Chapter

Ginger (*Zingiber officinale*) Antimicrobial Potential: A Review

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Abstract

Zingiber officinale Roscoe, commonly known as gengibre, ajengibre, jengibre dulce (Brazil, Argentina, and Spain), ginger (United States and England), and gingembre (France), is a perennial herbaceous plant that produces a fleshy and articulated rhizome, with rough brownish epidermis. As a medicinal plant, ginger is one of the oldest and most popular in the world. Several properties of the ginger have been verified in scientific experiments, with emphasis to the antimicrobial activity. Ginger essence oil has been investigated by several in vitro microbiological techniques, in which most of its essential oils presented antimicrobial activity against all selected bacteria. The antimicrobial effect is attributed mainly to several phytochemicals, such as camphene, phellandrene, zingiberene, and zingerone. This review provides an overview of the experimental evidence for the antimicrobial potential of *Z. officinale.*

Keywords: essential oil, chemical composition, ginger, gengibre

1. Introduction

Vegetable kingdom organisms are the major contributors to the significant number of organic substances in nature. Plants have enormous potential to biosynthesize the most varied types of molecular structures that perform various functions in your body. The substances responsible for ensuring the cells development and maintenance are called primary metabolites. From these compounds, through very complex biosynthetic routes, plants produce secondary metabolites, which help in the defense and adaptation of plants to the environment.

Composed of several secondary metabolites synthesized by plants, we highlight the essential oils that are characterized by being a complex mixture of low molecular weight liposoluble constituents with strong aroma. Essential oils stand out for their great therapeutic and economic importance, occupying a preponderant place in the pharmaceutical, cosmetic, and agri-food industries due to their high biological activity [1].

Although plants have been used since ancient times for spice and medicinal purposes, only in recent decades research has been intensifying for application of these compounds in food preservation and control of diseases of microbial origin.

Nowadays, there is a serious problem of bacterial resistance to commercially available antibiotics that occurs due to the wide distribution of antimicrobials and easy access to consumption by the population, which leads to indiscriminate use and self-medication. The uncertain diagnosis, the absence of a rational program for antimicrobial use, and subdoses of antimicrobial are also factors that contribute to the increased prevalence of drug-resistant microorganisms, rendering antibiotics ineffective [2].

Assuming the resistance of microorganisms to available drugs, the toxicity of synthetic antimicrobials, and the growing consumer awareness of the use of environmentally safe and health-friendly products, natural products emerge as a potential alternative for the replacement of synthetic antimicrobial agents.

One of the largest sources of research in this area is the evaluation of antimicrobial activity of plants popularly used for medicinal purposes. *Zingiber officinale* Roscoe, popularly known as ginger, is used in cooking, the pharmaceutical industry, and folk medicine to treat numerous conditions [3].

Thus, this review chapter aims to discuss the antimicrobial activity of ginger essential oil evaluated by various in vitro microbiological techniques against pathogenic microorganisms. This book chapter reviews the real contribution of ginger as a naturally occurring antimicrobial.

2. Methods

The bibliographic search was performed from May 2019 by a single researcher, searching for keywords such as antimicrobial, ginger, antibacterial, antifungal, *Zingiber officinale*, and their combinations, in PubMed and ScienceDirect. The productions were selected by reading and analyzing the titles and abstracts of all identified articles. After the initial screening, the selected studies were read, which allowed other texts that did not meet the review proposal to be excluded. The main information from the selected articles was synthesized in spreadsheets that guided the descriptive and critical analysis of the studies.

3. Results and discussion

3.1 Ginger plant

Ginger, scientifically named *Zingiber officinale* Roscoe, was first described in 1807 by the English botanist Willian Roscoe. It is a species in the Zingiberaceae family, from southwestern Asia and the Malay Archipelago, including over 1200 species and 53 genera [4].

Ginger has been known and used practically worldwide and in all medicines. It has been cultivated for thousands of years in China and India, reaching the West for at least 2000 years. The name of this genus, *Zingiber*, derives from a Sanskrit word meaning “horn-shaped" in reference to the protrusions on the surface of the rhizome. Ginger has several names, including gengibre, ajengibre, and jengibre dulce (Brazil, Argentina, and Spain), ginger (United States and England), and gingembre (France) [5, 6].

In Brazil, its cultivation was introduced shortly after the beginning of European colonization. However, only in the 1980s, with the introduction of giant rhizome varieties by Japanese farmers, ginger cultivation became effectively commercial in Brazil, especially in the coasts of Santa Catarina, Sao Paulo, and Paraná [7].

Ginger has a herbaceous habit, is perennial, produces articulated rhizome, and has adventitious roots and distal leaves, with the basilars reduced and floral bracts obliterated, each involving a single flower [8]. The ginger rhizome has an elongated, slightly flattened body, with a color ranging from yellow to bright brown leather, striated longitudinally, with endings known as "fingers" that arise obliquely from the rhizomes. Internally yellowish brown, it has a yellow endoderm, with numerous fibrovascular bundles and abundant oil cells. It presents pleasant and aromatic odor and strongly pungent taste [7].

As a medicinal plant, ginger is one of the oldest and most popular in the world. It is used to relieve symptoms of inflammation, rheumatic diseases, and gastrointestinal discomfort [9]. Its root has carminative, digestive, sweat, anti-influenza, and stimulating properties [8]. In gastronomy, ginger is used as a seasoning and flavoring, giving spicy and refreshing characteristics. It is a raw material for the manufacture of beverages and bakery products such as breads, cakes, cookies, and jams. In the cosmetics industry, its use is due to its fragrance [10].

Ginger has shown a variety of biological activities such as antifungal [11, 12], anti-inflammatory [13], antiviral [14], antimicrobial [3, 15], antioxidant [16], and antitumor [17–19]. Due to these properties, the use of rhizomes to obtain ginger essential oils, extracts, and concentrates has attracted interest from the pharmaceutical and food industries.

3.2 Chemical profile of ginger essential oils

Chemical analysis of ginger shows that it contains over 400 different compounds where the main components of ginger rhizomes are carbohydrates (50–70%), lipids (3–8%), terpenes, and phenolic compounds. Terpenes include zingiberene, β-bisabolene, α-farnesene, β-sesquifelenolene, and α-curcumene, while phenolic compounds include gingerol, paradols, and shogaol [20], as shown in **Table 1**.

In studies from 2006 to 2018 with *Z. officinale*, geranial and α-zingiberene were the major compounds in their chemical composition [12, 22, 27]. Significant quantities of the terpene family chemical constituents have also been reported [12, 22]. The least common constituent found in ginger essential oil is ar-curcumene [25, 27]. Compounds such as 1,8-cineole, eucalyptol, and 1,8-cinerol that are not very common in the chemical composition of *Zingiber officinale* have also been noted [21, 26, 28].

The variation in the composition of the essential oils obtained from this species may be due to genetic and/or environmental factors, plant age, and different extraction methods. The composition of essential oils directly influences their antimicrobial activity, as each secondary metabolite has a specific ability to break or penetrate the structure of the microorganism [24].

3.3 Antimicrobial assays with ginger

The most used methods for the determination of antimicrobial activity of *Z. officinale* vary among researches as can be seen in **Table 2**. The main methods are disk and well agar diffusion and agar and broth microdilution technique that determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC).

It was verified [16] that the *Z. officinale* essential oil tested by two methods showed strong inhibitory effects by well diffusion, demonstrating that the technique used can influence the result, while the agar diffusion test had less effect. As can be seen in **Table 2**, there is no standardization of ginger oil dilution, which can lead to uncertain results as it is an oil, and, because it is a less dense material than water, the oil cannot be diluted directly in the broth, which limits their miscibility

Reference	Major compounds	%
[12]	α-Zingiber	24.0
	Geraniale	15.0
	β-Phellandrene	8.0
[21]	Comphene	12.0
	β-Phellandrene	11.0
	1,8-cineal	10.0
	α-Zingiberene	7.0
[22]	α-Zingiberene	25.0
	β-Sesquiphellan	18.0
	β-Bisobeolene	12.5
[16]	Geraniale	26.0
	α-Zingiberene	9.5
	α-Farnesene	7.6
	Neral	7.4
[23]	Geraniale	16.0
	z-Citral	9.2
	β-Cedrene	8.6
	Geranyl acetate	8.4
[24]	Geraniale	26.0
	α-Zingibere	9.5
	Farnesene	7.6
	Neral	7.4
[25]	β-Sesquiphellandrene	27.0
	Caryophyllene	15.3
	Zingiberene	14.0
	α-Farnesense	10.5
[26]	ar-Curcumene	11.3
	Geraniale	11.0
	Camphene	5.0
	Eucalypto	3.0
[27]	α-Zingiberene	20.0
	ar-Curcumene	15.0
	β-Bisabalene	11.0
	β-Sesquiphellandrene	13.0
[28]	ar-Curamene	59.0
	1,8-Cinerol	8.0
	Citral	7.5
	α-Zingiberene	7.5

Table 1.
Chemical composition of different Zingiber officinale *essential oil described in literature.*

Method	Dilution	Reference
Disk and well diffusion agar	DMSO	[16]
Broth microdilution MIC and MBC	DMSO 5%	[21]
MIC—diffusion agar	Ethanol	[29]
Agar disk diffusion	Acetone	[30]
MIC—broth microdilution	Ginger essential oil	[31]
Agar disk diffusion	Essential oil	[32]
MIC—broth microdilution	Tween 80	[33]
Agar disk diffusion	Ginger essential oil	[34]
MIC-broth microdilution	Tween 126	[35]
Agar-agar diffusion	DMSO	[36]
Broth microdilution MIC and MBC	DMSO	[37]

DMSO, dimethyl sulfoxide; MIC, minimum inhibitory concentration; MBC, minimum bactericidal concentration.

Table 2.
Methods used to establish antimicrobial activity of Zingiber officinale *essential oil*.

in the test media. Therefore, a surfactant should be added, and we found that the most commonly used was DMSO [16, 21, 36, 37], tween [33, 35], some solvents like ethanol [29] and acetone [30], and even ginger oil [31, 32, 34].

The disk diffusion and well diffusion tests have been used to evidence antimicrobial activities, assuming that all components of the oil have the same solubility, but as verified in **Tables 3** and **4**, the diffusion of oil in the agar, during the test, may not diffuse into the agar, limiting the use of this method. However, the use of several methods to determine antimicrobial activity, as verified in [16], can directly interfere with the result. Although interference of chemical composition is possible, the MIC values found in several studies do not demonstrate a reproducibility using broth dilutions [21, 31, 33, 35, 37].

3.4 Antimicrobial activity of ginger

3.4.1 Antibacterial activity of ginger

Essential oils have a chemical composition rich in volatile and odorous secondary metabolites, mainly monoterpenes and sesquiterpenes. Several studies reported the antimicrobial properties of *Z. officinale* essential oil against various bacteria, as can be seen in **Table 3**.

A research showed that *Z. officinale* essential oil obtained by hydrodistillation verified that *L. monocytogenes* showed the highest sensitivity to oil when compared to other bacteria and presented the largest zone of inhibition (37 mm). Ginger essential oil has been shown to be active against the *V. alginolyticus* strain, despite the high MIC value range of 0.05–0.2 mg/mL reported [29].

The description of a moderate activity, with MIC values of 0.16–0.63 mg/mL, against Gram-positive bacteria indicates that Gram-negative bacteria are more resistant to *Z. officinale* essential oils compared to Gram-positive bacteria [21].

However, the essential oil showed activity against *Shigella* and *E. coli*, probably due to the presence of active constituents such as zingiberene, endoborneol, and gingerol [39]. The MIC value found for *K. pneumonia* (ATCC 13383) and *S. enterica* (ATCC 7251) strains was 1 mg/mL. These results are expected due to the

constitution of the Gram-negative cell wall [16], although the effect of high sensitivity on Gram-negative strains such as *K. pneumonia* has been observed [39]. A survey of 15 strains of bacteria reported results that validate the use of *Z. officinale* as a medicine to treat diseases of possible infectious origin [9].

Reference	Country	Bacteria	MIC	MBC	Halo (mm)
[16]	India	*P. vulgaris*			18.4
		K. pneumoniae			20.5
[21]	Tunisia	*V. alginolyticus*		>25	
[23]	Brazil	*S. mutans*	250 μg/mL	500 μg/mL	
[29]	Saudi Arabia	*S. aureus*			15.8
		B. cereus			8.3
		E. coli			0.0
		S. typhi			0.0
		P. aeruginosa			11.2
[30]	Brazil	*S. enteritidis*			8.8
		L. plantarum			7.0
[32]	Saudi Arabia	*E. faecalis*	61.94%		
		P. aeruginosa	21.65%		
		E. coli	106.02%		
		Shigella	119.79%		
[37]	Canada	*S. pyogenes*	>1000 μg/mL	>1000 μg/mL	
[33]	Brazil	*L. monoctogenes*	4.7 μL/mL	9.4 μL/mL	
		S. aureus	2.3 μL/mL	4.7 μL/mL	
		E. coli O157:H7	9.4 μL/mL	18.7 μL/mL	
		S. typhimurium	9.4 μL/mL	18.7 μL/mL	
		P. aeruginosa	2.3 μL/mL	4.7 μL/mL	
[38]	India	*B. cereus*			9.11
		L. monocytogenes			9.00
		M. l nkluteus			6.86
		S. aureus			8.90
		E. coli			8.00
		S. typhimurium			6.61
[39]	Negeri Sembilan	*B. licheniformis*	0.16 mg/mL		
		B. spizizenii	0.24 mg/mL		
		E. coli	0.31 mg/mL		
		K. pneumoniae	0.47 mg/mL		
		P. stutzeri	0.63 mg/mL		
[40]	Mexico	*S. aureus*	0.25 mg/mL		
		S. epidemidis	0.5 mg/mL		
		E. faecalis	1.0 mg/mL		

Table 3.
Antibacterial activity of Zingiber officinale *essential oil.*

Reference	Fungi	MIC	Disk diffusion	
			Halo	Concentration
[16]	*A.flavus*		20.6 mm	6 μg/mL
	A. solani		66.3 mm	
	A. oryzae		51.3 mm	
	A. Níger		66.7 mm	
	F. moniliforme		100 mm	
[35]	*C. albicans*		25 mm	100 μg/mL
	G. candidum		21 mm	
	F. oxysporum		22 mm	
	A. flavus		20 mm	
[36]	*F. verticillioides*	2500 μg/mL		
[41]	*A. terrus*		50%	10 μL
	A. Niger		31.3%	
	A. flavus		87.5%	
	F. oxysporum		87.5%	
	C. palliscens		87.5%	
	T. roseum		100%	
	F. graminearum		62.5%	
	F. monoliforme		75%	
[42]	*Penicillium* spp	869.2 mg/mL		

Table 4.
Zingiber officinale *antifungal activity.*

A research conducted in Brazil with a substance (zerumbone) isolated from ginger essential oil showed its efficacy against *S. mutans*, resulting in 250 μg/mL MIC and 500 μg/mL MBC. Another investigation of the effect of oil against growth activity and biofilm formation of *S. pyogenes* showed MIC and MBC of 1 mg/mL [37].

We found that the studies reported in this review show that the antibacterial effect of essential oil has significant differences according to the collection site, its genetic and environmental composition of the plant, and extraction methods, as well as significant differences in the inhibition of Gram-positive and Gram-negative bacteria. Gram-positive strains are more sensitive, suggesting that the cell wall composed of a thick layer of peptidoglycan surrounding the cytoplasmic membrane would be the microbial target of essential oil [43].

However, the possibility of another target is not ruled out, as we found that, depending on the location, the oil tested demonstrates a better effect on Gram-negative, suggesting other microbial targets, such as the plasma membrane, since the constituents of essential oils have lipophilic properties that interact with membranes by changing their fluidity and permeability [44].

3.4.2 Antifungal activity of ginger

In the evaluation of antifungal activity, we found that antifungal tests with *Z. officinale* oil showed inhibitory effects against all fungal tested. Ginger oil was found to completely inhibit *F. moniliforme* growth at the highest concentration tested, and *Aspergillus* inhibition was also reported.

A study with oils obtained by different drying methods against six fungi (*Candida albicans*, *Geotrichum candidum*, *Trichophyton rubrum*, *Aspergillus flavus*, *Fusarium oxysporum*, and *Scopulariopsis brevicaulis*) revealed that hot-drying ginger exhibited potent antifungal activity except against *T. rubrum* and *S. brevicaulis* when the oil was obtained by drying indoors. In open-air drying, the oil showed antifungal activity only against *C. albicans* [35].

The activity against *Fusarium verticillioides* determined by broth dilution exhibited MIC of 2500 μg/mL, suggesting that ginger oil is capable of controlling *F. verticillioides* growth and subsequent fumonisin production [36]. Both essential oil and ginger resin totally inhibited (100%) *Fusarium moniliforme* [41]. Activity against other fungi showed moderated to good effect (**Table 4**).

The antimicrobial activity of ginger oil can be attributed to its constituent monoterpenes and sesquiterpenes, as they are capable of altering the permeability and fluidity of the plasma membrane of microorganisms. The lipophilic character of its hydrocarbon skeleton and the hydrophilic character of some of its functional groups confer this property [40].

Z. officinale essential oil contains considerable amounts of phenolic compounds (eugenol, shogaols, zingerone, gingerdiols, gingerols, etc.), which may be responsible for the observed effects, and has different chemotypes in which the efficiency can be attributed to the major compounds, although the possibility of a synergistic action of all constituents is not ruled out either [41].

4. Conclusions

The studies reported in this literature review made the determination of the species, the indication of the place of collection, and the extraction method, since these data are fundamental for adequate comparison of the results, as well as a secondary metabolite identification technique where we found that the most used techniques were gas chromatography (GC) and liquid chromatography (HPLC) to indicate the present compounds. Geographical location, oil extraction method, techniques, media types, dilution used in antimicrobial activity at different concentrations, and microorganisms can certainly lead to different results. Ginger essential oil has compounds that are present in varying proportions as verified in this review; therefore, there is no parameter for their composition as they have several chemotypes. The lack of oil standardization makes it difficult to compare the work done and to obtain an adequate result of the antimicrobial activity of the oil. However, numerous reports of antimicrobial activity, even with the various variables described above, lead us to believe that ginger essential oil has a potential antimicrobial activity to be explored, and further studies are needed to ensure this activity.

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