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Antibacterial Activity of Ginger (*Zingiber Officinale* Rosc.) Rhizome: A Mini Review

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Abstract

Ginger rhizome (*Zingiber officinale*), is a famous plant product consumed as a spice as well as many uses in food industries and traditional medicine. Numerous studies have been conducted on its antibacterial potential, which showed varied results. The objective of the current mini-review is to highlight the antibacterial propereties of ginger rhizome, based on the published data. It was found that, out of 40 published papers on the antibacterial properties of ginger rhizome, 2 reported negative results, while 38 exhibited positive results against all or some of the tested bacteria. Even though, most of the positive results were not a competitor to the tested antibiotics (as positive controls). However, there were wide differences and contradictions between the positive results themselves even against the same bacterial species, indicating that the efficacy of this plant product is greatly affected by many reasons such as the method of extraction, antibacterial assay conditions, genetic variations among bacterial strains and its sources. Also, the source of plant sample is an important factor, since plants affected by geographic variations, environmental conditions and physiological factors which influence its bioactive phytochemical compounds. Accordingly, this mini-review suggests that the antibacterial properties of ginger rhizome have yet to be adequately explored using advanced multidisciplinary approach (*in vitro* and *in vivo*).

Keywords: Spices; Traditional Medicine; Ginger; *Zingiber Officinale*; Antibacterial

Introduction

Natural products are the most important source for drugs and drug discovery. The WHO estimated that about 65% of the World's populations are mainly relying on natural products derived from plants for their primary health care systems and most of them are from developing countries, the remaining 35% are mostly from developed courtiers who are also used natural products indirectly to maintain a good health [1]. Spices are important natural products, which have been used since ancient times and until now. The use of spices is not restricted to food flavoring only, but also used as food preservatives and colorants, extend shelf-life of food, prevent food spoilage, food-borne diseases and frequently prescribed in traditional medicine [2]. Antibiotics, which have made tremendous successes on bacterial infections at the beginning of the twentieth century, are now becoming less effective, as bacterial cells have developed gradual resistance for decades to common antibiotics while the human host remains unaware that antibiotic resistance catastrophe has emerged [3]. Accordingly, medicinal plants could be the new promising alternative to these deactivated antibiotics. The aim of this mini-review is to explore the efficacy of Ginger rhizome (*Zingiber officinale* Rosc.) as an antibacterial agent, by reviewing available published studies.

Ginger Rhizome in Traditional Medicine

The genus Zingiber, belonging to the family Zingiberaceae, comprises about 85 species of herbs mostly grown in Asia, South, Central America, and Africa [4]. Ginger (*Zingiber officinale* Roscoe) is a rhizomatous perennial herb, reaching up to 90 cm long. Rhizomes are aromatic, thick lobed, pale yellowish, bearing simple alternate distichous narrow oblong-lanceolate leaves. The herb develops several lateral shoots in clumps, which begin to dry when the plant matures. Leaves are long and 2-3 cm broad with sheathing bases, the blade gradually tapering to point. Inflorescence solitary, lateral radical pedunculate oblong cylindrical spikes. Flowers are rare, rather small, calyx superior, gamosepalous, three toothed, open by splitting on one side, corolla of three subequal oblong to lanceolate connate greenish segments [5].

Ginger rhizome Figure 1 is one of the most common and popular spices or flavoring agents around the world. It has been used as herbal remedy for centuries in Ayurvedic, Tibb-Unani, Chinese and Islamic herbal medicines [6,7]. Ailments, which have been treated with ginger, include colds, arthritis, nausea, hypertension, migraines, and many more [7].

Ali, et al. [6] reported that, the odor of ginger is mainly due to the presence of volatile oils, the yield of which usually varies between 1% and 3%. More than 50 components of the oil have been identified which are mainly monoterpenoids. The pungency of fresh ginger is mainly due to the presence of the gingerols, which are a homologous series of phenols and the most abundant is 6-gingerol. On the other hand, the pungency of dry ginger is mainly due to the presence of shagaols (such as 6-shagaol), which are considered as dehydrated forms of gingerols. The concentrations of gingerols in the dry ginger are slightly reduced from that of fresh ginger, while the concentrations of shagaols increases [6,8].

Figure 1: Ginger rhizome *Zingiber officinale* Rosc.

Ginger Rhizome as Antibacterial Agent

Information regarding the antibacterial activity of ginger rhizome was collected from the major scientific databases such as Science Direct, Pubmed, Web of Knowledge, and Google. Table 1 Summarize up to 40 papers on the antibacterial properties of ginger rhizome, which provide detailed information regarding solvent used in extraction, antibacterial assay and the tested microorganisms. Since it is difficult to tabulate the tested microorganisms from these huge number of papers, only the most frequently tested bacteria were recorded representing the gram-positive and the gram-negative bacteria; namely, Escherichia coli, *Staphylococcus aureus, Staphylococcus epidermidis,* Klebsiella pneumoniae, *Enterococcus faecalis, Salmonella typhi, Salmonella typhimurium, Pseudomonas aeruginosa, Proteus sp., Bacillus cereus, Bacillus subtilis, Bacillus megaterium and Streptococcus faecalis*. Some other bacteria that are rarely studied were neglected. It was also found that the methods of extraction and solvent used were greatly diverse. These studies used raw extract, chloroform, Methanol, Water, Ethanol, Petroleum ether, Dichloromethane, Carbon tetrachloride, n-Hexane, Ethyl acetate, Essential oils (hydro-distillation), Oleo-resin, Fresh Ginger oil, Dry Ginger oil, Isopropanol or Acetone. Different antibacterial assays were also used, such as antibacterial assay also varied, which were well-diffusion, disc-diffusion and/or Minimum inhibitory concentration test.

Solvent used in extraction	Antibacterial Assay	Microorganism*												Ref.
		Gram negative bacteria						Gram positive bacteria						
		E.c.	K.p.	S.t.	P.a.	P.s	S.tm	S.a.	S.e.	E.f.	S.f.	B.c.	B.s.	
H_2O	DD	-	22	-	-	24	-	24	-	-	-	-	-	9
H_2O	WD	-ve	-	13	-ve	11	-	9	-	-	-	-	-ve	10
EtOH	WD	-ve	-	10	14	17	-	13	-	-			-ve	
EtOH-H_2O	MIC (µg/ml)	-	-	-	416	-	-	52	-	-	-	-	-	11
Raw	WD	-ve	-	13	-	-	-	-	-	-	-	-	-ve	12
Cold H_2O	WD	17	-	15	-	-	-	-	-	-	-	-	-ve	
Hot H_2O	WD	-ve	-	14	-	-	-	-	-	-	-	-	-ve	
EtOH	WD	18	-	20	-	-	-	-	-	-	-	-	-ve	
EtOH	DD	9	-	10	-	-	-	-	-	-	-	-	-	13
H_2O	DD	-ve	-	8	-	-	-	-	-	-	-	-		
EtOH	DD	-	-	-	-	-	-	23	-	24	-	-	-	14
H_2O	DD	12.3	11	11	13	-	-	13	12.6	-	-	-	12.3	15
MeOH	DD	14.5	12	11.7	13.6	-	-	14.3	12	-	-	-	11.3	
EtOH	DD	15	11	11.3	14	-	-	13	15	-	-	-	13.6	
EO	MIC (% v/v)	>2·0	>2·0	-	>2·0	-	>2·0	2·0	-	>2·0	-	-	-	16
MeOH	WD	12	14	-	-	12.5	-	17	16.5	14.5	-	-	-	17
n-Hex	WD	18	-ve	-	-	20.5	-	16.5	18	15.5	-	-	-	
H_2O	WD	18	-	-	-	-	-ve	-	-	-	-	-	-	18
EtOH	DD	12	5	-	21	9	-	11	-	-	-	-	-	19
H_2O	MIC (%)	8.7	-	-	-	-	-	-	-	-	-	-	-	20
EtOH	DD	15.5	7.5	-	14.4	13.5	-	13.5	-	-	-	-	-	21
n-Hex	DD	-	-	-	-	-	-	-	4.5	-	-	-	-	22
E-Ac	DD	-	-	-	-	-	-	-	5	-	-	-	-	
EtOH	DD	-	-	-	-	-	-	-	6.5	-	-	-	-	
H_2O	DD	-	-	-	-	-	-	-	-ve	-	-	-	-	
EtOH	MIC (mg/ml)	> 20	-	-	2.5	2.5	20	0.0024	-	-	-	0.31	0.31	23
H_2O	WD	-	7	-	-	-	-	13	-	-	-	-	-	24
MeOH	WD	-	13	-	-	-	-	16	-	-	-	-	-	
H_2O	DD	-ve		-	-	-	-	-ve	-	-	-	-	-	25
EtOH	DD	-ve		-	-	-	-	-ve	-	-	-	-	-	
Raw	DD	-	7	-	-	-	-	7	-	-	-	-	-	26
Boiled Raw	DD	-	7	-	-	-	-	7	-	-	-	-	-	
H_2O	WD	-	-	-	19	-	-	27	-	-	-	-	-	27
$CHCl_3$	WD	17	-	-	-	-	-	19	-	-	-ve	-	16	28
EO (Fresh)	DD	-	-	-	7.11	-	-	-	-	-	-	-	6.05	29
EO (Dried)	DD	-	-	-	9.06	-	-	-	-	-	-	-	5.12	
H_2O	DD	-	-	-	-	-	-	32	-	-	-	-	-	30
EtOH	DD	-	-	-	-	-	-	35	-	-	-	-	-	
EO	MIC (µg/mL)	-ve	-ve	-	100	-	-ve	100	6.25	100	-	-	-ve	31
MeOH	WD	2.99	4.93	-	4.01	1.99	-	3.75	-	-	-	-	-	32

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EO	DD	-ve	20.5	-	18.8	18.4	-	-ve	-	-	-	-	-	33
EtOH ole.	WD	-ve	-ve	-	15.4	13.6	-	-ve	-	-	-	-	-	
MeOH ole.	WD	-ve	-ve	-	15.7	-ve	-	-ve	-	-	-	-	-	
CCl_4 ole.	WD	-ve	16.4	-	16.8	15.4	-	-ve	-	-	-	-	-	
Isooctane ole.	WD	-ve	-ve	-	19.1	14.2	-	-ve	-	-	-	-	-	
Isopro	MIC (v/v)	-	-	-	-	-	07-08	-	-	-	-	-	-	34
Isopro: Hex (7:3)	MIC (v/v)	-	-	-	-	-	08-09	-	-	-	-	-	-	
Hex	MIC (v/v)	-	-	-	-	-	>10	-	-	-	-	-	-	
EtOH	WD	16	-	-	-	-	-	14	-	-	-	-	-	35
MeOH	WD	15	-	-	-	-	-	13	-	-	-	-	-	
Hex	WD	15	-	-	-	-	-	20	-	-	-	-	-	
Ac	WD	-ve	-	-	-	-	-	-ve	-	-	-	-	-	
$CHCl_3$	WD	-ve	-	-	-	-	-	-ve	-	-	-	-	-	
H_2O	WD	-ve	-	-	-	-	-	-ve	-	-	-	-	-	
EtOH	WD (-ve/+ve)	-ve	-	-	-ve	-	-	-ve	-	-	-	-	+ve	36
Ole.	MIC (mg/mL)	10	-	-	-	-	-	50	-	-	-	-	20	37
EO	MIC (mg/mL)	173.8	-	-	-	-	-	8.69	-	-	-	-	86.92	
Raw	WD	-ve	-	-ve	-	-	-	6.67	-	-	-	6.67	-	38
EO	DD	9.6-13.6	9.6	9.6	-	-	-	17.3-32.6	16-21	22	-	-	-	39
MeOH	DD	8	-	-	-	-	-	7	-	-	-	9	-	40
CO_2	WD	-ve	-	-	8.8-10.0	-	-ve	13.8-16.7	-	-	-	-	-	41
EO	WD	-ve	-	-	1.16	-	2.45	8.15	-	-	-	-	-	
Raw	DD	-ve	-	-	-	-	-	-ve	-	-	-	-	-ve	42
H_2O	DD	-ve	-	-	-	-	-	-ve	-	-	-	-	-ve	
EtOH	MIC (v/v%)	9	-	-	-		08-10	2	-	-	-	0.4	-	43
EO	DD	-ve	-	-	17.5	-	-	-	-	-	-	-	23.3	44
Diethyl ether: hex (2:5)	DD	-ve	-	-	9.8	-	-	-	-	-	-	-	11.7	
EO	WD	4·3	-	-	-	-	-	4·5	-	-	-	-	-	45

Table 1: Antibacterial activity of Ginger rhizome (Zingiber officinale Rosc.).
Raw= Raw extract, $CHCl_3$= chloroform, MeOH= Methanol, H_2O= Water, EtOH= Ethanol, Pet.ether= Petroleum ether, DCM= Dichloromethane, CCl_4= Carbon tetrachloride, n-Hex= n-Hexane, Hex /n-Hex= Hexane, E-Ac= Ethyl acetate, EO= Essential oil, Ole= Oleo-resin, FGO= Fresh Ginger oil, DGO= Dry Ginger oil, Isopro= Isopropanol, Ac= Acetone, -ve= No activity, - = Not tested, E.c.= *Escherichia coli*, S.a.= *Staphylococcus aureus*, S.e.= *Staphylococcus epidermidis,* K.p.= *Klebsiellapneumoniae*, E.f.= *Enterococcus faecalis*, S.t.= *Salmonella typhi*, S.tm. = *Salmonella typhimurium,* P.a.= *Pseudomonas aeruginosa*, Ps= *Proteus* sp., B.c.= *Bacillus cereus*, B.s.= *Bacillus subtilis,* B.m.= *Bacillus megaterium,* S.f.= *Streptococcus faecalis,* DD= Disc diffusion (mm), WD= Well-diffusion (mm), MIC=Minimum inhibitory concentration (μg/ml).
*Not all studied microorganisms are mentioned in the table.

As mentioned before, bacterial species enlisted in Table 1, are the most frequent microorganisms in scientific research on Ginger rhizome. However, some other bacterial species were also showed varied degrees of susceptibility against ginger extracts, such as *Listeria monocytogenesis* and Methicillin-resistant *Staphylococcus aureus* [11], *Shigella* sp. [15], *Acinetobacter baumannii*, *Aeromonas sobria* and *Serratia marcescens* [16], *Pseudomonas florescent* [17], *Morganella morganii* [19], *Enterobacter* sp. and *Bacillus* sp. [21], viridans streptococci and coliform bacilli [22], *Salmonella enteric* [23], *Luteococcus sanguinis, Corynebacterium accolens, Serratia ficaria, Pasteurella pneumotropica, Aeromonas caviae, Pasteurella Pneumotropica, Pleisomonas shigelloides, Vibrio parahaemolyticus* [24], *Streptococcus mutans, Lactobacillus acidophilus, Norcadiaasteroides, Actinomycesviscosus, and Veilonellaalcaligens* [27]. *Streptococcus pyogene* [30], *Enterobacter aerogenes, Serratia marcescens, Salmonella enterica* and *Klebsiella oxytoca* [39], *Vibrio parahaemolyticus* [40], *Salmonella enteritidis* and *Campylobacter jejuni* [45], *Streptococcus mutans* [46], *Porphyromonas gingivalis, Porphyromonas endodontalis* and *Prevotella intermedia* [47], *Citrobacter freundii* and Lactic acid bacteria [48].

Ginger rhizome has been used extensively in food industries and traditional medicine; consumers still showing increasing interests in this plant product. However, variations in antibacterial results could be attributed to the facts that ginger rhizome greatly affected by the surrounding conditions which could alter the quality and quantity of the bioactive phytochemical compounds; among these are the abiotic stresses including the environmental stress factors like light, moisture, temperature, soil nutrients and ozone, besides the biotic stress factors such as herbivores, insects, microorganisms and the human factor such as timing in harvesting and handling the plant material [49]. In addition, the method of extraction, the solvent used, the bacteria tested and the source from which these bacteria are collected could play an important role in differences of antibacterial results of ginger rhizome. In literature, ginger rhizome was found to be rich in many phytochemical compounds of diverse bioactivity on the human body, such compounds could be useful particularly against antibiotics-resistant bacteria, putting into consideration that ginger rhizome did not exhibit antibacterial activity competitor to antibiotics in the majority of the published reports. It is assumed that this plant product could act in synergy, so when these compounds separated with extraction processes and different solvents, the antibacterial effects decreased greatly. This can be clearly observed from Table 1, where the most active extract was the essential oils (EO).This assumption has yet to be adequately explored. Sibanda and Okoh [50] claimed that phytochemical compounds of plants may act in synergy with intrinsically produced efflux pump inhibitors, this synergy property could be exploit to revive the efficacy of some deactivated antibiotics by means of increasing bacterial cell permeability and sensitivity to these antibiotics.

On the other side, among 40 paper reviewed, Onyeagba, et al. [25] and Patel, et al. [27] reported that ginger rhizome has no antibacterial activity. Their results support our previous assumption, that many biotic and abiotic factors influence the antibacterial efficiency of ginger rhizome. Such negative results are very important to understand and explain the results. Weintraub [51] mentioned that negative results are very important to adjust their research plans, understand and interpret the situation, saving effort and money and reducing the positive bias in the scientific literature. According to these two negative results on the antibacterial activity of ginger rhizome beside the contradictions of results between some published papers, it is suggested that further integrated and advanced studies are recommended, in order to explore the potential antibacterial activity of ginger rhizome.

Conclusion

Ginger rhizome is a famous medicinal plant with multiple applications in food industries and traditional medicine, numerous studies confirmed its antibacterial efficacy against some bacterial species, while little studies reported weak or no antibacterial activity. According to this mini-review, many studies exhibited wide spectrum antibacterial activity of ginger rhizome, the extract of remarkable antibacterial activity was the essential oils. It was also observed that, there are many conflicting reports about the antibacterial effectiveness of ginger against bacteria from different resources (clinical, industrial or environmental). Indicating the need for a multidisciplinary approach, combining microbiology, organic chemistry, molecular physiology pharmaceutical and medical sciences would have great potential to explore and isolate these bioactive agents, which could be used alone or in combination with other agents as a natural antibacterial drug.

Conflict of interest

There are no conflicts to publish our article in this Journal.

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