Chapter

Harnessing the Therapeutic Properties of Ginger (*Zingiber officinale* Roscoe) for the Management of Plant Diseases

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Abstract

Ginger (*Zingiber officinale* Roscoe) is one of the most widely used spices in the world. The therapeutic benefits of ginger are mainly due to the presence of volatile oils, phenols, alkaloid, and high oleoresin content. Ginger extracts have been extensively studied for a broad range of biological activities including antibacterial, antifungal, antiviral, anticonvulsant, analgesic, antiulcer, gastric antisecretory, and antitumor. This is all the more necessary because ginger is of plant origin, specifically more biodegradable, readily available, cheaper, and environmentally friendlier than synthetic chemicals. Since, some farmers in developing countries use ginger extracts as traditional medicine in the treatment of human diseases, it will be easy for them to adopt these extracts as biopesticides for the management of plant diseases. This book chapter seeks to outline the bioactive compounds and therapeutic benefits of ginger in plant disease management, and the mechanisms of action are also discussed.

Keywords: antibacterial, antifungal, biodegradable, synthetic chemicals, ginger

1. Introduction

Ginger (*Zingiber officinale* Roscoe) is a spicy aromatic plant from the family Zingiberaceae. There are about 150 species in the genus *Zingiber,* but *Zingiber officinale* is the widely cultivated and spicy species [1]. Ginger is largely grown in the tropics [2]. In China, ginger has been useful in various indigenous medicines over the centuries [3]. Ginger is regarded as a general medicinal material in the Chinese ayurvedic culture for the treatment of digestion-related discomforts [4]. According to the Transparency Market Research [5] report, ginger is among the high-valued and economic herbal commodities of about the 6.5% per year projected increase in market value which could go up as high as US$ 4.18 billion with about 7.5% estimated rapid growth in consumption by 2022.

Ginger has several uses or functions in our daily lives. It is importantly used in households, pharmaceutical, brewery, food, and other related industries to manufacture products such as ginger oil, ginger wine, gingerbread, ginger cake, ginger spice, ginger syrup, ginger drink, and ginger coffee [6]. Ginger oil is produced in economic and commercial quantities in countries like Australia, China,

Indonesia, and India. Recently, the oil obtained from ginger has been found to protect and maintain the kidney against toxicity [7]. Ginger is a medicinal plant and antimicrobial agent. It contains gingerols as its primary bioactive compound with high flavonoid, phytochemical, and pharmacological effects [3]. Various studies in vivo, in vitro, and clinical analysis have over the years been carried out and, thus, affirmed ginger's therapeutic properties which cannot be downplayed. For instance, some of the volatile oils contained in red ginger, namely, trimethyl-heptadienol, ar-curcumene, camphene, carbaldehyde, sesquiphellandrene, and nerol, were found to inhibit the growth of bacteria including *Bacillus cereus*, *Escherichia coli*, *Salmonella typhimurium*, and *Pseudomonas aeruginosa* [8].

2. Nutritional components of ginger

Ginger is extensively used in various traditional and manufactured foods as a result of its richness in essential nutrients. The rhizome, which is the principal economic part of the ginger plant, possesses good amount of carbohydrate, minerals, and vitamins, among others. Ginger rhizome is a rich source of minerals including iron, calcium, and phosphorous. It also contains vitamins such as thiamine, riboflavin, niacin, and vitamin C. Ginger rhizomes also possess a potent proteolytic enzyme called zingibain [9]. Torch ginger (*Etlingera elatior* Jack.) inflorescence contains high amounts of dietary fiber, unsaturated fatty acids (palmitoleic acid, linoleic acid, and oleic acid), and essential amino acids (leucine and lysine) [10]. The inflorescence of torch ginger is enriched with essential minerals such as K (1589 mg/100 g), Ca (775 mg/100 g), Mg (327 mg/100 g), P (286 mg/100 g), and S (167 mg/100 g) with lower levels of heavy metal contaminants (Cd, As, Pb, Hg, Ni) [11, 12]. Raw ginger is also reported to contain useful minerals like Mg, Ca, Mn, Fe, Cu, and Zn [13]. Studies on ginger rhizomes obtained from Malaysia and Nigeria showed higher moisture (90.9% vs. 76.9%), crude fiber (3.8 g/100 g), and lower carbohydrate content (6.3 g/100 g sample) than the USDA database [14]. In other studies, inductively coupled plasma-mass spectrometry-based multi-elemental profiling was used to evaluate the quantitative complement of elements and nutritional quality of ginger rhizome, and the result revealed an abundance of 18 elements quantified [13]. The acid-digested rhizomes were found to have K > Mg > Fe > Ca > Na > Mn > Zn > Ba > Cu > Cr > Ni > Pb > Co > Se > As > Be > Cd metals in that order of abundance. Generally, it is supposed that paradol, formed on hydrogenation of shogaol, in ginger plant contains significant antioxidant content which produces protective health benefits in various diseases [15].

3. Bioactive components of ginger

Ginger is a rich source of some important bioactive molecules and compounds such as phenolic groups, alkaloids, and steroids which have medicinal effect [14]. The main aromatic agent of the rhizome is the zingiberol [3]. It has embedded in it some bioactive compounds such as shogaols, zingerone, paradols, and gingerols, which are structurally shown (**Figure 1**). These components do not easily vaporize and are responsible for the "burning" effect, felt in the mouth [16]. In addition to the main bio-compounds, ginger also contains other sub-compounds like 4-gingerol, 6-gingerol, 8-gingerol, 10-gingerols, 6-shogaols, 14-shogaols (**Figure 1**), and many other identified components which are reactive against inflammation [17] (**Table 1**).

The most identified and investigated components of ginger which act against oxidation reactions in biological systems are shogaols and gingerols, possessing a lot

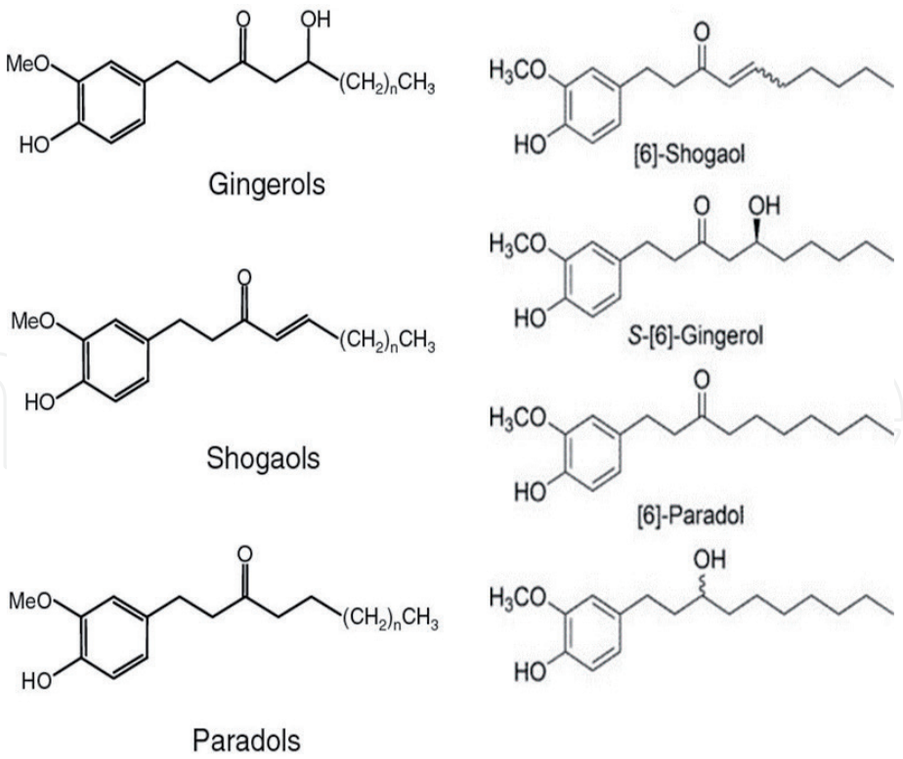

Figure 1.
Chemical structure of major bioactive compounds of ginger.

Ginger constituent	Mechanism of actions	References
Zingerone	Act against inflammation of cells Moderation of prostaglandins synthesis	[19]
10-Gingerol	Inhibition of cell expression, declining the rate of cell multiplication, halt and weakening of the S phase cell cycle	[20]
Paradol	Controlling blood sugar levels Enhances cells recovery and resistance against cancer Promoting the formation and action of antibodies	[21]
8-Gingerol	Inhibition of cancer cell growth Antiplatelet actions Inhibition of blood vessels generations	[22]
Flavonoid	Antioxidant actions against reactive oxygen, which can endanger plant and cells. Protecting cells against risks of damage by oxidation related imbalances	[23, 24]
Oleoresin	Antimicrobial actions against the growth of plants and animal disease microorganism like *Staphylococcus aureus*, *Candida albicans*, *Escherichia coli*	[25–27]
6-Gingerol	Causing cell cycle actions in the G0/G1-phase to cease Reducing cyclin E1, cyclin A, and cyclin D1 levels. Increasing caspase manifestation Stopping the sensing channel of mammalian target of rapamycin (mTOR)	[28]
Phenolic acid	Inhibiting reactive nitrogen and oxygen generation in plants and animal cells, as a result of its ability to stop certain enzymes from action Removing reactive oxygen and nitrogen from cells	[24, 29]
6-Shogaol	Suppress prostaglandin E2 and nitric oxide generation	[30]
Essential oil	Inhibitory actions against microbes Antioxidative reactions	[25, 27]

Table 1.
Some ginger constituents and possible means of bio-actions.

of therapeutic properties like anti-hepatotoxicity and antiprostaglandin production among others [18]. Ginger contains some chemical derivatives and other constituents aside the primary bioactive compounds, which are also highly reactive and with useful therapeutic mechanisms (**Table 1**).

4. Methods of extraction of components of ginger

Before the introduction of modern methods, conventional methods such as infusion, decoction, and percolation, which are a direct simple solvent extraction, were used [31]. Although new techniques have been developed, these conventional methods are still used in Phytochemistry Laboratories. Traditional extraction techniques, though still in use, pose several challenges during extraction. These methods consume a lot of energy and time as well as require large amount of solvents and are also difficult to automate. In recent times, modern extraction techniques such as microwave-assisted, ultrasound-assisted extraction, negative pressure cavitation extraction, and accelerated solvent extraction have been developed to curb the challenges associated with the traditional extraction methods. These techniques are easy to automate and require shorter extraction time and smaller amount of solvents [31].

5. Pharmacological properties

Ginger is used in herbal treatment for colds and other viral infections, poor appetite, digestive problems, arthritis, and headache [32]. Ginger and its constituents have antiemetic, antithrombotic, anti-inflammatory, and antioxidant effects [33]. The major pharmacological activity of ginger appears to be due to gingerol and shogaol [34]. Studies have shown that ginger exhibits several pharmacological activities, such as antioxidant, cytotoxic agent, gastrointestinal, cardiovascular disorders and anti-vomiting, anti-inflammatory, antimicrobial action, and pesticidal effects [34].

5.1 Antioxidant effects of ginger

Many cell culture studies have revealed the antioxidant actions of ginger [35–38]. Some progressive biological studies also show the protective actions of gingerol and ginger extract on many tissues against shocks on the account of several actions that cause oxidation [35]. Ginger is a strong antioxidant substance and may either mitigate or prevent generation of free radicals. Ginger, which is the underground stem or rhizome of the plant *Zingiber officinale Roscoe*, contains polyphenol compounds (6-gingerol and its derivatives), which have a high antioxidant activity [39].

Beverage products obtained through lactic anaerobic biochemical processing of plants from the ginger family contain antioxidant properties [40]. Ginger is one of the prominent herbs noted for its "shock-absorber" actions, which helps to promote insulation for the human system including pregnancy [41, 42]. The antioxidant property of ginger was also confirmed in a study where the extract effectively inhibited rancidity of fats and prevented linoleic acid from oxidizing [43]. The application of ginger also interfered with the generation of nitric oxide [44].

5.2 Cytotoxic properties

The potency of ginger against various forms of cancer like cervical, breast, and prostate have been largely studied [45, 46], and ginger has been found to be effective

against the rapid degeneration of cancers, the death of affected cells [22, 47]. Ginger terpenoids were found to promote the stimulation of p53 and thus making the cancer cells relating to endometrium inactive [48]. Rapid multiplication of PC-3 prostate cancer cell was cooperatively prevented by the double mixture of 6-shogaol, 8-gingerol, 6-gingerol, and 10-gingerol [49]. Cell culture studies have demonstrated that ginger served as an inhibitory substance toward cancer of the skin and abnormal growth in the bladder and lung [50, 51].

Recent studies have shown that the administration of ginger powder at two grams per day for a period of 4 weeks suppresses the development of cyclooxygenase-1, an inflammatory-related enzyme which is closely associated with cancer of the large intestine [52]. In similar studies, it was reported that 6-gingerol, a bioactive component responsible for the stingy sensation of ginger, was highly effective against the formation and generation of new blood vessels either within an organism or in an artificial medium outside an organism, and this action could best prevent an abnormal growth and spread of cancers from one cell to the other [53]. Research has revealed that 6-shogaol exhibited inhibitory action against cancer of the breast by stopping the colonization of cells and decreasing of metalloproteinase-9 manifestation [54].

5.3 Gastrointestinal properties of ginger

Ginger has been helpful in the alleviation of numerous gastrointestinal discomforts such as ulcers of the duodenum and other digestive canal. The stomachic mucous membrane is being secured against a number of potential ulcer factors due to its antagonistic reactions toward oxidation [55, 56]. Essence from ginger reportedly blocked *Helicobacter pylori* in a study conducted in an artificial environment [57]. A study has shown that signs of vomiting and nausea were effectively relieved when the powdered form of ginger was administered by mouth, 4 times per day at 250 mg, to 27 gravida women with pregnancy-related morning discomfort for more than a 4-day period [58]. Ginger helps to get rid of constipation when used in the fresh form [59]. The phenolic content in aqueous extract of ginger is reported to have potential ulcer-preventing ability; the aqueous extract of ginger will also reduce free radical damage during ulceration. Hence, ginger is used as an ulcer-preventive agent [60].

5.4 Cardio and antivomitory actions of ginger

Several studies have identified the medicinal properties of shogaol and gingerol bioactive groups of ginger components. Ginger helps to stimulate the muscles of the heart to facilitate blood flow, lower the concentration of blood, and boost metabolic reactions in the cells, which greatly secure the organ systems against offensive muscular contractions [61]. Powdered ginger root in the dose used was found to be effective in reducing nausea and vomiting induced by low-dose cyclophosphamide in combination with drugs causing mild emesis [62].

The 6-gingerol, 6-shogaol, and other ginger-based compounds with two carbonyl groups are catalytically active against the bio-generation of leukotriene, prostaglandin, and thromboxane [63]. Chemo-constituents of ginger like alkaloids, flavonoids, saponins, peptides, and non-primary amino acids showed characteristic actions of dilation and blood pressure reduction [64].

Ginger is a good bio-inhibitory agent against neurotransmitter receptors, which promote flexibility and movement in the lumen of the intestines. Ginger also induces a supportive counteraction in the alimentary canal toward the 5-hydroxytryptamine receptors [55, 56]. Powdered ginger administered at 1 g or more per day

suppressed intense and excessive vomiting during pregnancy for about 92% of the studies carried out [65].

5.5 Anti-inflammatory action of ginger

The expression of an inflammation-producing related gene was inhibited in LPS-activated BV2 neuron-supportive cells of the immune system, thereby suppressing neuron-related inflammations [66]. Oral administrations of ginger oil and eugenol against acute arthritis in rats significantly inhibited the expression of joints and paw swollen [67]. The infusion of ginger oil can inhibit prolonged swelling of joints [68].

Ginger structural components like shogaol and gingerol effectively stopped leukotrienes and prostaglandins bio-generations by preventing either 5-lipoxygenase or prostaglandin synthase from expressing [69, 70]. In a published report, ginger was found to have given an outstanding performance against arthritis actions in humans, when consumed in a fresh a state [71]. The study also found out that the generation of many arthritics or inflammation reactions related genes was actively suppressed by using *Alpinia galanga* and essence of ginger [19].

5.6 Antimicrobial action of ginger

Ginger extract has showed antimicrobial activity against a broad spectrum of pathogenic microorganisms. Ginger extract at the rate of 10% has been reported to possess some economic level of anti-pathogenic properties against disease-causing organisms [72]. The floral part and root of ginger contain an extractable oil that averagely act positively against *Bacillus licheniformis*, *Staphylococcus aureus* (gram-positive bacteria), *Klebsiella pneumonia*, and *Pseudomonas stutzeri* (gram-negative bacteria) [73].

An in vitro analysis demonstrated the suppressive ability of ginger essence and other components against the growth and development of contagious bacteria like *Listeria monocytogenes* [74]. Studies have shown that ginger impedes the reproduction and growth of the colon bacteria, some strains of *Salmonella*, carcinogen (23, 24), and *Aspergillus*. Again, the undiluted juice obtained from ginger rhizome has proven to be effective, under room temperature at the rate of 12 and 4% against the development of *Mycoderma* spp. and *Aspergillus niger*, respectively [75].

A study conducted by Chakotiya et al. [76] also revealed how the development of a breed of *Pseudomonas aeruginosa* was suppressed by ginger and its bioactive compounds through the prevention of the synthesis of biofilms. Paste prepared from ginger also exhibited a positive counteraction against the growth of O157:H7 strain of *Escherichia coli* (*E. coli*) when studied in laboratory culture, using beef and laboratory broth [77, 78]. In our previous studies, it was found that the growth of *Aspergillus niger* on yam tubers was suppressed by 65.5% when treated with an ethanol ginger extract [79]. Similarly, *Z. officinale* inhibited the growth of *Rhizopus stolonifer*, *Aspergillus niger*, *Aspergillus flavus*, *Fusarium oxysporum*, and *Botryodiplodia theobromae* significantly [80].

Several reports have demonstrated the effectiveness of ginger against viruses, some parasites, and a group of fungi [81–83]. The highly valued oil extracted from ginger has showed high potency against *Aspergillus flavus* development and the multiplication of certain genes linked to aflatoxin [84, 85]. An ethanol-containing extract obtained from ginger was found to have high efficacy against the multiplication of candida bacteria [86]. Ginger was used to cure tuber rot disease, a fungal disease of an economic importance in yam, by suppressing the growth of *Fusarium oxysporum*, *Penicillium oxalicum*, and *Trichoderma viride,* which are the primary causative agents [87].

6. Pesticidal properties of ginger

It has been reported that ginger extract at 3% exhibited pesticidal potential thereby reducing cabbage looper (*Trichoplusia binotalis*) [88]. Several studies have shown that the methanol extract obtained from ginger can be used in controlling trypanosomiasis, commonly known as "sleeping sickness" due to its counteractions against parasites [89–91]. A good result was achieved when an extract of ginger was evaluated for pestilence against leaf hoppers and defoliators of cowpea (*Vigna unguiculata* L.) in a field study [92].

Studies have also shown that ginger is effective in managing pests like hoppers, root-knot nematodes, aphids, American bollworm, thrips, and mango anthracnose, among others [93]. In a study under both field and laboratory environments, the residues taken from the water extraction process of ginger was found to be active at the rate of about 25–30% in suppressing the oviposition process and development of matured flea beetle of okra (*Callosobruchus maculatus* F.) on the field and in storage [94].

7. Other useful properties of ginger

It has been reported that an ethanolic essence of ginger ultimately reduces the sugar level of blood when given orally to a rat suffering from diabetes. Oral intake of 100 mg/kg of ginger extract, dissolved in 80% of alcohol, gave 38% suppression of yeast-associated fever among rats [95, 96]. 6-Gingerone helps to control obesity by inhibiting and reducing of fats buildup and weight gain among mice [97]. 10-Gingerol exhibited an excellent performance against the growth of *Angiostrongylus cantonensis* larvae, a type of nematode of an economic importance in some regions of the Pacific and Asia [98]. Several studies in recent times have identified ginger as a suppressive medicinal material, which influences recollection ability of the minds and is capable of relieving or preventing neuron inflammations that may help to control infections associated with debasement of neurons [99, 100]. Ginger plays a preventive role against rapid multiplication of cell and growth of cancer-affected cells [101, 102]. Ginger has also been reported to have a good antagonistic action against the virulence of the hepatitis C virus [61, 103].

8. Conclusions

This particular review tried to bring together various research findings and reports of the past, on the therapeutic characteristic properties of ginger. The review also comments on the numerous applications of ginger in the traditional medicine and its pharmaceutical importance. A good number of therapeutic reactions of ginger have been identified, which include anti-inflammatory actions, anti-cancer properties, antioxidant actions, anti-pesticidal properties, cytotoxicity, gastrointestinal actions, antimicrobial effects, and other conventional uses of ginger in plants, animals, and human health. Ginger is a recognized plant in the world of medical and health sciences. It contains gingerols as its primary bioactive compound with high flavonoid and phytochemical and pharmacological effects. Several studies in vivo, in vitro, and clinical analysis have over the years been conducted out and, thus, affirmed ginger's therapeutic properties which cannot be overlook.

Conflict of interest

The authors declare no conflict of interest.

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