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MINI REVIEW

Ginger rhizomes (*Zingiber officinale*) functionality in food and health perspective: a review

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Abstract

Ginger is a spice type used by rhizome. Ginger has long been used to heal various diseases, including inflammation and digestive disorders. As the development of science, the food and health sector, mostly use ginger as functional food and medicine because of its usefulness. Ginger's role as food and medicine has been recognized as safe, classified in Generally Recognized as Safe (GRAS) by the Food Drug and Administration (FDA). The content of bioactive compounds in ginger classified as volatile and non-volatile compounds contributes positively to food and health. Ginger can be used as fresh, dried, essential oils, oleoresin, extracts, or powders. Oleoresin and essential ginger oil are extracts used extensively in food and health fields. To obtain the extract, an extraction that multiplies thermal and non-thermal processes can be performed. Many use gingers as a condiment for food. Ginger gives a spicy taste that's typical of food and drink. It also contributes to a natural antioxidant, extends food products' shelf-life, and improves the organoleptic quality of food products. Whereas ginger consumption can help decrease blood glucose in type 2 diabetes mellitus, analgesics, reduce uric acid, lessen muscle pain, and increase the body's immune system. In this study, we have reviewed ginger, the red ginger extraction process, and functional compounds, food, and health benefits.

1. Introduction

Ginger (*Zingiber officinale Rosc.*) is indeed a plant type from the Zingiberaceae family. Its name "*Zingiber*" comes from the Greek "*Zingiberi*" and Sanskrit "*Singabera*" meaning horn because the ginger rhizome has a shape nearly the same as a deer antler and the name "*Officinale*" comes from the Latin "*Officina*" meaning it is used in medicine or pharmacy (Vasala, 2012). Ginger rhizomes can be widely used in food and drinks. It's due to ginger's nature as a spicy spice and gives a savory sensation. Ginger is also used in a variety of food and beverage applications, providing specific functional properties due to their bioactive compounds (Srinivasan, 2017). You can also use ginger rhizome products in the form of fresh ginger, durable ginger, dried ginger, ginger powder, ginger essential oil, ginger oleoresin, and ginger paste (Vasala, 2012).

In traditional medicine, the ginger rhizome has long been used to treat a variety of foods to help digestion and to treat colic, diarrhea, and nausea (Sharifi-Rad *et al.,* 2017). At present, ginger extracts of water-ethanol produce oleoresin and essential oils which contain many phenolic compounds. The compounds extracted have functional and pharmacological properties such as antioxidants, antihyperglycemic, antimicrobial, anticarcinogenic, anti-inflammatory, immunomodulatory, antilipidemic antitumor, and antimutagenic (Ali *et al*., 2008; Arablou and Aryaeian, 2018; Mahboubi, 2019). Phenolic compounds also have spicy properties, including volatile compounds like gingerol, shogaol, paradol, and zingerones (Ali *et al*., 2008; Arablou and Aryaeian, 2018; Srinivasan, 2017). It is also believed that ginger can fight the common influenza virus and influenza-like symptoms (Sahoo *et al*., 2016). Fresh ginger proved effective against plaque formation induced in the airway epithelium by a human respiratory syncytial virus (HRSV). Fresh ginger's role hinders virus sticking and internalizing (Chang *et al*., 2013). Because of these properties, ginger has also been developed to improve its functionality in the form of nanoparticles as a drug delivery with various advantages that it needs to increase the prevention and treatment of inflammatory bowel disease (Zhang *et al*., 2018). This review provide critical insights on ginger, its constituent bioactive compounds, bioactive compound extraction,

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food and health perspectives and potential directives for future research.

2. Extraction and chemical composition of ginger bioactive compounds

As just a natural remedy, ginger is a diverse herb comprising 60-70% carbohydrates, 9% protein, 8% ash, 3-6% lipids, 3-8% crude fiber, 9-12% water, and 1-3% essential oils (Kim and Kim, 2010; Mahboubi, 2019). Ginger oil's chemical composition is influenced by rhizome source, freshness, or dryness and extraction method (Mahboubi, 2019). While oleoresin, consisting of gingerol, zingiberene, shogaol, is classified as a non-volatile component contributing to bitter and spicy taste. Zingerone is a stinging tastemaker from the ginger rhizome. It also works against Escherichia coli bacteria causing diarrhea and Bacillus subtilis as it has high zingerones and gingerol compounds (Ravindran and Babu, 2016). Gingerol provides a strong spicy taste (Baliga *et al*., 2013). The main compound responsible for spicy rhizomes is 6-gingerol, while some other gingerols (4-, 8-, 10- and 12-gingerol) were also available in limited amounts (Mahomoodally *et al*., 2019). However, because it is thermally labile, this compound is converted to shogaol at high temperatures, e.g. when cooking, giving the ginger a spicy-sweet aroma. Gingerol and shogaol biological properties have antimicrobial, anticancer, antioxidant, anti-inflammatory, and anti-allergic properties (Srinivasan, 2017; Vasala, 2012). Shogaol has an anti-coughing effect, while gingerol contributes to ginger's analgesic properties (Mao *et al*., 2019). Besides phenolics, diarylheptanoid and zingerone were also detected in ginger. Bioactive compounds are believed to be due to health benefits (Shukla and Singh, 2007; Febriani *et al*., 2018). Thereby, the nutritional supplement content of ginger is associated with the specificity of active substances, especially the main phenolic groups like gingerol, shogaol, zingiberene, paradol, and zingerone (Mao *et al*., 2019).

Different techniques were used to extract essential ginger oils. The most common method is the hydrodistillation (dos Santos Reis *et al*., 2020). Hydrodistillation, plant material undergoes a drying process aimed at inhibiting the activity of microbes and reducing the water content to ensure optimum extraction of essential ginger oil (Rahimmalek and Goli, 2013; An *et al*., 2016). The suggested drying time may vary from 3 to 7 days, guess it depends on the dried herb's temperature and humidity (I Rahimmalek and Goli, 2013; Indiarto and Rezaharsamto, 2020a). The drying stage can lower the volatile oil content because chemical elements are volatilized or degraded when they are excessive temperature and too long (Rahimmalek and Goli, 2013; Indiarto *et al*., 2019; Subroto *et al*., 2019). Enzymatic pretreatment is used to remove drying and improve extraction efficiency (Reis *et al*., 2020). It can increase the efficiency of ginger essential oil hydrodistillation by 47.95% at 40°C for 130 mins (dos Santos Reis *et al*., 2020). Various ginger extraction methods provide specific functional properties, as shown in Table 1.

3. Ginger functionality for food

Ginger is widely used in food processing, such as pickled ginger, biscuits, candy, gingerbread, beer (ginger ale), powder, and syrup (Vasala, 2012). Processed ginger in form ginger candy was able to reduce the rate of vomiting in pregnant women in the first trimester (Anita *et al*., 2020). Adding ginger extract to turmeric white drinks increases antioxidant activity. It is due to phenolic compounds in ginger, which play a role in eliminating free radicals and radicals (Lobo *et al*., 2010; Indiarto *et al*., 2019). Oleoresin in ginger contains 6-gingerol, shogaol, and zingerone, exceeding vitamin E (Sueishi *et al*., 2019). Gingerol and shogaol compounds in ginger that function as a spicy flavor and zingiberene that gives a warm feel (Panjaitan *et al*., 2012; Semwal *et al*., 2015). Using ginger powder in processed meatballs affects the flavor and taste of zingiberol and zingiberene compounds that contribute to the fragrant odor (Tritanti and Pranita, 2019). Using ginger powder, however,

Table 1. Ginger extraction methods and resulting functional properties

Material Process	Extraction method	Functional properties	References
Ginger polysaccharide extraction	Hot water extraction; ultrasonic cell grinder extraction; enzyme assisted	Antitumor	Liao *et al.* (2020)
Ginger essential oil extraction	Crude multi-enzymatic extracts	Phytochemical, natural additive, flavoring agent	dos Santos Reis *et al.* (2020)
Extraction and fractionation of dried ginger essential oil	Supercritical CO_2 extraction coupled with fractionation	Natural bioactive compounds, such as vitamins, essential fatty acids, and flavors	Shukla *et al.* (2019)
Polysaccharide extraction from pomace ginger	Hot water and ultrasonic-assisted	Antioxidant	Chen *et al.* (2019)
Ginger powder extraction	Ultrasonication-assisted extraction	Antioxidant	Hsieh *et al.* (2020)
Ginger essential oil extraction	Supercritical carbon dioxide	Antioxidants, antimicrobials	Marzlan *et al.* (2020)

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meatballs color and suppleness are not affected. Proteolytic enzymes also influence color in ginger meatballs (Thompson *et al*., 1973), livestock, myoglobin, and hemoglobin concentrations, as well as non-enzymatic browning reactions between meat proteins and sugar reduction (Tiven *et al*., 2007). Whereas, meatballs thickness is influenced by the filler used, type, or meat part (Kusnadi *et al*., 2012). Ginger phenolic compounds like gingerol and shogaol can prevent peanut oil rancidity (O'Brien, 2004; Indiarto and Rezaharsamto, 2020b). These compounds contain benzene rings and hydroxyl groups to act as primary antioxidants (Lobo *et al*., 2010; Subroto *et al*., 2018; Indiarto and Qonit, 2020). Various studies on the functionality of the ginger for food are presented in Table 2.

4. Ginger functionality for health

Ginger also has several other health benefits such as reducing blood glucose in Type 2 diabetes mellitus patients as an anti-pain cream, analgesic, reduces uric acid, and reduces muscle pain. Ginger contains 6-gingerol compounds that can lower blood glucose (Sign *et al.,* 2009), increase insulin sensitivity by increasing preadipocyte differentiation of 3T3-L1 adipocytes as glucose uptake in cell membranes (Sekiya *et al*., 2004). Besides gingerol, shogaol, zingerone, diarylheptanoids, and their derivatives, ginger paradol can inhibit the enzyme cyclooxygenase work. It can reduce biosynthesis or prostaglandin formation, reducing pain intensity (Khan *et al*., 2008). The concentration of 10% and 20% ginger extract cream has been shown to reduce elderly pain (Setyawan and Tasminatun, 2013). Fresh ginger extract from water has optimum efficacy as an analgesic for 25 mins, while extracts from ethanol extraction have analgesic effects for up to 30 mins (Febriani *et al*., 2018).

Ginger can also be used to lower blood uric acid levels by consuming ginger boiled water extract containing oleoresin and essential oil. Oleoresin and ginger essential oil content that can reduce blood uric acid levels by inhibiting arachidonic acid metabolism and platelet aggregation and can relieve pain by inhibiting cyclooxygenase pathway to inhibit prostaglandin biosynthesis (essential pain mediators) (Pakpahan, 2015). Also, phenolic compounds in ginger 3 -7%, such as alkaloids and flavonoids, may inhibit xanthine oxidase enzyme activity, thus preventing uric acid formation (Hernani dan Winarti, 2013; Indiarto *et al*., 2020).

Ginger's efficacy as an anti-inflammatory has been proven, but its effect on pain is unknown. Ginger bioactive compounds like shogaol, gingerol, paradol, and zingerone are anti-inflammatory. These compounds can also inhibit prostaglandin and leukotrienes biosynthesis by inhibiting muscle pain-reducing cyclooxygenase and lipoxygenase (Haghighi *et al*., 2005). Zingerone can also work as an antioxidant to stabilize or neutralize free radicals (ROS) that cause muscle damage and pain (Peake *et al*., 2005). Ginger handles pain in NSAIDs the same way, but this red ginger does not show any side effects due to long-term consumption. It was recognized as safe, classified by FDA in Generally Recognized as Safe (GRAS) (Rayati *et al*., 2017). Table 3 shows various studies on ginger efficacy.

5. Potential of ginger to increase body immunity and antiviral properties

In addition to these health benefits, ginger is currently being targeted by the community as it is believed that it can increase the body's immune system to prevent the COVID-19 outbreak. COVID-19 is an infectious disease caused by SARS-CoV-2, a type of coronavirus that spreads through droplets from the respiratory tract such as coughing or sneezing. The lungs are the organs most affected by this virus, as the virus enters its host cells through the angiotensin 2 converting enzyme (ACE2), most commonly found in alveolar lung type II cells. One way to prevent this virus is to increase the immune system of the body to fight the infection when it enters the body (Letko *et al.,* 2020). If the

Table 2. Ginger functionality in foodstuffs

Material form	Food functionality	References
The nanoemulsion-based edible coating containing ginger	Increase the shelf-life of chicken breast fillets	Noori *et al.* (2018)
Sodium caseinate based on the edible film,	Prevent lipid oxidation in foods	Atarés *et al.* (2010)
Ginger powder	Prevents soybean oil lipid oxidation	Tinello and Lante (2020)
Powdered ginger added to the bread dough	Improving the bread's rheological characteristics	Balestra *et al.* (2011)
Antioxidant-rich ginger candy	Improve candy phytochemical properties	Kumar *et al.* (2018)
Whey protein isolate with ginger-polyphenol extract	Inhibiting microbial growth, physicochemical damage, and taste in Steak. It can also slow muscle softening, prevent lipid oxidation and extend steak shelf life up to	Chaijan *et al.* (2020)

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Table 3. Ginger products and health properties

Material form	Compound	Efficacy	References
Ginger extract	6-shogaol	Weakens diabetes neuropathy	Fajrin *et al.* (2020)
Ginger extract	Phenolic compounds	Prevention of necrotizing enterocolitis	Cakir *et al.* (2018)
Ginger essential oil	Monoterpenes; sesquiterpenes	Antimicrobial *Mycobacterium* spp.	Baldin *et al.* (2019)
Ginger extract	Shogaol	Inhibits oxidative stress and anticlastogenic	Kota *et al.* (2012)
Ginger volatile oil	β-phellandrene; camphene; linalool; geranial; zingiberene; β-sesquiphellandrene; neral; α-bisabolene; α-curcumene; α-farnesene and α-muurolene	Modulate the function of lymphocytes and the cellular immune response	Zhou *et al.* (2006)
Fresh ginger extract	Phenolic compounds	Antivirus human respiratory syncytial virus (HRSV)	Chang *et al.* (2013)
Ginger extract	6-gingerol, 6-shogaol, terpenoids citral and β-phellandrene	Anti-inflammatory	Podlogar and Verspohl (2012)
Ginger rhizome ethanol extract	Total polyphenols	Anticancer (against malignant melanoma)	Danciu *et al.* (2015)
Ginger extract	6-paradol; 6-shogaol; methyl 6-gingerol; 1-dehydro-6-gingerol; 5-, 6-, 8-, and 10- gingerol	Anti-inflammatory	Ezzat *et al.* (2018)
Ginger essential oil	Total polyphenols	Inactivation of Caprine alphaherpesvirus 1	Camero *et al.* (2019)

immune system is weakened, the protective capacity of the body also decreases so that pathogens, including viruses, can grow and multiply in the body, causing severe symptoms and fatal complications (Baratawidjaja and Rengganis, 2009). Therefore, an increase in the body's immune system is significant to protect the body from invading pathogens like viruses and bacteria, identify and destroy cancer cells that appear in the body, and clean old cells and damaged tissue (Sherwood, 2013).

In ginger, bioactive compounds play a role in increasing the body's immune system contained in the oleoresin content and essential oils. The essential ginger oil contains the active compounds zingiberene, β-sesquiphellandrene, β-bisabolene, farnesene, and geranyl acetate, widely used for aromatherapy (Jesudoss *et al*., 2017). Aromatherapy benefits from enhancing the body's immune system work by stimulating nerves, the brain nervous system that plays a role in regulating memory and emotions (Ali *et al*., 2015). When the body is more relaxed, it can stimulate the physiological response of the nerve, endocrine, or immune system (Institute of Medicine, 1994). Stress is a psychological factor affecting the body's immune system (Segerstrom and Miller, 2004).

Ginger can also increase the body's immune system, as it contains non-nutritional compounds with antioxidant properties. Ginger antioxidants play a role in counteracting free radicals entering the body, so free radicals do not damage the cells of the body's immune system. And cells to optimize the immune system, and antioxidants also play a role in increasing immunostimulatory activity (Andarina and Djauhari, 2017). Ginger is more immunostimulatory than turmeric (Sivagurunathan *et al*., 2011). The mechanism of the immunostimulant is to correct the imbalance of the immune system by increasing specific or non-specific immunity (Baratawidjaja and Rengganis, 2009). Specific immunostimulants are compounds that can give immune response antigenic specificities, such as vaccines or other antigens. Non-specific immunostimulant, by contrast, is a compound that has no antigenic specificity but may increase the immune response to different antigens or stimulate components of the immune system without antigenic properties such as adjuvants (Saxena *et al.,* 2012).

The use of ginger extract in a beverage provides functional properties to increase endurance. It is indicated by the body's immune response to foreign microbes entering the body and stimulating the proliferation of lymphocytes, which plays a vital role in the body's immune system (Radiati *et al*., 2003). Ginger extract can provide a therapeutic effect shown by increasing DNA repair, increasing antioxidants, reducing lipid peroxidase, and decreasing DNA damage from radiation to maintain the immune system of the body (Geng *et al.,* 2012).

6. Conclusion

Phenolic compounds in ginger had positive effects on food and health. Ginger application in both fields is closely related. Ginger is a natural functional food that provides pharmacological contributions like antioxidants, antihyperglycemic, antimicrobial,

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anticarcinogenic, anti-inflammatory, antitumor, antilipidemic, antimutagenic, and others. It means that whenever you consume ginger, these health effects will either be applied to food or as medicine. Ginger is also thought to be capable of combating common influenza viruses and influenza-like symptoms. Fresh ginger in the airway epithelium proved effective against plaque formation induced by a human respiratory syncytial virus (HRSV). Fresh ginger's role prevents virus adherence and internalization. Due to its properties, ginger is also developed to improve its functionality in the form of nanoparticles as a drug delivery with various advantages to increase prevention.

Conflict of interest

The authors declare no conflict of interest.

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