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,
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 (Ravinran 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 (Mahmoodally 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 Oleoresin in ginger contains 60% of phenolics, diarylheptanoid compounds that contribute to the fragrant odor of zingiberol and zingiberene (Sueishi et al., 2020). Ginger functionality for food

Table 1. Ginger extraction methods and resulting functional properties

<table>
<thead>
<tr>
<th>Material Process</th>
<th>Extraction method</th>
<th>Functional properties</th>
<th>References</th>
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<tr>
<td>Ginger polysaccharide extraction</td>
<td>Hot water extraction; ultrasonic cell grinder extraction; enzyme assisted extraction</td>
<td>Antitumor</td>
<td>Liao et al. (2020)</td>
</tr>
<tr>
<td>Ginger essential oil extraction</td>
<td>Crude multi-enzymatic extracts</td>
<td>Phytochemical, natural additive, flavoring agent</td>
<td>dos Santos Reis et al. (2020)</td>
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<tr>
<td>Extraction and fractionation of dried ginger essential oil</td>
<td>Supercritical CO₂ extraction coupled with fractionation</td>
<td>Natural bioactive compounds, such as vitamins, essential fatty acids, and flavors</td>
<td>Shukla et al. (2019)</td>
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<tr>
<td>Polysaccharide extraction from pomace ginger</td>
<td>Hot water and ultrasonic-assisted extraction</td>
<td>Antioxidant</td>
<td>Chen et al. (2019)</td>
</tr>
<tr>
<td>Ginger powder extraction</td>
<td>Ultrasonication-assisted extraction</td>
<td>Antioxidant</td>
<td>Hsieh et al. (2020)</td>
</tr>
<tr>
<td>Ginger essential oil extraction</td>
<td>Supercritical carbon dioxide</td>
<td>Antioxidants, antimicrobials</td>
<td>Marzlan et al. (2020)</td>
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meatolytic 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>
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<th>Table 2. Ginger functionality in foodstuffs</th>
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<tr>
<td>Material form</td>
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<tr>
<td>The nanoemulsion-based edible coating</td>
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<tr>
<td>containing ginger</td>
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<tr>
<td>Sodium caseinate based on the edible film,</td>
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<tr>
<td>which contains essential ginger oil</td>
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<tr>
<td>Ginger powder</td>
</tr>
<tr>
<td>Powdered ginger added to the bread dough</td>
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<tr>
<td>Antioxidant-rich ginger candy</td>
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<tr>
<td>Whey protein isolate with ginger-polyphenol extract</td>
</tr>
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Table 3. Ginger products and health properties

<table>
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<tr>
<th>Material form</th>
<th>Compound</th>
<th>Efficacy</th>
<th>References</th>
</tr>
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<tr>
<td>Ginger extract</td>
<td>6-shogaol</td>
<td>Weakens diabetes neuropathy</td>
<td>Fajrin et al. (2020)</td>
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<tr>
<td>Ginger extract</td>
<td>Phenolic compounds</td>
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<tr>
<td>Ginger essential oil</td>
<td>Monoterpenes; sesquiterpenes</td>
<td>Antimicrobial Mycobacterium spp.</td>
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<tr>
<td>Ginger extract</td>
<td>Shogaol</td>
<td>Inhibits oxidative stress and antiallergenic</td>
<td>Kota et al. (2012)</td>
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<tr>
<td>Ginger volatile oil</td>
<td>β-phellandrene; camphene;</td>
<td>Modulate the function of lymphocytes and the cellular immune response</td>
<td>Zhou et al. (2006)</td>
</tr>
<tr>
<td>Fresh ginger extract</td>
<td>Phenolic compounds</td>
<td>Antivirus human respiratory syncytial virus (HRSV)</td>
<td>Chang et al. (2013)</td>
</tr>
<tr>
<td>Ginger extract</td>
<td>6-geranol, 6-shogaol, terpenoids citral and β-phellandrene</td>
<td>Anti-inflamatory</td>
<td>Podlogar and Verspohl (2012)</td>
</tr>
<tr>
<td>Ginger rhizome ethanol extract</td>
<td>Total polyphenols</td>
<td>Anticancer (against malignant melanoma)</td>
<td>Danciu et al. (2015)</td>
</tr>
<tr>
<td>Ginger extract</td>
<td>6-paradol; 6-shogaol; methyl 6-geranol; 1-dehydro-6-gerinol; 5-, 6-, 8-, and 10-gerinol</td>
<td>Anti-inflamatory</td>
<td>Ezzat et al. (2018)</td>
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<tr>
<td>Ginger essential oil</td>
<td>Total polyphenols</td>
<td>Inactivation of Caprine alphaherpesvirus 1</td>
<td>Camero et al. (2019)</td>
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</table>

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 countercating 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 Djuahari, 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,
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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