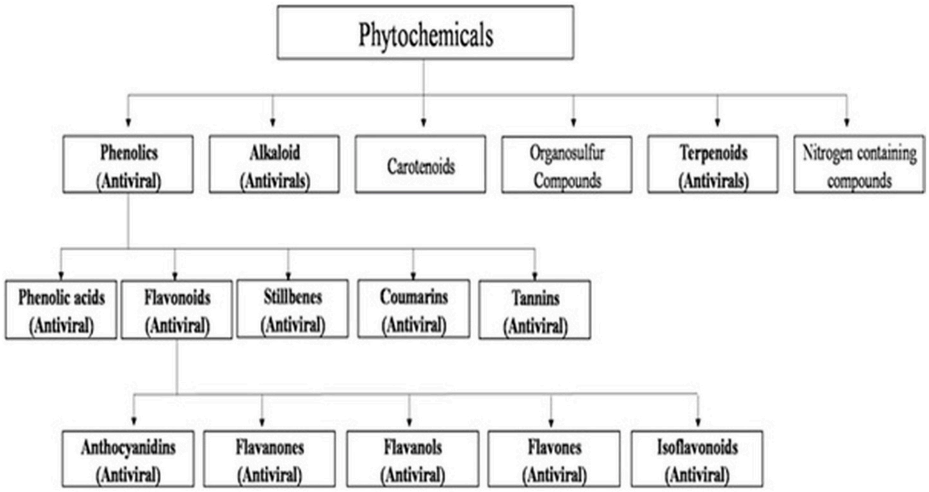

Fig. 3. - Classification of phytochemicals used as antivirals. Reproduced from Ghildiyal et al. (Ghildiyal, Prakash, Chaudhary, Gupta, & Gabrani, 2020), under the PMC Open Access Subset for unrestricted research re-use and secondary analysis in any form or by any means with acknowledgement of the original source (originally Fig. 1).

immunobiotics (e.g., *Lactobacillus* probiotics) (Camelo et al., 2014; Zelaya et al., 2016).

The effect of the gut microbiome on the immune response at distal sites or organs and its effects on the outcome of respiratory infections or disorders is now increasingly relevant and clear; gut microbiota assists in regulating the antiviral immunity (Abt et al., 2012; Ichinohe et al., 2011), and this has been especially exposed in infants nutrition (Berni Canani et al., 2017; Goehring et al., 2016) and adults with chronic illness as asthma (Williams et al., 2016). Potential plant-based drugs have been continuously screened for their antibacterial, antiviral, anti-cancerous, and antioxidant activities. More recently, antiviral properties have also been evaluated as plant-based antiviral natural compounds that may offer less toxicity and may be coupled with pre-existing therapies, along with improved delivery methods for greater effectiveness and bioavailability. Common plant compounds include flavonoids, phenolics, carotenoids, terpenoids, alkaloids, and many others, many of which have documented antiviral activities (Fig. 3).

The medical and scientific communities are increasingly interested in ethnophytopharmaceuticals, as they offer complementary therapeutic options, with easy and inexpensive access along with the low potential for toxicity. The traditional Korean diet is rich in ingredients with a long history of ingredients and elements with strong antioxidant, anti-inflammatory, antiviral, antibacterial, fat metabolism, and modulating gut microbiota properties that further support strong respiratory immunity. However, research on nutraceuticals, plants, and food elements remains inconsistent and very confusing. Collaborations across several fields, from agriculture to chemistry and biomedical, will be important to fill the gap. Different comprehensive studies are needed to corroborate and validate associations between consuming a food and the specific health status or conditions.

Moreover, well-planned preclinical, *in vitro* and *in vivo*, and chemical investigations are still lacking. In controlled feeding trials, validation, as well as small populations and non-standard evaluation systems hold limitations. Thus, adequate, comprehensive study designs are required to validate the clinical functions of any particular food. Additionally, before the COVID-19 pandemic, universal systems were proposed to study coronavirus-host interaction *in vitro* in an attempt to respond to the need for identification of antivirals, evaluation of compound toxicity, and viral inhibition (e.g. (Jonsdottir & Dijkman, 2016)). However, these systems have not been explored enough when it comes to report the antiviral properties of plants and foods. To adds up to the current information, recently a clinical practice guideline has also been developed for the treatment of the SARS-CoV-2 using the Korean herbal medicine (Lee, Lee, Kim, Choi, & Jung, 2020). Further a number of panel discussion has also been published on the role of the Korean Medicine including the traditional herbal medicine that includes plant based components for the treatment in the post COVID-19 era (Kwon et al., 2020; Park et al., 2020).

4. Chemical constituents in the Korean tradition foods with antiviral and anti-respiratory medicinal effects

4.1. Chemical constituents in kimchi

Kimchi is the most widely distributed and popular Korean fermented food, which is prepared with napa cabbage or the Chinese cabbage or with radish as its main ingredients (Patra, Das, & Paramithiotis, 2017). *Kimchi* is prepared by mixing baechu, radish, powdered red pepper, salt, garlic, ginger, scallion, fermented fish, sugar and flavor enhancers. The addition of all these ingredients enhances the nutritional value of kimchi by incorporating carotenoids, vitamin C, chlorophyll, capsaicin, sulfur-containing compounds, phenolic compounds, dietary fiber, and fermentation metabolites such as lactic acid, glycoproteins, and bacteriocin (Patra et al., 2017). In addition, the literature research states that most of the chemical constituents present in fermented Korean foods are metabolites of fermentation (Table 3). For instance, when amino acids are evaluated, most of the measured free amino acids are produced due to the proteolytic action of microbial enzymes (Patra et al., 2016).

4.2. Chemical constituents in chongkukjang, doenjang, and Gochujang

Chongkukjang is a traditional Korean food prepared in rice straw and boiled soybean fermented with *Bacillus* species rich in polyglutamic acid, isoflavones, phosphatide, and phenolic acids (Chang, 2018; Kim, Song, et al., 2008). Moreover, Kwon, Chung, and Jang (2019) stated that, unlike *Doenjang* and *Gochujang*, *Chongkukjang* fermentation takes only 2–4 days. Other reports mention that *Chongkukjang* has anti-inflammatory and antidiabetic properties, which are partially attributed to the chemical constituents of the soybean and its fermentative metabolites (Kwon et al., 2019; Wei et al., 2015). Also, *Doenjang* is a traditional Korean food made by mixing and fermenting soybeans for about six months using *Bacillus subtillis*, *Rhizopus* spp., and *Aspergillus* spp. (Lee, Kim, Park, Song, Nam, & Ahn, 2018).

Furthermore, *Gochujang* is a Korean traditional fermented food based on a paste of red pepper-soybean and is commonly used as a sauce in spicy Korean cooking. The main ingredients of *Gochujang* are red hot

Table 3
Chemical constituents of *Kimchi*.

Vegetable source	Compounds	References
Kimchi cabbages	Organic acids: acetic acid, citric acid, succinic acid, lactic acid, fumaric acid. Free sugars: fructose, glucose, sucrose, mannitol. Volatile compounds: allyl methyl disulfide, dimethyl trisulfide, diallyl tetrasulfide, 4-ethyl-5-methylthiazole, allyl methyl trisulfide, 3-vinyl-[4H]-1,2-dithin, and 2-phenylethyl isothiocyanate	(Choi, Yong, et al., 2019)
Kimchi fermented with *L. mesenteroides*[a]	Lactate, ethanol, acetate, mannitol, diacetyl, acetoin, and 2,3-butanediol	(Chun, Lee, Jeon, Kim, & Jeon, 2017)
Kimchi fermented with red pepper	Glucose, fructose, lactate, acetate, mannitol	(Jeong, Lee, Jung, Lee, et al., 2013)
Metabolite composition of *Kimchi* during long-term storage	Decreased levels of free sugars fructose and glucose during storage. Increased levels of lactate, acetate, succinate, gamma-aminobutyric acid, and mannitol.	(Jeong, Lee, Jung, Choi, & Jeon, 2013)
Metabolic features of *W. koreensis*[b] during Kimchi fermentation	Fermentation metabolites: D-lactate, ethanol, acetate, D-sorbitol, thiamine, folate. Carbohydrates: glucose, mannose, lactose, malate, xylose, arabinose, ribose, N-acetyl-glucosamine, and gluconate	(Jeong et al., 2018)
Kimchi prepared with napa cabbage and different salts	Volatile metabolites: α-pinene, camphen, myrcene, 1-phellan, dimethyl trisulfide, diallyl disulfide, dipropyl disulfide, 1-butene-4-isothiocyanate, phenethyl isothiocyanate. Nonvolatile metabolites: alanine, valine, proline, serine, threonine, glutamate, phenylalanine, mannitol, tryptophan, stearidonic acid, pinolenic acid, capsaicin, dihydrocapsaicin.	(Kim et al., 2017)
Thirteen Korean *Kimchi* samples from Jeonju	Resveratrol (from the conversion of polydatin into resveratrol by the strain *Lactobacillus kimchi* JB301), isorhapontigenin, oxyresveratrol.	Ko et al. (2014)
Kimchi fermented with *L. plantarum*[c]	Increased lactic acid levels, glycerol, pyrotartaric acid, pentanedioic acid, 2-keto-1-gluconic acid, ribonic acid, isocitric acid, and palmitic acid.	(Park et al., 2016)
Mustard leaf *kimchi* extracts	Catechin, chlorogenic acid, epicatechin, epigallocatechin gallate, *p*-coumaric acid, gallocatechin gallate, ferulic acid, epicatechin gallate, rutin, catechin gallate, naringin.	(Park et al., 2017)
L. pentosus[d] isolated from *Kimchi* from Gyeonggi-do, Korea	Ginsenoside Rd, ginsenoside F2, compound K	Quan et al. (2010)
L. plantarum[c] HD1 isolated from *Kimchi* from home, restaurants, and temples located in South Korea	5-oxododecanoic acid, 3-hydroxy decanoic acid, 3-hydroxy-5-dodecanoic acid	Ryu, Yang, Woo, & Chang (2014)
Kimchi prepared with different salt contents (0 and 5%)	Lactic acid, acetic acid, xylitol, and fumaric acid.	(Seo et al., 2018)

[a] *Leuconostoc mesenteroides.*
[b] *Weissella koreensis.*
[c] *Lactiplantibacillus plantarum.*
[d] *Lactobacillus pentosus.*

Table 4
Chemical constituents of *Chongkukjang*, *Doenjang*, and *Gochujang*.

Vegetable source	Compounds	References
Chongkukjang	Poly-γ-glutamic acid	Ratha & Jhon, 2019
Chongkukjang	Genistein, daidzein	(Kim, Song, et al., 2008)
Doenjang prepared with different content of garlic (2%, 6%, 10%), and thermal processes (heat-drying and freeze-drying)	Essential amino acids: isoleucine, leucine, lysine, methionine, phenylalanine, valine. Non-essential amino acids: arginine, proline, tyrosine, glycine, alanine, serine, glutamic acid, aspartic acid. Non-proteinogenic amino acids: ornithine, *o*-phosphoserine, taurine, sarcosine, L-citrulline, y-aminobutyric acid, ethanolamine, hydroxylysine.	Bahuguna et al. (2019)
Doenjang	Amino acids: glutamate, serine, valine, glycine, leucine, phenylalanine	(Chun, Kim, Jeong, & Jeon, 2020)
Soybean koji *Doenjang*	Acids: 2-methylpropanoic acid, acetic acid, 2-methylbutanoic acid, 3-methylbutanoic acid. Alcohols: 3-methylbutan-1-ol, pentan-1-ol. Carbonyls: benzaldehyde, butane-2,3-dione. Phenols: 2-methoxy phenol.	(Jeong et al., 2020)
Doenjang	Daidzein, glycitein, genistein	(Kim & Kim, 2014)
Doenjang	Genistein, daidzein, glycitein, genistein	(Kim et al., 2018)
Doenjang	Apigenin, soyasaponin A2, trihydroxyflavone, luteolin, daidzein, glycitein, genistein, soyasaponin, soyasaponin I, soyasaponin III, soyasaponin βg	(Kim, Kwak, & Kim, 2020)
Doenjang	Daidzein, glycitein, genistein, daidzin-β-glucoside, glycitin-β-glucoside, genistein-β-glucoside, daidzin malonylglucoside, glycitin malonylglucoside, genistein malonylglucoside, daidzin acetylglucoside, glycitin acetylglucoside, genistein acetylglucoside	Kwak, Son, Chung, and Kwon (2015)
Doenjang submitted to steaming, drying, meju fermentation, brining, and aging	Isoflavones: malonyldaidzin, malonyglucitin, malonygenistin, acetyldaidzin, acetylglycitin, acetylgenistin, daidzin, glycitin, genistein, daidzein, genistein. Soyasaponins: soyasaponin I–V, soyasaponin γg, soyasaponin γa, soyasaponin Bd, soyasaponin Be	(Lee, Lee, et al., 2014)
Doenjang and metabolites in rat plasma	Isoflavones: daidzein, genistein, glycitein, malonyl daidzin, malonyl genistein, malonyl glycitin, acetyl daidzin, acetyl genistein, acetyl glycitin. Isoflavone metabolites: 3-hydroxygenistein, hydroxydihydrogenistein, daidzein-4′-glucuronide, daidzein-7-glucuronide, daidzein-4′-sulfate, genistein-4′-glucuronide, genistein-7-glucuronide, genistein diglucuronide, genistein-4′-sulfate, genistein-7-sulfate-4′-glucuronide	(Lee et al., 2018)
Gochujang fermented with *A. oryzae*	Genistein, daidzin, apigenin 7-O-β-D-glucopyranoside, quercetin 3-O-α-L-rhamnopyranoside	(Cho et al., 2013)
Gochujang	Capsaicin, dihydrocapsaicin	Ha et al. (2010)

(continued on next page)

Table 4 (*continued*)

Vegetable source	Compounds	References
Three *Gochujang* types (white rice, brown rice, and wheat)	Isoflavones: daidzin, genistein, daidzein, glycitein, genistein. Soya saponins: soya saponin.	(Jang, Shin, et al., 2017)
Gochujang prepared with different cereals (wheat, brown rice, and white rice) and peppers (*Capsicum annuum*, *C. annuum* cv. Chung-yang, and *C. frutescens*)	Apigenin-C-hexoside-C-pentoside, dihydrocapsiate, linoleic ethanolamide, luteolin-C-hexoside, quercetin-O-rhamnoside, dihydrocapsaicin	(Lee, Suh, Jung, & Lee, 2016)
Gochujang products prepared with combinations of fungal rice koji with *B. amyloliquefaciens* CJ 3–27 and *B. amyloliquefaciens* CJ 14-6	Genistein, acetylgenistin, daidzin, luteolin-diglucoside, genistein, apigenin-diglucoside, apigenin-glucoside, isovitexin-glucoside, daidzein, glycitein, luteolin, hydroxydaidzein, capsaicin, dihydrocapsaicin	Shin et al. (2016)

pepper powder, waxy rice flour, and fermented soybean (known as *meju*). *Gochujang* is usually fermented using *Aspergillus* sp. and *Bacillus* sp. strains (Cho et al., 2013). Due to the inclusion of red pepper and meju, some of the main constituents of *Gochujang* are capsaicin and isoflavones derivatives. The chemical constituents present in *Chongkukjang, Doenjang,* and *Gochujang* are shown in Table 4.

4.3. Chemical bioactive ingredients used in Korean Foods

Some of the most common ingredients in fermented Korean cuisine are napa cabbage, garlic, and ginger. These ingredients are a rich source of bioactive compounds like phytochemicals, which are secondary metabolites produced as a defense mechanism in plants against biotic and abiotic stresses. Some of the most common phytochemicals found in food-stuff are alkaloids, terpenes, glucosinolates, and phenolic compounds (Croteau, Kutchan, & Lewis, 2015). Regular intake of these compounds in the diet has been related to a decreased incidence of non-communicable diseases, and some have also been used to treat infectious diseases. In this regard, some studies point to the antiviral potential of some Korean ingredients.

For instance, Dong, Farooqui, Leon, and Kelvin (2017) reported that ginsenosides commonly found in ginseng could interact with a viral hemagglutinin protein, preventing the attachment of the H1N1 virus to host cells. The chemical structure of ginsenoside was determined to be crucial as the sugar moieties in these molecules are pivotal for their bonds with viral hemagglutinin. Moreover, fresh ginger showed *in vitro* antiviral interest against the human respiratory syncytial virus, preventing viral attachment and internalization (Chang, Wang, Yeh, Shieh, & Chiang, 2013). Some studies also hypothesize that bioactive compounds from garlic have antiviral properties against influenza A and V, rhinovirus, viral pneumonia, and rotavirus (Bayan, Koulivand, & Gorji, 2014). Also, obesity, cardiovascular diseases, and diabetes have been described to increase the risk of some respiratory viral diseases. On this subject, Korean fermented foods have been reported with the potential to decrease the formation of macrophage foam cells by inhibiting lipid peroxidation induced by oxidized low-density lipoprotein (Yun, Kim, & Song, 2014). Furthermore, *in vitro* studies have shown that garlic extracts have antiviral properties against the influenza A and B virus (Mehrbod et al., 2009; Sharma, 2019). It is important to mention that the reported compounds commonly found in ingredients used in the preparation of traditional Korean fermented foods go through a lactic acid fermentative process, which metabolizes the compounds to produce different metabolites. In this sense, some reports state that Korean fermented foods have potential beneficial health effects, like antiviral potential against the influenza virus (Park et al., 2013), as stated in section 1.

4.3.1. Cabbage

Chinese cabbage or napa cabbage (*Brassica rapa* L.) is used to prepare *Kimchi*, the most popular fermented Korean food. Chinese cabbage is a rich source of bioactive compounds, and these constituents may be related to the antioxidant and health-promoting properties of *Kimchi*. Some of the bioactive constituents most commonly identified in Chinese cabbage are glucosinolates, carotenoids, tocopherols, sterols, policosanols. Some of the most common glucosinolates found in Chinese cabbage are 4-hydroxyglucobrassicin, 4-methoxyglucobrassicin, glucoalyssin, glucobrassicanapin, glucobrassicin, gluconapin, gluconasturtiin, neoglucobrassicin, progotrin, and sinigrin (Fig. 4) (Baek, Jung, Lim, Park, & Kim, 2016). Some of the most commonly identified bioactive compounds in Chinese cabbage are shown in Table 5.

4.3.2. Garlic

Garlic contains many bioactive compounds, such as organosulfur and phenolic constituents. Some of them are phenolic compounds, like hydroxybenzoic acid derivatives, such as gallic and vanillic acid; and hydroxycinnamic acid derivatives, such as chlorogenic acid, caffeic acid,

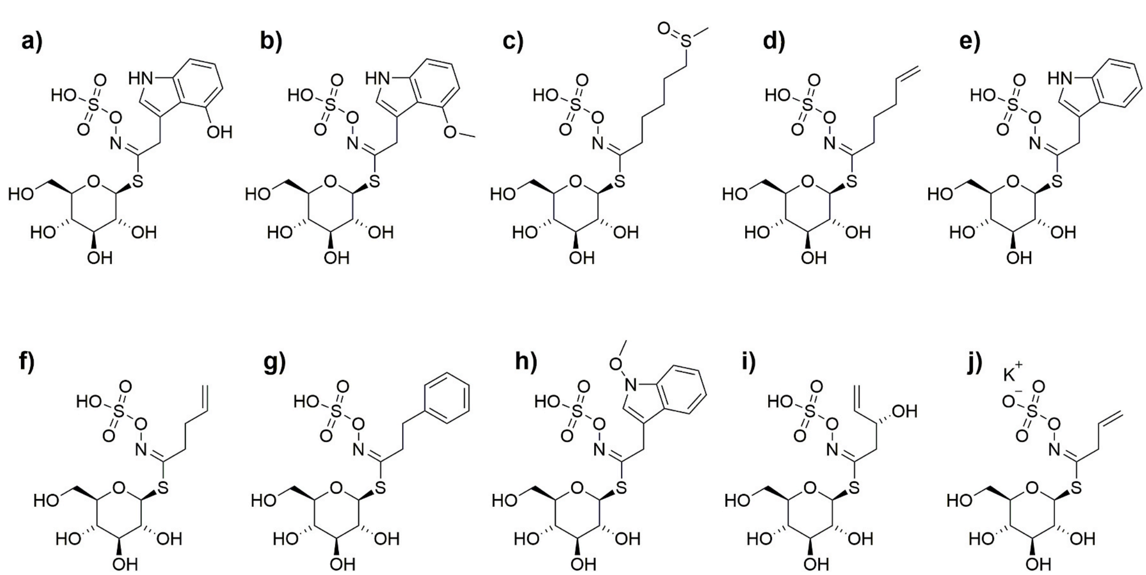

Fig. 4. Glucosinolates commonly found in Chinese cabbage. a) 4-hydroxyglucobrassicin, b) 4-methoxyglucobrassicin, c) glucoalyssin, d) glucobrassicanapin, e) glucobrassicin, f) gluconapin, g) gluconasturtiin, h) neoglucobrassicin, i) progotrin, j) sinigrin.

Table 5
Metabolites with potential health-promoting effects in Chinese cabbage used in the preparation of traditional Korean foods.

Sample	Identified compounds	Method of identification	References
Chinese cabbage	Glucosinolates: progoitrin, sinigrin, glucoalyssin, gluconapin, glucobrassicanapin, glucoeurucin, glucocochlearin, 4-hydroxyglucobrassicin, glucobrassicin, 4-methoxy-glucobrassicin, neoglucobrassicin, gluconasturtiin. Carotenoids: violaxanthin, antheraxanthin, lutein, α-carotene, β-carotene, chlorophyll.	LC-qTOF-MS	Baek et al. (2016)
Hairy roots of Chinese cabbage induced by CuO nanoparticles	Glucosinolates: gluconasturtiin, glucobrassicin, 4-methoxyglucobrassicin, neoglucobrassicin, 4-hydroxyglucobrassicin, glucoallysin, glucobrassicanapin, sinigrin, progoitrin, and gluconapin. Hydroxycinnamic acids: *p*-hydroxybenzoic acid, protocatechuic acid, syringic acid, gentisic acid, vanillin. Hydroxycinnamic acids: *p*-coumaric acid, ferulic acid, chlorogenic acid, t-cinnamic acid. Flavonols: myricetin, quercetin, kaempferol, catechin, naringenin, rutin, hesperidin.	UHPLC and UHPLC-TQMS	Chung, Rekha, Rajakumar, and Thiruvengadam (2018)
Non-heading Chinese cabbage	Phenolic compounds: kaempferol-O-sophoroside-O-hexoside, kaempferol-dihexoside, kaempferol-sophoroside, kaempferol hexoside, myricetin-O-arabinoside, ferulic acid, quinic acid, protocatechuoyl hexose	UPLC-MS	Managa, Remize, Garcia, & Sivakumar (2019)
Chinese cabbage sprouts	Aliphatic glucosinolates: progoitrin, sinigrin, glucoalyssin, gluconapin, glucobrassicanapin. Indolic glucosinolates: 4-hydroxyglucobrassicin, glucobrassicin, 4-methoxyglucobrassicin, neoglucobrassicin	HPLC-DAD	Samec, Pavlovic, Redovnikovic, and Salopek-Sondi (2018)
Chinese cabbage (leaves and roots)	Glucosinolates: glucobrassicin, 4-methoxy glucobrassicin, neoglucobrassicin	HPLC	Zang et al. (2015)
Chinese cabbage	Glucosinolates: glucoallysin, sinigrin, progoitrin, gluconapin, glucobrassicanapin, gluconasturtin, glucobrassicin, 4-methoxyglucobrassicin, neoglucobrassicin, 4-hydroxyglucobrassicin	UPLC	Thiruvengadam, Kim, & Chung (2015)

Abbreviations: HPLC - High Performance Liquid Chromatography; HPLC-DAD - high-performance liquid chromatography with a diode-array detector LC-qTOF-MS - liquid chromatography in combination with hybrid quadrupole time-of-flight mass spectrometry; UPLC - ultra performance liquid chromatography; UPLC-MS - Ultra performance liquid chromatography - tandem mass spectrometer; UHPLC-TQMS - ultra-high performance liquid chromatography coupled with a triple quadrupole mass spectrometry.

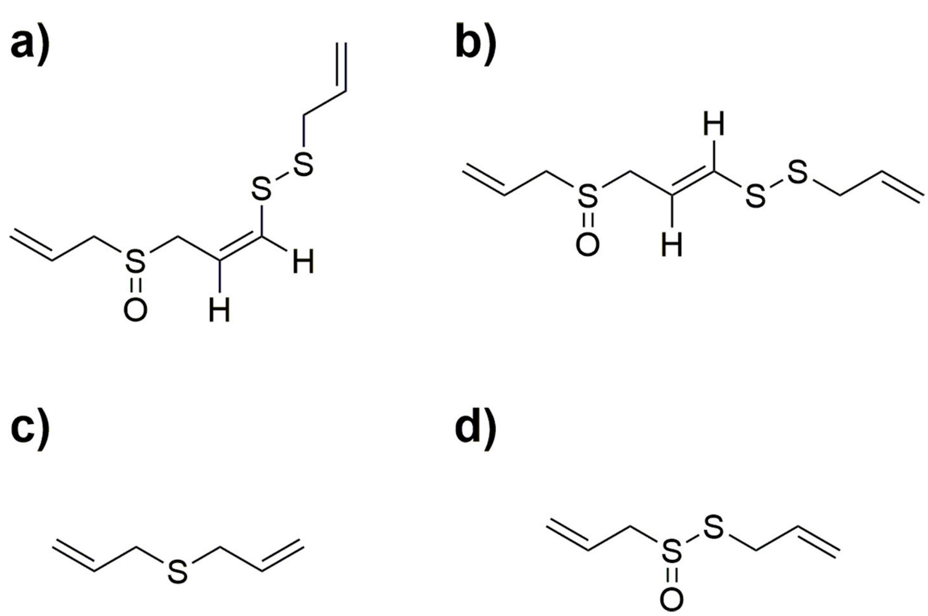

Fig. 5. Graphical representation of some bioactive compounds in garlic: a) (Z)-ajoene, b) ajoene, c) diallyl sulfide, d) allicin.

ferulic acid, *p*-hydroxybenzoic acid, *m*-coumaric acid, *o*-coumaric acid, *p*-coumaric acid (Beato, Orgaz, Mansilla, & Montano, 2011; Kim, Kang, & Gweon, 2013). Garlic is also the source of flavonoids like the flavanols catechin, epicatechin, and epigallocatechin gallate; flavonones like quercitrin and apigenin; flavonols like myricetin, resveratrol, morin, quercetin, and kaempferol (Fig. 5) (Kim et al., 2013). Furthermore, one the most important bioactive compounds identified in garlic is the non-volatile amino acids containing sulfur-like alliin, allicin, (E)-ajoene, diallyl sulfide, (Z)-ajoene, and 1,2-vinyldithiin (Lu et al., 2011; Martins, Petropoulos, & Ferreira, 2016).

4.3.3. *Ginger*

Ginger is one of the main ingredients in many food preparations in Korea. Ginger is a rich source of phytochemicals with potential health-promoting effects. Some of the main bioactive constituents found in this root are phenolic compounds, such as gingerols, like 6-gingerol, which is the compound responsible for the pungency of fresh ginger; while shogaols are the main causes of pungency in dry gingers, and these compounds are derived from gingerols; some other constituents are zingerone, paradols like 6-deoxy gingerol and methyl paradols (Fig. 6) (Alsherbiny et al., 2019). Some other gingerols found in ginger are 8-gingerol, 10-gingerol, 6-shogoal (Brahmbhatt, Gundala, Asif, Shamsi, & Aneja, 2013). Also, different ginger plants of the *Boesenbergia* species have phenolic compounds like quercetin, kaempferol, rutin, naringin, hesperidin, caffeic acid, *p*-coumaric acid, sinapic acid, chlorogenic acid, gallic acid, luteolin, and diosmin (Jing, Mohamed, Rahmat, & Abu Bakar, 2010). Some terpenes found in ginger are β-bisabolene, α-curcumene, zingiberene, α-farnesene, and β-sesquiphellandrene.

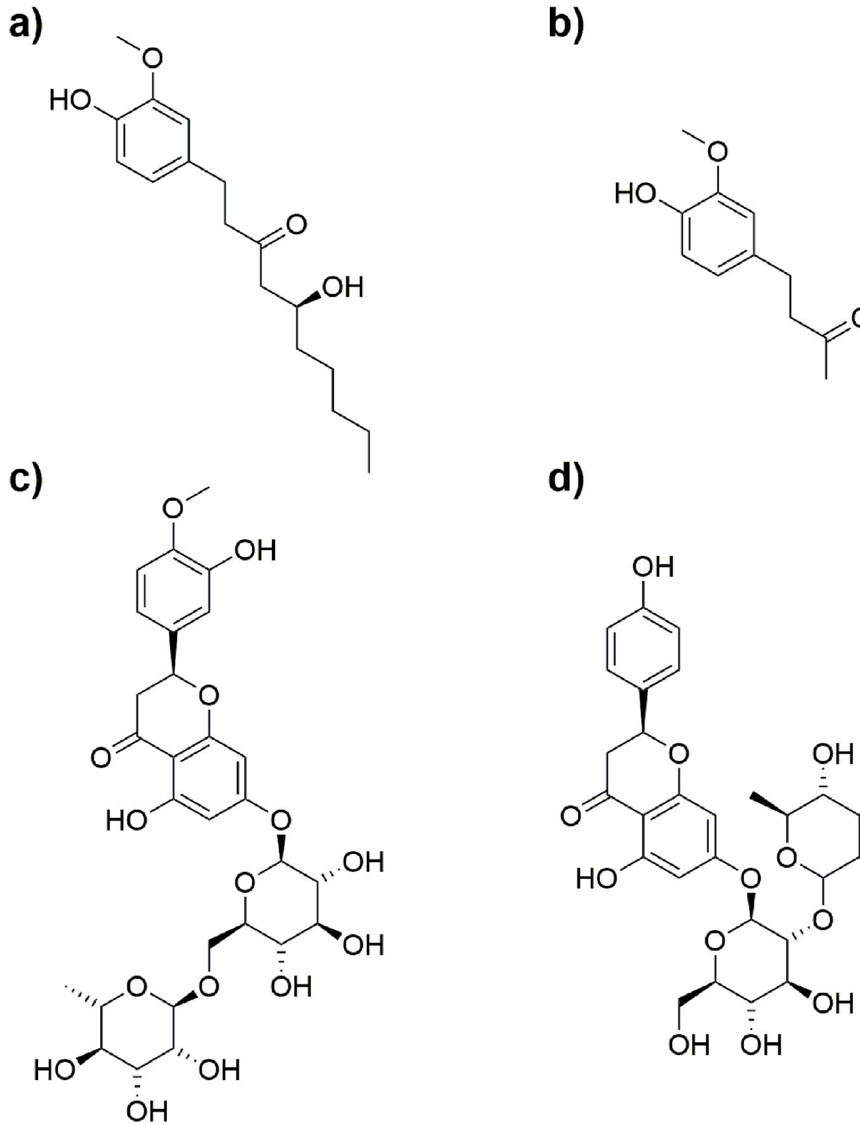

Fig. 6. Graphical representation of some bioactive compounds found in ginger: a) gingerol, b) zingerone, c) hesperidin, d) naringin.

5. Pre-clinical and clinical effectiveness in humans

Dietary measures are widely used as adjuvant treatments against influenza infections. Many fermented foods have antioxidant abilities, which promote the inhibition of essential enzymes and the disruption of cell membranes, thus avoiding viral binding and enhancing the capacity of the immune system. As stated in previous sections, fermented Korean foods are of great value by the multiplicity of microorganisms with a positive impact on the microbiota (protect the intestinal mucosa) and confer greater resistance to the immune system – immunobiotics and/or probiotics. Several microorganisms from fermented foods have been described to improve human immune response against viral infections (Arena et al., 2018). Antiviral effects of lactic acid bacteria (LAB) may be due to increased intestinal barrier function or stimulation of the immune system through the increase of macrophage activity and the production of antiviral inhibitory substances (H_2O_2, organic acids). The potential of heat-killed *Lactobacillus* probiotics against influenza was highlighted (Park et al., 2018).

Patra et al. (2016) reviewed many health benefits of *Kimchi*. Among different pharmacological properties of these foods, namely *Kimchi*, are their role in modulating the immune system. Activators for the potent transcription factor Nrf2 (nuclear factor erythroid-2-related factor 2) presented in some fermented Korean vegetables, as *Kimchi*, are suggested to improve health and metabolism. Fermented cabbage was recently proposed to increase the Nrf2-related antioxidant effects against COVID-19, modulating the severity of the symptoms and patient outcomes (Bousquet et al., 2020). The potential of dietary use of some fermented foods, probiotics, and prebiotics are being discussed as strategies to promote gut and upper respiratory tract immunity to better face a possible viral infection as by Sars-Cov-2, including in patients with COVID-related gastro-intestinal symptoms (Antunes, Vinderola, Xavier-Santos, & Sivieri, 2020).

The *Lactiplantibacillus plantarum* (previously designated *Lactobaccilus plantarum*) strain YU (LpYU), originally isolated from traditional Japanese fermented foods and one of the lactic acid bacteria (LAB) well known for its positive effects on immune function, was reported to activate Th1 immune responses on mice and prevent infection by the influenza A virus (A/NWS/33, H1N1) (Kawashima et al., 2011). In this work, mice were dosed with 0.011, 0.21, or 2.1 mg/day for 14 d, prior to intranasal inoculation of influenza A virus (IFV). Lungs and bronchoalveolar lavage fluids (BALFs) were studied to demonstrate that LpYU activated the innate and acquired immune systems.

The intake effects of two Korean traditional fermented soybean products, *doenjang* and *cheonggukjang*, or a mixture of both, have also

Table 6

Pre-clinical studies on the effects of microorganisms from Korean fermented foods on laboratory animal models. Abbreviations: BALFs - bronchoalveolar lavage fluids; CGJ - *Cheonggukjang*; EPS - exopolysaccharides; IAV - influenza A virus; IFV- influenza vírus; i.p. intraperitoneal; nF1 - heat-killed *Lactiplantibacillus plantarum*; OVA - ovalbumin; MLD50 - 50% mouse lethal dose; CFU - colony-forming unit; FFU – fan filter unit; IFN-α - interferon alpha; IgA – immunoglobulin A antibody; PFU – plaque-forming unit.

Aims	Animal model	Exposure route	Evaluated Parameters	Dosing and period	Main Results	Reference
Evaluate L. *brevis*[a] KB290 impacts against influenza virus infection in mice	Mice	Oral		Lyophilized KB290 suspended in PBS for 14 days and then intranasally infected with 50% mouse lethal dose of IFV	*L. brevis*[a] alleviated clinical symptoms, by production of IFN-α and increase of IFV-specific IgA production	Waki et al. (2014)
Evaluate if pretreatment of mice with *L. plantarum*[b] from the fermented Korean cabbage can increase protection against influenza virus infection	Mice	Intranasal or oral exposure	BALFs and lungs	Animals were treated once with (107 CFU/mouse) of *L. plantarum* DK119 strain (, 4 days prior infection with a lethal dose of influenza virus	*L. plantarum*[b] showed to be a beneficial probiotic against influenza virus infection byintranasal or oral exposure	(Park et al., 2013)
Evaluate the therapeutic effect of CGJ on a mouse model of ovalbumin (OVA)-induced asthma by the suppression of histamine release	Mice	I.p.	BALFs, lungs	After sensitized by i.p. of OVA and then turned with OVA inhalation, animals were administered i.p. ethanol-extracted CGJ (100 mg/kg/day) for 16 days.	Efficacy of CGJEs as a dietary therapy of histamine-mediated allergic diseases, probably by inhibition of mast cell activation.	Bae, Shin, See, Chai, and Shon (2014b)
Evaluate the health benefits of regular oral intake of nF1 against influenza virus infection	Mice	Oral		Daily oral intake (10 mg) of nF1 for 14 days followed by intranasally MLD50 of influenza A and B viruses, and the same feeding regimen for 14 days	Daily oral intake of nF1 delayed death of infected mice; increased survival rates	(Park et al., 2018)
Evaluate anti-rotavirus activity by the bacterial supernatant, lysate, and the EPS from *L. plantarum*[b]	Mice	Oral	Blood, heart, and small intestine	EPS (1 mg/mouse) for 2 days prior and 5 days after pups infection with the murine rotavirus epidemic diarrhea (10 μL of 2 × 10[d] FFU)	Decreased the duration of diarrhea, limited epithelial lesions, reduced rotavirus replication in the small intestine, and better animal recovery by EPS	(Kim et al., 2018)
Evaluate the immune-stimulatory effects of *L. bulgaricus*[c] on the OSV-induced suppression of local and systemic humoral immunity in mice infected with IAV	Mice	Oral	BALFs, lungs	Daily single oral dose of 400 μL of *L. bulgaricus*[c] for 35 days. On d22, intranasal infection with 0.5 pfu IAV; followed by oral 50 μg of OSV in 100 μL of 5% methylcellulose (MC) as a vehicle or MC alone, twice daily	Regular intake of *L. bulgaricus*[c] can stimulate humoral immunity of anti-PR8-specific S-IgA and IgG in BALF and anti-PR8-specific IgG and IgA in serum against IAV infection	Takahashi, Sawabuchi, Kimoto, Sakai, & Kido, 2019
Evaluate if *S. succinus*[d] from doenjang normalises immune response and benefits allergic diseases	Mice	Oral	BALFs, lung, mediastinal lymph nodes, mesenchymal lymph nodes and spleen	*S. succinus*[d] (5×10^7 CFU/mouse) every other day to day 20, then sensitized and replaced by ovalbumin as an allergen	Therapeutic potential for allergic asthma, due to suppression of airway inflammation by increase in Treg (regulatory T cells) responses	(Kim, Song, Lim, Lee, & Lee, 2019)

[a] *Levilactobacillus brevis.*
[b] *Lactiplantibacillus plantarum.*
[c] *Lactobacillus bulgaricus.*
[d] *Staphylococcus succinus.*

been evaluated on the mice's immune response. However, no antiviral properties were explored in this study (Lee, Paek, Shin, Lee, Moon, & Park, 2017). The conclusion pointed to the increase in humoral and cellular immunity via Th1 responses in mice fed both products, suggesting an improved synergic effect. However, the antiviral properties of *Lactiplantibacillus plantarum* DK119, a microorganism isolated from fermented Korean cabbage, has been studied against the influenza virus, using a mouse model in a dose and route -dependent way (Park et al., 2013). In this study, animals infected with influenza virus were intranasally or orally exposed to *Lactiplantibacillus plantarum* DK119, which effectively lowered lung viral loads. The bronchoalveolar lavage fluids from mice showed elevated concentrations of cytokines IL-12 and IFN-γ, and a low degree of inflammation, which indicates the bacteria's antiviral effects by modulating innate immunity.

Other pre-clinical studies demonstrated the antiviral effects of some microorganisms from fermented Korean food on the influenza virus. Table 6 displays some representative studies involving lactic acid bacteria (LAB) isolated from fermented foods and their immunobiological activity on animal models infected with the virus under different conditions. The preclinical studies presented in Table 6 demonstrate that the intake of Korean fermented foods, such as *Kimchi* and *Cheonggukjang* or even *Lactobacillus* isolated from these foods, improves the immune system, not only of healthy animals but also in models infected with various types of virus or with asthma. The microorganisms present in this type of foods can offer protection for some viral diseases. They have been shown to have protective and immunomodulatory effects, namely upon regular oral intake of heat-killed forms isolated from *Kimchi*.

As the polyherbal formula Mahwangyounpae-tang (MT), other Korean dietary supplements have been used to treat respiratory diseases, including asthma (Park, Choi, Kim, Lee, & Ku, 2010). This supplement, which contains 22 types of herbal extracts, was orally given to different groups of rats for 28 d at different doses (800, 400, and 200 mg/kg per day) and showed no significant toxic effects, confirming, therefore, the safety of these products. Previous studies investigated the pharmacological efficacy for the asthma treatment in mice only using 30 mg/kg of MT (Kim, Kim, & Kam, 2003). Also, in humans, Korean fermented foods as *kimchi* were investigated for potential immune system-stimulating effects (Lee, Kim, Lee, Jang, & Choue, 2014). In this study, healthy college students aged over 20 and having a body mass index of 18.5–23.0 kg/m^2 took 100 g of *Kimchi* once a day for one month.

However, no significant immunomodulatory effects were detected, possibly due to the short period of intake of *Kimchi*.

Clinical trials involving school-aged children were also conducted by Huang, Chie, & Wang (2018), focusing on the therapeutic impacts of *Lacticaseibacillus paracasei* (LP), *Limosilactobacillus fermentum* (LF), and the co-exposure (LP and LF) on asthma, biomarkers of immune function, and fecal microbiota or flora. These probiotics with well-known immunomodulatory effects were given to the children for three months. A co-exposure was reported most effective, resulting in risen peak expiratory flow rates and decreased IgE levels. As Korean fermented foods are rich in several of these pro- and pre-biotics, it offers a possible nutraceutical/supplement or functional food value that is yet to be characterized to treat respiratory disorders and infections, including in children, holding it at their fair safety. Clinical studies are still few to elucidate better the role of these foods in infections of the respiratory system.

6. Conclusion

Korean traditional foods are widely recognized for their delicious and spicy flavor, as well as health benefits. One of the most recognized Korean fermented foods is *Kimchi* (a mixture of fermented vegetables) among others such as *Meju*, *Doenjang*, *Jeotgal,* and *Mekgeolli*, which exhibit several medicinal effects (e.g., anticancer, antiobesity, antioxidant, anti-inflammatory, antidiabetes) and involve several beneficial microorganisms (e.g., *Leuconostoc mesenteroides*, *Lactiplantibacillus plantarum*, *Aspergillus* sp., *Bacillus* sp., *Halomonas* sp., *Kocuria* sp., *Saccharomyces cerevisiae*). It should be noted that other epidemiological situations caused by the new influenza A (H1N1) and more recently the pandemic COVID-19, induced by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has been devastating, causing more than 1.21 million deaths worldwide. In addition, edible plants and mushrooms are used in Korean traditional medicine to treat different health events. The consumption of traditional Korean foods, such as those fermented by lactic acid bacteria, is recognized to produce metabolites with antiviral effects against respiratory diseases (e.g., influenza virus H1N1) by stimulating the immune system. In fact, increased levels of interferons (INF-α and INF-β) and interleukins (IL-6), in addition to the high secretion of cytokines IL-2, IL-12 and IFN-γ are produced upon, for example, *Lactobacilli* intake. Adding to this, fermented foods such as *kimchi* and *doenjang* also provide a set of antioxidants and vitamins (e.g., ascorbic acid), strengthening the immune system and preventing or modulate allergic reactions such as rhinitis and asthma.

The role of gut microbiota on viral infections has been highlighted in the literature. The gut-lung or axis relationship already reported before the COVID-19 outbreak may predict the patient's prognosis for SARS-CoV-2 infection, particularly when considering gut symptoms (such as diarrhea and nausea) in patients with worse outcomes. Thus, the Korean diet, rich in fibers and a variety of vegetables, fruits, whole grains, nuts and seeds, herbs and spices, and fermented foods (such as Kefir, *kimchi,* and *sauerkraut*) may lead to a healthy gut microbiome, which may support a better immune response to viral infections, thus inducing an effective protective response to COVID-19.

In addition, plant-based compounds with antiviral properties (e.g., flavonoids, phenolics, carotenoids, terpenoids, alkaloids, and many others) may aid with an improved immune response besides the nutritional and medicinal values already well recognized. Moreover, this type of diet can also help COVID-19 patients to recover and improve clinical outcomes due to the high levels of antioxidants and phenolic compounds that further support a healthy balance for immunity and gut microbiota. In summary, the regular consumption of a healthy diet that includes, e.g., the Korean functional foods can support human respiratory health, namely via the antiviral properties of its ingredients, particularly due to their immune-promoting nutraceutical properties. It has been suggested by the clinical research that the food supplements such as curcumin and zinc have great potentials in terms of their antiviral activities and thus these types of food supplements can be useful in the treatment of COVID-19 to boost the immune system. Although these types of food supplements with their immense medicinal potentials proves helpful in the treatment of COVID-19, however the food supplement-drug interaction should be taken into consideration in terms of increasing toxicity and their drug efficiency. Although much is already known on the properties of functional foods, well-planned preclinical and clinical studies are required to elucidate their role in infections of the respiratory tract. In addition, chemical investigations on the nutraceutical/biomedical properties of both these ingredients and fully prepared foods may offer a template for improved therapeutics for respiratory infections.

Declaration of competing interest

The authors declare no conflict of interest with the manuscript.

Acknowledgments

The authors are grateful to their respective institutions for support. GD, HSS and JKP acknowledges Dongguk University, Republic of Korea for support. This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2020R1G1A1004667), the Republic of Korea. MLP acknowledges the project CICECO-Aveiro Institute of Materials, UIDB/50011/2020 and UIDP/50011/2020, national funds by FCT/MCTES.

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