Int. J. Plant Bas. Pharm. (2022) 2(1), 98-110

INTERNATIONAL JOURNAL OF PLANT BASED PHARMACEUTICALS

https://ijpbp.com

REVIEW

OPEN ACCESS

Plants based materials as the antifungal and antibacterial agents

Venkatesh K. Bhovi[a,*]

[a] *PG Studies and Research in Chemistry, Vijayanagar College, Hosapete, Vijayanagara, Karnataka, 583201, India*

ARTICLE INFO

Article History:

Received: 30 November 2021
Revised: 27 January 2022
Accepted: 28 January 2022
Available online: 01 February 2022

Edited by: B. Tepe

Keywords:
Antimicrobials
Antifungal
Phytochemistry
Medicinal plant materials
Primary and secondary metabolites
Pharmaceutical importance

ABSTRACT

The medicinal plants are a distinguished source of our earth, which cannot be replaced even though many developments in science and technology have been. Plants are very rich in bio-medicinal properties, as well as fabrication applications. Natural product materials play a vital role in curing many diseases without having many side effects; that's why many researchers were working on phytochemistry. Plant organo-compounds such as quinine, alkaloids, polypeptides, lectins, coumarin, terpenoids, flavones, flavonoids, flavonols, fatty acids, tannins, and essential oils are metabolites for biological activities. In this review, plant materials and plants part, which are responsible for antimicrobial activity, have been discussed.

1. Introduction

1.1. Historical perspective

Plants are a fundamental part of our universe; it has shown their potentiality since primordial time. Human beings are so connected to the natural resource that life cannot exist on the earth. Plant-based materials have been used as a classical resource for traditional medicine and pharmaceutical drugs for a long time; they have played a vital role in treating all kinds of diseases that infect humans and farm animals. Pesticides traditionally used at large scales are synthetic chemicals that have non-target action as well along some of them have persistence in the environments.

To overcome these problems for the last two decades, intensive effort has been made by agricultural and botanical researchers to discover chemical compounds from plant origin having an antibacterial and antifungal activity (Sofowora, 1993; Egamberdieva et al., 2017). Most chemically synthesized compounds are halogenated, hazardous, and toxic to the environment and living organisms. It is very indispensable to have naturally occurring compounds be used as drugs. Synthetic pesticide, along with fungicides, has been used to control diseases and harmful organisms; however, most of these synthetic compounds exhibit teratogenicity, mutagenicity, carcinogenicity, phytotoxicity, and residual effects (Bajaj and Ghosh, 1975).

"Evolution" is a process by which all living organisms live here and flourish with many modifications adaptations are the biggest boon that the mother earth has blessed us with. As rightly said in Bhagavad-Gita, that "Every flora must be seen as the incarnation of God". There are different tales in many civilizations that are close to the plant kingdom and its uses to the human race. Ancient people knew the wisdom of nature and its uses. Plants and plant products have proved to be the biggest resource next to air and water, and of course, all three are interconnected within. The plant kingdom has not only given the food resources but they have been used as the

* Corresponding author:
E-mail address: venki.kb123@gmail.com (V.K. Bhovi)
e-ISSN: 2791-7509
doi: https://doi.org/10.62313/ijpbp.2022.20

Please cite this article as: Bhovi, V.K., 2022. Plants based materials as the antifungal and antibacterial agents. International Journal of Plant Based Pharmaceuticals, 2(1), 98-110, https://doi.org/10.62313/ijpbp.2022.20.

medicine for curing many diseases innumerable times. "Sushruta Samhita" is considered the olden and golden medicinal book, which contains major works in the field of Ayurveda chiefly deals with different sides of fundamental principles and the concept of surgery. These ancient books describe the more than 100 types of surgical apparatus, including scissors, forceps, scalpels, specula, etc. were explicated with their uses and applications. Dissection and operative procedures were explained, making use of vegetables and cadavers. It contains an explanation of nearly 650 drugs and confers different facets related to other surgery-related topics such as embryology, anatomy, toxicology, and applied therapeutics. Maharshi-Patanjali used the amalgamation of natural products, yoga, and the spiritual mind as the best medicine for disease-less life and bliss. Same has been defined today as a definition of health "health is not merely the absence of disease but a social, intellectual, spiritual well-being," which reiterates the old concept of Ashtanga yoga which Patanjali prescribed.

1.2. Use of medicinal plants, strategies, and challenges

Medicinal plants have attained major importance in medical care, diverse ailments in different civilizations of the world (Shikhsamani et al., 2011). World Health Organization (WHO) has published a well-sorted strategy for the advancement and promoting traditional medicinal wisdom in four major areas (Naseri, 2004) which include,

- Identification and classification of plants of medicinal value, presentation of suitable policy and proposals,
- Development and funding of research and education, particularly at the level of university and higher,
- Establishment of harmony and cooperation between stakeholders of traditional medicine and researchers of modern medicine,
- Cultivate the herbs of medicinal importance and check the annihilation of natural resources and, many times, protect the unique ecosystem in which it habilitates.

Table 1. List of some plants and their active parts used

Sl No	Examples of common plants	Active parts used
1	Turmeric	Rhizome
2	Sandalwood	Heartwood region of the stem
3	Neem	Whole plant
4	Ginger	The rhizome (root)
5	Chinchona	Bark
6	Holy basil(tulsi)	Whole plant
7	Cloves	Unopened buds
8	Pepper	Seeds
9	Coconut	Endosperm part
10	Periwinkle	Flowers and leaves

These plans have depicted the vitality of the phyto-resources for the treatment and prevention of many dreadful diseases. Nowadays, there is a renaissance in the consumption of herbal formulations in standardized crude extracts. These are measures of their manifested side effects, the high cost of chemical drug synthesis, and intellectual property rights were less concerned. Many-medicinal plants such as garlic, onion, and ginger have gained admiration from the masses to treat and prevent numerous chronic disorders. The influence of various journals on publishing data on medicinal plants is getting lots of attention towards plant materials' phytochemicals and biomedicines activities. Mounting drift can include phytotherapy and plant-based medicines in the school curriculum of medicine, which is also considered the revival of Ayurvedic methods in modern outfits. Nowadays, more than 70% of German physicians prescribe plant extracts, and St. John's Wort is more generally used to treat depression than any other modern chemical drug. Phyto-therapy is now being accepted as one of the safest treatment methods as it does not contain any specific drug but a mixture of phytochemicals of natural origin which act as effect-multiplier and side effect nullifying, although which is still debatable. Natural available medicinal plants demonstrate the varieties of antioxidants properties and are extensively used to treat many infections around the globe. On the other hand, these plant materials also display other activities such as antimicrobial, anticancer agents, anti-diabetic agents (Chaleshtori et al., 2011), anti-atherosclerosis and immuno-modulatory (Shahrani et al., 2009), and many times may also act asreno-protection (kidney protector) or hepatoprotective effects (liver protective) (Baradaran et al., 2013).

1.3. Biological activities of plants

Extensive research work was done on medicinal plants, giving you an idea about the significant antioxidant activity properties (Chaleshtori et al., 2011). Incidentally, a different category of animal models comprising of diabetes, autoimmune diseases, encephalo-myelitis, inflammation of bowels, ischemia in rat striated muscle tissues and kidney, renal toxicity hepatotoxicity, hyperlipidemia, radiation-induced necrosis, and cataracts for recording antioxidative effects of traditional plants have been worked and are published in different journals worldwide. Incidentally, medicinal plants have proven to be a novel source for preparing new drugs. One astonishing advantage over the isolated drug is that the crude plant extract of the plant containing the designated drug has a very little affinity towards antibiotic resistance over the isolated drug delivery. The crude extract of a plant that contains numerous phytochemicals has a cumulative effect on the harmful pathogens than a specific drug. It is also assumed that the cumulative effect on the pathogens confuses the immune system of the pathogen, and antibiotic resistance is checked. Nowadays, researchers are forcefully reliant on traditional medicinal plants to discover new potential drugs with minimal side effects. Focus is now given to plant-mediated drug therapy and drug discovery. Multilayered teamwork, including ethnobotanists, physicians, pharmacologists, and phytochemists, is essential for the successful results of medicinal plant research. Vitally, stringent policy making is also needed to enhance the efficacy quality without compromising the safety when delivering the drugs. Various nations define herbal medicines differently. Besides, countries have adopted vivid licensing, manufacturing, marketing, dispensing, and medicinal produces. In most countries in the west, herbal medicines are either licensed as medicines with proven efficacy by significant clinical trials. However, few underdeveloped and developed countries such as the Islamic Republic of Iran, China, and the United States of America were treated medico-herbal products are considered food supplements and, thus, are not required to meet the international drug standards.

1.4. Plant active parts (seeds, fruits, barks, leaves)

It is astonishing to know that we use the root of ginger as medicine (Mashhadi et al., 2013) but not the leaves. Similarly, in Santalum's album (sandalwood), the oil extracted is used as a product of economic value but not any other part. So, it is to be observed that the phytochemicals present in the plant are not present in all the regions of the plant but present in a specific part of the plant like stems, roots, leaves, flowers, and fruits. Some of the important active compounds and their active site are listed in Table 1.

This review sheds light on the antimicrobial and other pharmacological aspects of the commonly used plants of day-to-day life. The biological and pharmacological properties are illustrated in Figure 1. One part of the plant may not hold good for the other part of the same plant; hence proper literature survey and perfection are very much needed for the analysis in phytochemistry.

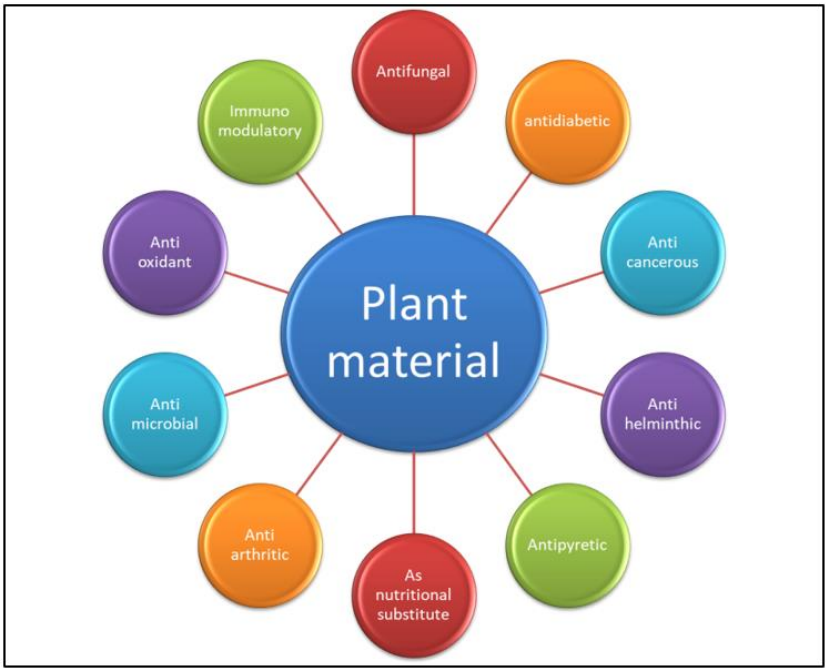


Figure 1. Schematic representation of bioactivity of plant materials

2. Neem (*Azadirachta indica*)

2.1. Systematic position

Kingdom: Plantae
Clade: Angiosperms
Order: Sapindales
Family: Meliaceae
Genus: *Azadirachta*
Species: *A. indica*

2.2. General description of the plant

The neem tree (*A. Indica*) is one of the most common trees in the Indian sub-continent, which has many ethnopharmacological uses and ethical properties attributed to it. Neem plants are generally regarded as possessing powerful health-promoting properties for ages. Indeed, many shreds of evidence show that the neem leaves and their bark were used as medicine for wound ailments 4500 years ago (Bhardwaj and Rajput, 2010). Maharshi Patanjali documented reveals that neem plant materials are medicine for Vata-related diseases (vataja). Even today, the *A. indica* tree is admired as the "Rural Dispensary" as every part of it shows distinctive therapeutic properties (Figure 2).

2.3. Distribution of neem on the basis of geography and climate

Neem belongs to the family of the Meliaceae family (WCSP, 2016). The Meliaceae family has naturally grown rapidly with less special treatment, a perennial, evergreen tree with a property of drought resistance. The neem tree grows into a large shady tree with a round canopy and has a life span of 150-200 years. Neem possesses the characteristic properties by its strong repulsive odor (Subapriya and Nagini, 2005), which is seen extensively in its oil; its flowers have a specific honey-like aroma that can be smelled from miles flowering season is from April to May. This is a fast-growing tree that needs scarce water; neem is also renowned as a remarkable renewable resource as it gives a very good substitute for the costly trees like teak rosewood, etc.

2.4. Ethnomedical importance

During the Ayurvedic era, neems were used to balance the vata. Its anti-cold and dry qualities tend to intensify vata. Therefore, neems are habitually recommended with other herbs that help soothe its vata-intensifying nature. Ethnically, people have used neem to clean teeth with neem twigs. Juice of neem is again considered a noble tonic to increase appetite and antipyretic eradicate helminths present as hosts in the intestine. Therapeutically, its aqueous crude extracts of bark and fresh leaves have been used for centuries in ethnic medicines to control diseases such as leprosy, ascariasis, and chronic respiratory disorders (Prieto et al., 1999).

Figure 2. Photography of neem plant

2.5. Phytochemical constituents

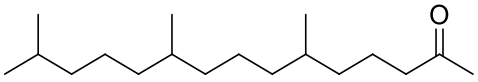
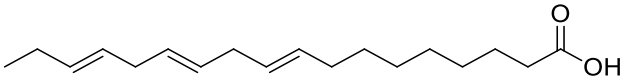
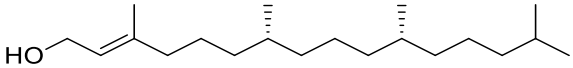
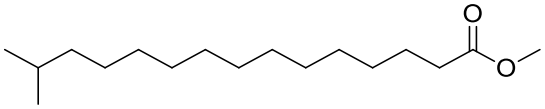
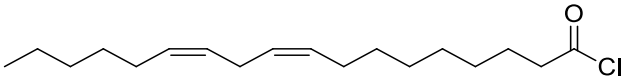
The dominant phytochemical constituents in ethyl acetate crude extracts reported are hexahydrofarnesyl acetone, 9,12,15-octadecatrienoic acid, and (9E,12E,15E)-9,12,15-octadecatrien-1-ol. One of the leading chemical compounds which were extracted in aqueous chloroform extracts are methyl-1,4-methylpentadecanoate, lineoleoyl chloride, phytol, methyl isoheptadecanoate, (2E)-3,7,11,15-tetramethyl-2-hexadecen-1-ol, and nonacosane. Lastly, the butyl alcohol (butanol) extracts of the fresh leaves contain (2E)-3,7,11,15-tetramethyl-2-hexadecen-1-ol, lineoleoyl chloride, levoglucosenone, benzaldehyde,2-methyl, methyl-14-methylpentadecanoate, and hentriacontane (Hossain and Nagooru, 2011; Hossain et al., 2011). The different compounds extracted from neems include hydrocarbons, terpene, terpenoids, phenolic compounds, alkaloids, long-chain fatty acids, and their derivatives. Literature survey shows that most of the compounds identified in neem are tabulated in Tables 2 and 3 (Cock et al., 2009; Kauroo et al., 2021).

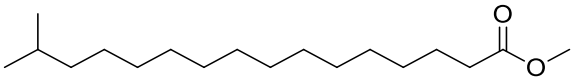
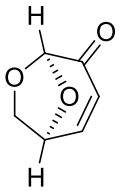
Table 2. The phytochemicals recorded in neem

Phytochemical constituents	Methanol extract	Ethanol extract	Chloroform extract
Alkaloids	+	+	+
Saponin	+	+	+
Steroid	+	+	+
Tannin	+	+	+
Anthocyanin	+	+	+
Phenol	+	-	+
Terpenoids	+	+	-
Anthroquinone	+	+	+
Gums	+	+	-
Resins	+	+	+

+ = Present; - = Absent

Table 3. The phytochemicals constituent present in neem (Alzohairy, 2016; Hossain et al., 2013)

Sl No	Chemical Name	Common name	Chemical structure
1	6,10,14-Trimethyl-2-pentadecanone	Perhydrofarnesyl acetone	
2	Octadeca-9,12,15-trienoic acid	9,12,15-Octadecatrienoic acid	
3	(2E,7R,11R)-3,7,11,15-tetramethyl-2-hexadecen-1-ol	Phytol *trans*-Phytol	
4	Methyl 14-methylpentadecanoate	Methyl isohexadecanoate	
5	(9Z,12Z)-Octadeca-9,12-dienoyl chloride	Linoleoyl chloride	

Sl No	Chemical Name	Common name	Chemical structure
6	Methyl 15-methylhexadecanoate	Methyl isoheptadecanoate	
7	(1S,5R)-6,8-Dioxabicyclo[3.2.1]oct-2-en-4-one	Levoglucosenone	
8	Hentriacontane	*n*-Hentriacontanone	

2.6. Antifungal and antibacterial activities

Anti-fungal and antibacterial properties of extracts from neem leaves were reported; they have been studied in both methods, which are intricate *in vitro* or *in vivo*. The study reveals the presence of different antimicrobial active components in leaves of neem trees, such as quercetin, desactylimbin, and sitosterol. On the contrary, the researcher explains the presence of other phytochemical components which held responsible for enhancement active constituents like triterpenes or the limonoids such as meliantriol, azadirachtin, desactylimpin, quercetin, sitosterol, nimbin, nimbinin, nimbosterol, nimbidin, and margisine, and different bitter-tasting substances such as gums, alkaloids, terpenes, resins, glycosides, and phenols (Lucantoni et al., 2010; Grewal and Grewal, 1988). Lyer and Williamson (1991) have credited the antifungal properties of neem extracts to the reduction in protease activity of dermatophytes induced by the organic neem extract. A crude extract of neem juice acts as an antibacterial agent and is useful in inhibiting vibrios in marine shrimp. Neem may likely have acted as an adjuvant in using nature-antibiotics auxiliary antibiotics, which have dominated the current market. The effectiveness of neem in inhibiting bacteria is a well-known Ayurvedic medicine in rural India. The decoction prepared from the leaves of neem has been used to treat skin problems, especially measles. Aqueous and organic extracts from the neem leaves showed their reductional effect in all the standardized concentrations against the sex pathogenic fungi. These human pathogenic fungi are four *Aspergillus* species (*A. terrues*, *A. flavus*, *A. niger*, and *A. fumigatus*) which are generally known to cause aspergilloses, adding to this, *Microsporum gypseum* (a dermatophyte) and *Candida albicans*, the causative agent of dreadful dermatophytosis and candidiases. It is also recorded that all standard concentrations of the aqueous extract effectively suppresses the growth of mycelia of these fungi, and its effect was recorded to have increased with increasing concentration (Kannusamy et al., 2016). These human pathogens (*Aspergillus* and *C. albicans*) are the causal agent of dermatophytosis and candidiases (Okemo et al., 2001).

Figure 3. *Z. officinale* (ginger) rhizome (Ayodele et al., 2018)

3. Ginger (*Zingiber officinale*)

3.1. Systematic position

Kingdom: Plantae
Clade: Angiosperms
Order: Zingiberales
Family: Zingiberaceae
Genus: *Zingiber*
Species: *Z. officinale*

3.2. General description

Ginger is one of the frequently found common spices used extensively in different parts of the world because of its medicinal properties. It has made its revered regards in the kitchen of India and the European continent. Rhizome or root part of ginger (genus *Zingiber*) is the active part of the plant used in medicine for the treatment of various diseases like cough, cold, nausea, vomiting, diarrhea, gastrointestinal ulcers (peptic ulcers), diabetes, fever, reducing cholesterol levels of the arteries, rheumatoid arthritis, dry

mouth/xerostomia, sore throat, cancer, migraine headache, minor respiratory disorders. *Z. officinale*, commonly called ginger, belongs to the Zingiberaceae family. Gengibre Ancoas is the most commonly recognized trivial Spanish name of ginger (GRIN, 2017), but in Hindi and Urdu, it is known as "Adrak". The horizontally solid underground stem/rhizome of ginger is the most extensively used cooking ingredient and spice in daily household cooking activities (GRIN, 2017). Ginger is also esteemed in ayurvedic, Unani, allopathic, and household medicines despite its use as a food and flavoring agent. The rhizomes of the ginger can be utilized in the form of a paste, ginger juice in preparing tea (flavoring), dried powder for preparing medicinal tonics (Kashaya), and preserved slice its juice and decoction (Figure 3).

3.3. Distribution of neem on the basis of geography and climate

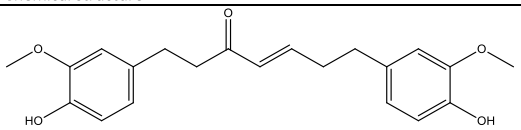
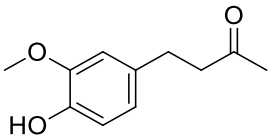
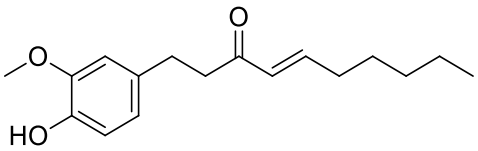
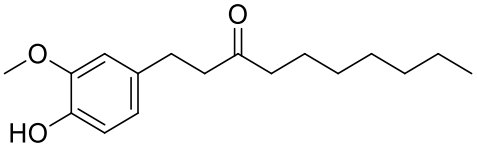
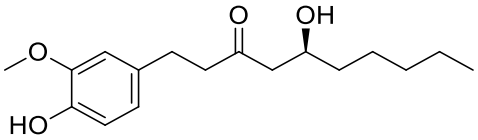
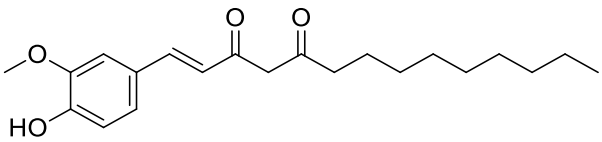
Ginger has wildly seen in southern China, Asia, and West Africa. In ancient times, ginger cultivation was exceptionally common in different countries like Japan, China, Indonesia, Nigeria, India, Brazil, Sri Lanka, and the Philippines. It is ethnically called a fixed deposit of farmers as it can even spread its rhizomes during drought conditions (GRIN, 2017).

Table 4. The phytochemicals recorded in ginger

Bioactive principle	Chloroform extract of ginger	Methanol extract of ginger
Alkaloids	+	+
Tannins	+	+
Glycosides	+	+
Saponins	+	+
Steroids	-	-
Flavonoids	+	+
Terpenoids	+	+
Pholobotannins	+	+

+ = Present; - = Absent

Table 5. The most common phytochemical constituents present in ginger (Rahman, 2014; Liu et al., 2019)

Sl No	Chemical Name	Common name	Chemical structure
1	*(E)*-1,7-bis(4-hydroxy-3-methoxyphenyl)hept-4-en-3-one	Gingerenone-A	
2	4-(4-Hydroxy-3-methoxyphenyl)butan-2-one	Zingerone Zingiberone	
3	*(E)*-1-(4-Hydroxy-3- methoxyphenyl)dec-4-en-3-one	Shagoals	
4	1-(4-Hydroxy-3-methoxyphenyl)decan-3-one	Paradol	
5	(S)-5-Hydroxy-1-(4-hydroxy-3-methoxyphenyl)-3-decanone	Gingerol	
6	1-(4-hydroxy-3-methoxyphenyl)tetradec-1-ene-3,5-dione	1-Dehydro-10-gingerdione	

3.4. Phytochemical constituents

Documentary of ginger's phytochemical constituents of roots (rhizome) was tabulated below. Cumulative effects of alkaloids, tannins, and saponins have been attributed to acting as the ginger's antifungal and antibacterial activities (Ayodele et al., 2018) listed in Tables 4 and 5.

3.5. Antibacterial and antifungal activities

It is recorded that diverse bacterial strains exhibit various levels of sensitivity gradient against the extract of ginger. The biggest havoc of today's world is the development of antibiotic resistance by bacteria (pathogenic microorganisms). To overcome this worrying menace, finding new novel active compounds against new targeted microorganisms and reducing their overall side effects is the utmost matter of urgency. Most of the available spices extracted in an

aqueous medium or organic solvents have active biological compounds, mainly used in the formulation, extraction, and synthesis of potent drugs. Thus, ginger, a normal ingredient in Indian daily food delicacies, can provide a natural defense against certain natural foes like bacterial pathogens. It is also to be noted that the single bioactive compound extracted and treated to certain diseases has a high risk of getting resistance, whereas the natural extract, which is a mixture of many phytochemicals, is notably the novel method to treat the bacterial diseases without the fear of antibiotic resistance. The diversified significant statistics of the effects of ginger on different strains of fungi are recorded. *Aspergillus* spp., *Penicillium* spp., and *Fusarium* spp. were predominant mycotoxigenic fungal contaminants of Pearl millet grains. Methanolic extracts of ginger (*Z. officinale*) roots possess good antifungal activity against *A. flavus*, *A. oryzae*, *A. fumigatus*, *Penicillium italicum*, *P. chrysogenum*, *P. oxalicum*, *Fusarium oxysporum*, *F. subglutinans*, and *Trichoderma harzianum* (Kim et al., 2009; Ravindran and Babu, 2016). This confirms the presence of biologically active compounds such as alkaloids, tannins, flavonoids, and saponins, which, when purified, can be used as a biocontrol agent in the prevention of deterioration in agricultural products and could also be explored as a therapeutic agent in the control of mycotoxigenic fungi associated diseases in humans (Naveena et al., 2004).

Figure 4. *C. longa* (turmeric) rhizome

4. Turmeric (*Curcuma longa*)

4.1. Systematic position

Kingdom: Plantae
Clade: Angiosperms
Order: Zingiberales
Family: Zingiberaceae
Genus: *Curcuma*
Species: *C. longa*

4.2. General description

Turmeric (*C. longa*) is a perennial herb of the ginger family. Ginger's physiological properties were reported elsewhere (Ajav and Ogunlade, 2014; Funk et al., 2016). It grows up to 3 feet long with aromatic green leaves. The rhizome part of the plant has a characteristic aroma, a bitter taste, and stains deep orange-yellow color. The color changes to red in higher alkaline pH. Turmeric is an active ingredient that adds colors and flavors to most foods (like curry, relishes, pickles, and spiced kinds of butter for vegetables, poultry, fish and egg dishes, rice, and pork). Due to its medicinal and cosmetic properties, it has a wide range of applications (Figure 4).

4.3. The distribution of neem on the basis of geography and climate

Southern India and Indonesia have grown larger and most common spice. India itself owes 40 different species of turmeric having a different flavor, color, and shape of the rhizome (Prasad and Aggarwal, 2011).

4.4. Ethnomedical importance

C. longa (turmeric) is a rhizome part of the plant that has been used as an antimicrobial and antiseptic agent and an insect repellant for a very long time in India. It has also been adored as the symbol of marriage in south Indian culture. Several studies have reported that a vibrant spectrum of antimicrobial activity attributed to curcumin includes antiviral, antibacterial, antifungal, and antimalarial activities. It is a safe food additive as its antimicrobial activity, and negligible toxicity are well pronounced even at high doses (12 g/day), which was accessed by clinical trials on humans; that's apart, it is also used as a key to designing the new antimicrobial agents. Curcumin was used as a standard drug for synthesizing many modified and developed drugs for the synthesis and various derivatives relating to curcumin. It also has a greater application in textile industries as an antimicrobial agent suitable for textile materials. Turmeric is the active substance in herbal remediation and the spices of food value. The bright yellow color imparts turmeric and curry, which are usually isolated from the rhizome part of the plant. *C. longa* is a natural, healthy, and safe product to use even without any clinical prescriptions. Turmeric has huge benefits recorded in traditional medicine, such as treating rheumatoid arthritis (Pourhabibi-Zarandi et al., 2021), jaundice, eye infections, liver cirrhosis, and dental arches (Praditya et al., 2019). Also, the exploitation of biological potency of turmeric in new medicine has been permitted, such as anti-inflammatory, hypoglycemic agent,

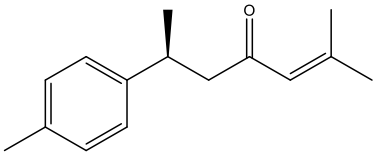
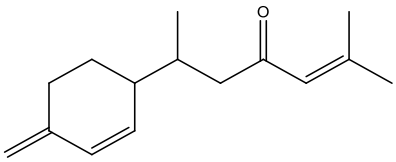
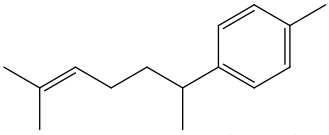
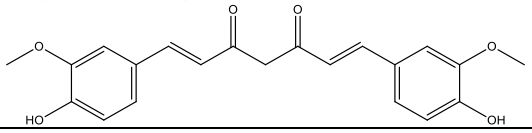
antioxidant, necrosis healer, and antimicrobial activities. In India, it is common that turmeric powder is smeared on the wounds and cuts for a quicker healing process. The mechanism of its antifungal activity is not properly analyzed and recorded, but it has been recommended that its fungicidal mechanism would involve the accumulation of chitin over the outer layer of the cell wall. However, curcumin has been advised as a wonderful antibacterial and antifungal agent. Some antiviral activities are also recorded in turmeric traditionally (Zorofchian Moghadamtousi et al., 2014).

Table 6. The phytoconstituents in *C. longa*

Phytoconstituents	Methanol extract	Ethanol extract	Chloroform extract
Alkaloids	+	+	+
Saponin	+	+	+
Steroid	+	+	+
Tannin	+	+	+
Anthocyanin	+	+	+
Phenol	+	-	+
Phlobatannin	+	+	-
Anthraquinone	+	+	+

+ = Present; - = Absent

Table 7. The phytochemicals present in *C. longa* (turmeric) (Oghenejobo and Bethel, 2017; Niranjan and Prakash, 2008)

Sl No	Chemical Name	Common name	Chemical structure
1	(6S)-2-methyl-6-(4-methylphenyl)hept-2-en-4-one	*(+)-(S)-ar*-turmerone	
2	2-methyl-6-(4-methylidenecyclohex-2-en-1-yl)hept-2-en-4-one	Curlone	
3	2-Methyl-6-*p*-tolyl-2-heptene	*aryl*-Curcumene *alpha*-Curcumene	
4	*(1E,6E)*-1,7-Bis(4-hydroxy-3-methoxyphenyl)hepta-1,6-diene-3,5-dione		

4.5. Phytochemical constituents

The major phytochemicals of turmeric oil were curlone, *ar*-turmerone, and *ar*-curcumin. It is said that the major photo-constituent *ar*-turmerone would be responsible for turmeric's antioxidant activity. Due to the presence of phenyl ring portion and a 1,3-unsaturated ketone functions of *ar*-turmerone, *in vitro,* antioxidant properties of turmeric oil are highly pronounced (Chanda and Ramachandra, 2019). Increased levels of superoxide dismutase, glutathione, and glutathione reductase enzyme levels in blood and glutathione-S-transferase and superoxide dismutase enzymes in the liver were reported in mice after the oral administration of turmeric oil for one month (Rudrappa and Bais, 2008). Saponins have been reported in turmeric, which acts as an antimicrobial agent added to which they also act as a key precursor for steroidal substances. These steroidal substances have recorded a vibrant spectrum of pharmacological activities (Liju et al., 2011). The terpenoids and sesquiterpenes isolated from the oils of turmeric also exhibit anti-inflammatory and antimicrobial effects. Preliminary phytochemical screening of methanolic extract of turmeric shows tannins, phenolic compounds, alkaloids, terpenoids, phytosterols, saponins, and flavonoids. The scientific method of phytochemical screening offers a comprehensive scientific validation for its use in treating spectra of disorders and diseases. The phytochemical constituents are listed in Tables 6 and 7.

4.6. Antibacterial and antifungal properties of turmeric

Various works have been reported on turmeric in exploring the antimicrobial potency against infectious bacteria and different strains of the dreadful fungi which cause various types of diseases in many studies on aqueous extract of *C. longa* rhizome revealed that MIC (minimum inhibitory concentration) value, MBC (minimum bactericidal concentration) is found to be 4-6 g/l and 16-32 g/l respectively, against *Staphylococcus epidermidis* ATCC 12228, *S. aureus* ATCC 25923, *Klebsiella pneumoniae* ATCC 10031 and *Escherichia coli* ATCC 25922 (Niamsa and Sittiwet, 2009). The antibacterial studies of ethanolic extracts and essential turmeric oil have shown degrees of sensitivity on microbes. This may be due to the active phytochemical compounds present in the extracts. The phytochemical analysis confirms the presence of flavonoids, glycosides, and phenols in varieties of turmeric. This result is comparable with the results of Luthra et al. (2001), who proved that the ethanol and methanol extracts of *C.longa* were active against different strains of fungi. The leaf extract was significantly effective ($p < 0.05$) against the test pathogens. Of all the extracts, the maximum zone was exhibited by methanol extract against *E. coli*

and the least one by ethanol leaf extract against *Serratia marcesens* (6.5 mm). The leaves of *C. longa* showed a zone of inhibition against most test microbes in a comparable quantity with the rhizomes (Singh et al., 2002). Antifungal activities about curcumin are attributed to the most significant effect recorded against *Candida* spp. and *Paracoccidioides brasiliensis*, although curcumin showed fungicidal effects on various fungal strains. Although different biological activities have been reported on curcumin, no proper clinical literature have been reported so far for this compound, and satirically, clinical trials are still under examination for different diseases, namely, multiple myeloma (type of cancer), colon and pancreatic cancers, myelodysplastic syndromes, Alzheimer, and psoriasis (Hashemi et al., 2008). Until 2013, over 65 clinical trials on curcumin have been reported, and still, more are underway.

Figure 5. *O. sanctum* (Tulsi or Holy Basil)

5. Tulsi or Holy basil (*Ocimum sanctum*)

5.1. Systematic position

Kingdom: Plantae
Clade: Angiosperms
Order: Lamiales
Family: Lamiaceae
Genus: *Ocimum*
Species: *O. sanctum*

5.2. General description

O. sanctum (L.) is well known for its sacred uses and holiness more than its pharmacological properties (Prakash and Gupta, 2005; Pattanayak et al., 2010). It has a very special status in the Indian traditional families where its presence is very important for the prayers and is predominantly grown for religious practices, ethnomedicinal purposes, and its essential oil (Siva et al., 2016). It is largely known across the Indian subcontinent as a common household medicinal plant, and its addition to the tea makes it a delicious beverage. An herbal decoction (Kashaya), commonly used in Ayurveda, also has appreciated the use of Tulsi. Tulsi is considered the goddess and has an important role in the Vaishnavite cult of Hinduism (madhwa and srivaishnava philosophy), in which devotees perform worship involving holy basil plants or leaves as the favorite plant of the Lord. The other traditional names for the *O. sanctum* are Tulsi or Holy basil (Figure 5).

5.3. Distribution of neem on the basis of geography and climate

It is an aromatic herb belonging to the family Lamiaceae. It is native to India and found predominately in Southeast Asia. It is a perennial herb growing 3-4 feet with aromatic seeds and leaves. There are many species and subspecies in *Ocimum,* seen in India. It is extensively used in ancient Ayurvedic medicine and the Siddha system of medicine to cure various infirmities. It is regarded as one of the holiest and sacred herbs grown in the Indian subcontinent.

5.4. Ethnomedical importance

This plant has uppermost medicinal properties, which exhibit biomedicinal applications such as analgesic, anti-inflammatory, antistress, antimicrobial, hypoglycemic, immunomodulatory, antiseptic, and hypertensive activities (Sofowora, 1993; Devendran and Balasubramanian, 2011). The Indian subcontinent has used this medicinal plant for ages to manage different diseased conditions from ancient times better. But, in contrast, very less is known about the mode of action at different molecular mechanisms that need to be studied. Tulsi plants parts are generally used on the common cold, cough, fever as a stimulant and antihelminthic (Buchineni et al., 2015). It is also used as a mosquito and insect repellent (Singh et al., 2012). *O. sanctum* leaf extract has been shown to stimulate biochemical pathways of insulin production and release into the bloodstream. The ethanolic extract substantial reduction in tumor cell size and an increased life span of mice suffering from sarcoma-180 solid tumors (Yamani et al., 2016); on the other hand, benzene extract fraction in the albino rat has been shown to reduce the total sperm count and sperm motility and leading to the condition called oligospermia (Sood et al., 2005). *In vivo* studies on different animals have shown that extracts of Tulsi leave showed a reduction in plasma level of the stress hormone-corticosterone induced by both acute and chronic noise stress. This is in good accordance with the traditional use of eating Tulsi leaves during acute headaches, and even today, many ayurvedic practitioners prescribe Tulsi as a chief drug for treating migraine.

5.5. Phytochemical constituents

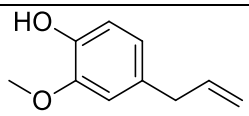
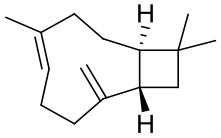
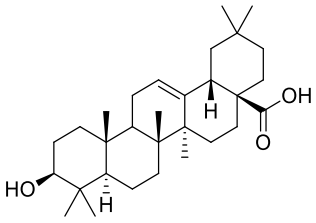
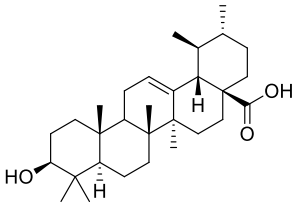
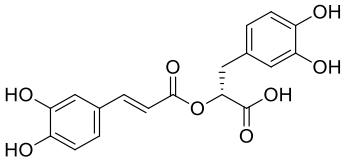
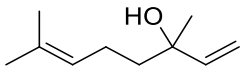
The Tulsi is mainly composed of different active biomolecules such as terpene, terpenoids, alkaloids, tannin, saponin, and steroids are very complex and contain many different types of phytochemicals. Qualitative phytochemical analysis of the extracts from the leaves of *O. sanctum* divulged the presence of phytochemicals such as steroids, flavonoids, terpenoids, tannins, saponins, and cardiac glycerides. Similarly, the phytochemical constituents like phlorotannin, which, as expected, were found to be nil. The phytochemical compounds present in the hydroalcoholic extracts of *O. sanctum* were identified by GC-MS analysis. The active principles were analyzed with their retention time (RT), molecular formula, MW (molecular weight), and concentration (%) are recorded (Sethi et al., 2003). The leaves contain eugenol and caryophyllene, dominantly responsible for various antimicrobial activities. Eugenol, largely seen in Tulsi, is mainly responsible for its mosquito repellent properties. The same eugenol is also considered an anti-oxidant drug. This property enables us to maintain proper health conditions and prevent the occurrence of the change of heart diseases by reducing the accumulation of various free radicals in the body and triggering many other biochemical reactions. Eugenol is the major compound found in the whole plant of *O. sanctum,* which is being used for pharmacological work. Saponins, which are seen in huge amounts in O. sanctum, are generally regarded as an anti-nutrient but are also believed to be useful in the human diet for controlling cholesterols. Therefore, its presence in this plant could suggest that the plant is of medicinal value. Saponins confirmed by the foam test was done in ancient days to identify the presence of saponins so that the given plant extract could be administered for stomach ailments. Tannins (Table 8) are also severe, tasting that precipitate and bind to different protein structures and destabilize them and is seen in various plants of Plantae kingdom. Tannins have usually considered non-nutritional phytochemical, but they may be applied pharmacologically in hemostatic, antidiarrheal, and anti-hemorrhoidal compounds in treating the various ailments. The chemical composition and structure are listed in Table 9.

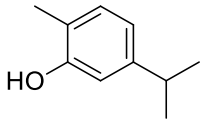
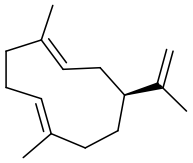
Table 8. Phytochemicals recorded in Holy Basil

Phytoconstituents in *O. sanctum*	Presence or absence
Alkaloids	+
Tannin	+
Saponin	+
Steroid	+
Phlobatannin	+
Terpenoid	+
Flavonoid	+

+ = Present; - = Absent

Table 9. Phytochemicals present in *O. sanctum* (Chaudhary et al., 2020; Singh and Chaudhuri, 2018; Jacob et al., 2016)

Sl No	Chemical Name	Common name	Chemical structure
1	2-Methoxy-4-(prop-2-en-1-yl)phenol	Eugenol	
2	(1R,4E,9S)-4,11,11-Trimethyl-8-methylidenebicyclo[7.2.0]undec-4-ene	Caryophyllene	
3	(4aS,6aR,6aS,6bR,8aR,10S,12aR,14bS)-10-hydroxy-2,2,6a,6b,9,9,12a-heptamethyl-1,3,4,5,6,6a,7,8,8a,10,11,12,13,14b-tetradecahydropicene-4a-carboxylic acid	Oleanolic acid	
4	(1S,2R,4aS,6aR,6aS,6bR,8aR,10S,12aR,14bS)-10-Hydroxy-1,2,6a,6b,9,9,12a-heptamethyl-2,3,4,5,6,6a,7,8,8a,10,11,12,13,14b-tetradecahydro-1H-picene-4a-carboxylic acid	Ursolic acid	
5	(2*R*)-3-(3,4-dihydroxyphenyl)-2-{[(2*E*)-3-(3,4-dihydroxyphenyl)prop-2-enoyl]oxy}propanoic acid	Rosmarinic acid	
6	3,7-Dimethyl-1,6-octadien-3-ol	Linalool	

Sl No	Chemical Name	Common name	Chemical structure
7	2-Methyl-5-(propan-2-yl)phenol	Carvacrol	
8	(1E,5E,8S)-1,5-dimethyl-8-(prop-1-en-2-yl)cyclodeca-1,5-diene	Germacrene	

5.6. Antifungal and antibacterial properties of O. sanctum

Methanolic extract of *O. sanctum* possesses antimicrobial potential against both gram-negative and gram-positive bacterial strains (Yamani et al., 2016). Due to its vibrancy in the efficacy of both types of bacteria, it is considered the efficient drug of antimicrobial properties. The study shows a solid indication that extracts of *O. tenuiflorum* contain bioactive compounds that are of medicinal significance and thus justify using plant species as traditional medicine for the treatment of various diseases. It is also known for its antibacterial properties against gram-positive (*S. aureus* and *Bacillus subtilis*) and gram-negative (*Pseudomonas putida* and *K. pneumoniae*, *E. coli*) bacterias (Mallikarjun et al., 2016). A well-diffusion assay used to test the sensitivity of bacterial strains towards antibiotics with a clear zone around the well depicts the bacterial sensitivity towards antibiotics which showed *Ocimum* leaves extract exhibited significant inhibition levels against the five selected bacterial strains. According to Baliga et al. (2013), plant extracts of Tulsi were notably toxic against some fungal and gram-positive microorganisms and exhibited mild toxicity against *E. coli*. Basil is also considered one of the home remedies for simple fungal infections. The leaf juice was applied on the older days on the infected area for the ailment. On literature survey, the effect of basil leaves is studied on ten different strains, namely *Rhizoctonia solani*, *R. batticaloa*, *Phomasorghina*, *Colletotrichum gloeosporioides*, *F. pallidorosem*, *F. oxysporum* (ciceri), *Sclerotium rolfsii*, *Sclerotinia sclerotiorum*, *Alternaria solani,* and *A. alternate* and all the ten strains of fungi multiplication was reduced significantly by the different concentrations of the extract, but not even the single form could critically inhibit the growth on any one of these fungi strains. The boiled extract at 10% is far more effective than powdered, crude and ethanol extracts against five fungal pathogens, i.e., on *R. solani*, *R. batticaloa*, *S. rolfsii*, *S. sclerotiorum*, *A. solani*, and *A. alternata*. The efficacy of boiled, crude, and powdered extract against the respective fungal strains was progressively improved with the increase in the concentration level from 15 to 20%, but the total inhibition of test fungus was not recorded even at a maximum standard concentration of 20%. This may be because, in the boiled extract, the protein denaturation is done by tannins, and saponins are in the activated state, which directly acts on the cell membrane of the fungi and inhibits the growth of cancer in different cell types (Gurib-Fakim, 2006).

6. Prospects, challenges, and limitations

The world is nourished with innumerable types of different plants and animals all playing their unique role in maintaining the ecological balance of the natural system. Therefore, Ruskin Bond once says “every organism is the rightful inheritor of this earth”. Plants have their unique properties which are of economical uses and very essentially, possess medical values. If exploited rightly, they are the cure for almost all diseases that mankind is suffering from today. Researchers must center their exploration in identifying the right plant for its medicinal properties which is used as medicine for the ailments of various disorders.

This review has enlightened on traditional medicinal plants, which are commonly used in the day-to-day life of every human being irrespective of continental barriers. These plants have been used as a medicinal substitute, food additive for a very long time, yet even today, true scientific significance is not understood by most common people. Therefore, amalgamating ancient wisdom and modern techniques is the only way to make scientific research more characterized.

We have focused on a limited number of plants due to the vastness of the available data; otherwise, it would be hard to concise the content and become illegible to read and understand. Also, the different approaches in analyzing the phytoconstituents are to be considered so that the specificity of the phytochemical and its biological effect is divulged more precisely.

7. Conclusions

The modern world has modern problems with modern diseases that need a combination of technology and ancient wisdom for smart solutions. Pathogens are also evolving as we are in this nature, so pharmacology is again an ever-evolving subject, and so is the life sciences. In India, it's commonly said that “every plant has its uses and side effects,” which is true to every word and opens up a huge flood of opportunities for the researchers in quest of developing many drugs which are of medicinal importance. Today the world is split in differences; the isolation of phytochemical compounds is advantageous over the crude extract. One simple answer that could be derived is that the amalgamation of two polarized contexts must be bought together as every pathogen acts unique to different drugs. Isolated compound delivery may be very accurate in curbing the pathogen, but it has a high risk of developing resistance to the drug. One instance which could be given is the quinine resistance by *Plasmodium* sp within a decade. Contrastingly the cinnamon bark extract (decoction) administered over many years never showed the resistance, but the cure rate was slowed. So, the amalgamation of these two concepts of the research must be the need of the hour which shall pave a new pathway for the modern drug delivery strategies. As cited earlier, the plant-based extraction of drugs and their efficacy on many strains of bacteria, fungi, and other microorganisms has been the hot subject for researchers nowadays but needs strict vigilance of the eco-committee as many plants of economic value are on the verge of extinction.

In this review, the medicinal plants of incredibly common needs of the home were selected to discuss their antimicrobial and antifungal activities, which enhances their use of their cultivation and its uses on a large scale. Turmeric, a rhizome, has been used in many food delicacies used as a coloring agent, food ingredient, and flavoring

agent has many antiseptic, antimicrobial, and antifungal activities. It also has the anticancer property, which is still under investigation.

Ginger (*Z. officinale*) has long been used in naturopathy, Ayurveda, and Chinese medicine due to its potential antimicrobial activity against different pathogens. The study enables us to determine the antimicrobial activity of ginger using chloroform, ethanol, acetone, and petroleum ether solvents against *F. oxysporum* and *F. lycopersici*. These strains are infecting tomato crops, due to which the farmer is under loss. Biological pest control, which is the major strategy in IPM (integrated pest management), also advocates the use of natural products and biological means as the best treatment for the pests of crops.

Neem, which has been used as an antibacterial agent for a very long time, also shows the antifungal effects on different species of fungi against *Curvularia* sp. followed by that of *Aspergillus* sp. and *Fusarium* sp. Extracts of the neem tree (*A. indica*) showed to be pejorative against *Vibrio alginolyticus,* and *V. parahaemolyticus* worked on cultured marine shrimps. The fresh neem juice showed a zone of inhibition that reported a direct linear link to the concentration of neem juice against both bacterial strains.

O. sanctum (Holy basil) is another example of a plant with antibacterial and antifungal properties. There is an expensive possibility of chemical compounds including eugenol, ursolic acid, carvacrol, linalool, caryophyllene, limatrol, methyl carvacrol, sitosterol anthocyanins, etc. is found in this plant. The therapeutical studies describe the present review of the therapeutic value of *O. sanctum;* hence, the plant's utility for human and animal consumption and disease treatment strategies reinforces the significance of the ethnobotanical approach as a potential source of biogenic substances.

Acknowledgments

The author is gratified to PG Chemistry, Vijayanagara College Hosapete, for providing well-established research facilities.

Conflict of interest

The author confirms that there are no known conflicts of interest.

CRediT authorship contribution statement

Venkatesh K. Bhovi: The author performed all parts of the study alone.

ORCID Numbers of the Authors

V.K. Bhovi: 0000-0002-0620-9097

Supplementary File

None.

References

Ajav, E.A., Ogunlade, C.A., 2014. Physical properties of ginger (*Zingiber officinale*). *Global Journal of Science Frontier Research: D Agricultural and Veterinary*, 14(1), 1-8.

Alzohairy, M.A., 2016. Therapeutics role of *Azadirachta indica* (Neem) and their active constituents in diseases prevention and treatment. *Evidence-Based Complementary and Alternative Medicine*, 2016, 7382506.

Ayodele, O.A., Akinyosoye, F.A., Arotupin, D.J., Owoyemi, O.O., Oyindamola, A.B., 2018. Phytochemical screening and antifungal activities of *Zingiber officinale* (Roscoe) on mycotoxigenic fungi associated with the deterioration of *Pennisetum glaucum* grains. *Journal of Advances in Microbiology*, 13, 1-11.

Ayodele, O.A., Akinyosoye, F.A., Arotupin, D.J., Owoyemi, O.O., Oyindamola, A.B., 2018. Phytochemical screening and antifungal activities of *Zingiber officinale* (Roscoe) on mycotoxigenic fungi associated with the deterioration of *Pennisetum glaucum* grains. *Journal of Advances in Microbiology*, 13, 1-11.

Bajaj, B.S., Ghosh, A.K., 1975. Advance in mycology and plant pathology published by Prof. R.N. Tondon's Birthday Celebration Committee, New Delhi, Antifungal Antibiotic, pp, 297-311.

Baliga, M.S., Jimmy, R., Thilakchand, K.R., Sunitha, V., Bhat, N.R., Saldanha, E., Palatty, P.L., 2013. *Ocimum sanctum* L (Holy Basil or Tulsi) and its phytochemicals in the prevention and treatment of cancer. *Nutrition and Cancer*, 65(sup1), 26-35.

Baradaran, A., Rafieian-Kopaei, M., 2013. Histopathological study of the combination of metformin and garlic juice for the attenuation of gentamicin renal toxicity in rats. *Journal of Renal Injury Prevention*, 2(1), 15-21.

Bhardwaj, R.L., Rajput, R., 2010. Wound healing properties of neem oil (*Azadirachta indica* Juss) and turmeric powder (*Curcuma longa*). *Indian Journal of Veterinary Surgery*, 31(1), 59-61.

Buchineni, M., Pathapati, R.M., Kandati, J., 2015. Anthelmintic Activity of Tulsi Leaves (*Ocimum sanctum* Linn.) An *In vitro* Comparative Study. *Saudi Journal of Medical and Pharmaceutical Sciences*, 2, 47-49.

Chaleshtori, R.S., Chaleshtori, F.S., Rafieian, M., 2011. Biological characterization of Iranian walnut (*Juglans regia*) leaves. *Turkish Journal of Biology*, 35(5), 635-639.

Chanda, S., Ramachandra, T.V., 2019. Phytochemical and pharmacological importance of turmeric (*Curcuma longa*): A review. *Research & Reviews: A Journal of Pharmacology*, 9(1), 16-23p.

Chaudhary, A., Sharma, S., Mittal, A., Gupta, S., Dua, A., 2020. Phytochemical and antioxidant profiling of *Ocimum sanctum*. *Journal of Food Science and Technology*, 57(10), 3852-3863.

Cock, I., Setzer, W.N., Ruebhart, K.D., El Dahshan, O.A., Tomczyk, M., 2009. An anti-diabetic and hypolipidemic effects from *Azadirachta indica* leaves. *African Journal of Biotechnology*, 8(13), 3084-3091.

Devendran, G., Balasubramanian, U., 2011. Qualitative phytochemical screening and GC-MS analysis of *Ocimum sanctum* L. leaves. *Asian Journal of Plant Science and Research*, 1(4), 44-48.

Egamberdieva, D., Wirth, S., Behrendt, U., Ahmad, P., Berg, G., 2017. Antimicrobial activity of medicinal plants correlates with the proportion of antagonistic endophytes. *Frontiers in Microbiology*, 8, 199.

Funk, J.L., Frye, J.B., Oyarzo, J.N., Chen, J., Zhang, H., Timmermann, B.N., 2016. Anti-inflammatory effects of the essential oils of ginger (*Zingiber officinale* Roscoe) in experimental rheumatoid arthritis. *PharmaNutrition*, 4(3), 123-131.

Grewal, P.S., Grewal, S.K., 1988. Selective fungicidal properties of some plant extracts to mushroom weed moulds/Proprietà fungicide selettive di alcuni estratti di piante a muffe. *Phytopathologia Mediterranea*, 27(2), 112-114.

GRIN (Germplasm Resources Information Network), 2017. *Zingiber officinale*. Agricultural Research Service (ARS), United States Department of Agriculture (USDA). Retrieved 10 December 2017.

Gurib-Fakim, A., 2006. Medicinal plants: traditions of yesterday and drugs of tomorrow. *Molecular Aspects of Medicine*, 27(1), 1-93.

Hashemi, S.R., Zulkifli, I., Hair Bejo, M., Farida, A., Somchit, M.N., 2008. Acute toxicity study and phytochemical screening of selected herbal aqueous extract in broiler chickens. *International Journal of Pharmacology*, 4(5), 352-360.

Hossain, M.A., Al-Toubi, W.A., Weli, A.M., Al-Riyami, Q.A., Al-Sabahi, J.N., 2013. Identification and characterization of chemical compounds in different crude extracts from leaves of Omani neem. *Journal of Taibah University for Science*, 7(4), 181-188.

Hossain, M.A., Nagooru, M.R., 2011. Biochemical profiling and total flavonoids contents of leaves crude extract of endemic medicinal plant *Corydyline terminalis* L. Kunth. *Pharmacognosy Journal*, 3(24), 25-30.

Hossain, M.A., Shah, M.D., Sakari, M., 2011. Gas chromatography–mass spectrometry analysis of various organic extracts of *Merremia borneensis* from Sabah. *Asian Pacific Journal of Tropical Medicine*, 4(8), 637-641.

Jacob, J.K.S., Carlos, R.C.A., Divina, C.C., 2016. Phytochemical composition, antibacterial and antifungal activities of sweet basil (*Ocimum basilicum*). *Advances in Environmental Biology*, 10(7), 84-90.

Kannusamy, G., Rengaswamy, Gopal., 2016. Phytochemical constituents and *in vitro* antibacterial activity of a various extract of *Azadirachta indica* (Neem). *International Journal of Current Pharmaceutical Research*, 8(3), 52-55.

Kauroo, S., Govinden-Soulange, J., Ranghoo-Sanmukhiya, V.M., Miranda, K., Cotham, W.E., Walla, M.D., Nagarkatti, P., 2021. Extracts of select endemic plants from the Republic of Mauritius exhibiting anti-cancer and immunomodulatory properties. *Scientific Reports*, 11(1), 1-17.

Kim, M., Miyamoto, S., Yasui, Y., Oyama, T., Murakami, A., Tanaka, T., 2009. Zerumbone, a tropical ginger sesquiterpene, inhibits colon and lung carcinogenesis in mice. *International Journal of Cancer*, 124(2), 264-271.

Liju, V.B., Jeena, K., Kuttan, R., 2011. An evaluation of antioxidant, anti-inflammatory, and antinociceptive activities of essential oil from *Curcuma longa*. L. *Indian Journal of Pharmacology*, 43(5), 526-553.

Liu, Y., Liu, J., Zhang, Y., 2019. Research progress on chemical constituents of *Zingiber officinale* Roscoe. *BioMed Research International*, 2019, 5370823.

Lucantoni, L., Yerbanga, R.S., Lupidi, G., Pasqualini, L., Esposito, F., Habluetzel, A., 2010. Transmission blocking activity of a standardized neem (*Azadirachta indica*) seed extract on the rodent malaria parasite *Plasmodium berghei* in its vector *Anopheles stephensi*. *Malaria Journal*, 9(1), 66-70.

Luthra, P.M., Singh, R., Chandra, R., 2001. Therapeutic uses of *Curcuma longa* (turmeric). *Indian Journal of Clinical Biochemistry*, 16(2), 153-160.

Lyer, S.R., Williamson, D., 1991. Efficacy of some plant extracts to inhibit the protease activity of *Trichophyton* species. *Geobios*, 18(1), 3-6.
Mallikarjun, S., Rao, A., Rajesh, G., Shenoy, R., Pai, M., 2016. Antimicrobial efficacy of Tulsi leaf (*Ocimum sanctum*) extract on periodontal pathogens: An *in vitro* study. *Journal of Indian Society of Periodontology*, 20(2), 145-150.
Mashhadi, N.S., Ghiasvand, R., Askari, G., Hariri, M., Darvishi, L., Mofid, M.R., 2013. Anti-oxidative and anti-inflammatory effects of ginger in health and physical activity: review of current evidence. *International Journal of Preventive Medicine*, 4(Suppl 1), S36-S42.
Naseri, M., 2004. Traditional Iranian Medicine (Tim) and it's promotion with guidelines of World Health Organization. *Daneshvar Science and Research Journal*, 52, 53-66.
Naveena, B.M., Mendiratta, S.K., Anjaneyulu, A.S.R., 2004. Tenderization of buffalo meat using plant proteases from *Cucumis trigonus* Roxb (Kachri) and *Zingiber officinale* roscoe (Ginger rhizome). *Meat Science*, 68(3), 363-369.
Niamsa, N., Sittiwet, C., 2009. Antimicrobial activity of *Curcuma longa* aqueous extract. *Journal of Pharmacology and Toxicology*, 4(4), 173-177.
Niranjan, A., Prakash, D., 2008. Chemical constituents and biological activities of turmeric (*Curcuma longa* L.)-A review. *Journal of Food Science and Technology*, 45(2), 109-116.
Oghenejobo, M., Bethel, O.U., 2017. Antibacterial evaluation, phytochemical screening and ascorbic acid assay of turmeric (*Curcuma longa*). *MOJ Bioequivalence & Bioavailability*, 4(2), 232-239.
Okemo, P.O., Mwatha, W.E., Chhabra, S.C., Fabry, W., 2001. The kill kinetics of *Azadirachta indica* A. Juss. (Meliaceae) extracts on *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Candida albicans*. *African Journal of Science and Technology*, 2(2), 113-118.
Pattanayak, P., Behera, P., Das, D., Panda, S.K., 2010. *Ocimum sanctum* Linn. A reservoir plant for therapeutic applications: An overview. *Pharmacognosy Reviews*, 4(7), 95-105.
Pourhabibi-Zarandi, F., Shojaei-Zarghani, S., Rafraf, M., 2021. Curcumin and rheumatoid arthritis: A systematic review of literature. *International Journal of Clinical Practice*, 75(10), e14280.
Praditya, D., Kirchhoff, L., Brüning, J., Rachmawati, H., Steinmann, J., Steinmann, E., 2019. Anti-infective properties of the golden spice curcumin. *Frontiers in Microbiology*, 10, 912.
Prakash, P., Gupta, N., 2005. Therapeutic uses of *Ocimum sanctum* Linn (Tulsi) with a note on eugenol and its pharmacological actions: a short review. *Indian Journal of Physiology and Pharmacology*, 49(2), 125-131.
Prasad, S., Aggarwal, B.B., 2011. Turmeric, the golden spice: From Traditional Medicine to Modern Medicine. In: Benzie IFF, Wachtel-Galor S, editors. Herbal Medicine: Biomolecular and Clinical Aspects. 2nd edition. Boca Raton (FL): CRC Press/Taylor & Francis; Chapter 13.
Prieto, P., Pineda, M., Aguilar, M., 1999. Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: specific application to the determination of vitamin E. *Analytical Biochemistry*, 269(2), 337-341.
Rahmani, A.H., 2014. Active ingredients of ginger as potential candidates in the prevention and treatment of diseases via modulation of biological activities. *International Journal of Physiology, Pathophysiology and Pharmacology*, 6(2), 125-136.
Ravindran, P.N., Babu, K.N. (Eds.)., 2016. Ginger: the genus *Zingiber*. Boca Raton, Florida, USA, CRC Press, 551.
Rudrappa, T., Bais, H.P., 2008. Curcumin, a known phenolic from *Curcuma longa*, attenuates the virulence of *Pseudomonas aeruginosa* PAO1 in whole plant and animal pathogenicity models. *Journal of Agricultural and Food Chemistry*, 56(6), 1955-1962.
Sethi, J., Sood, S., Seth, S., Talwar, A., 2003. Protective effect of Tulsi (*Ocimum sanctum*) on lipid peroxidation in stress induced by anemic hypoxia in rabbits. *Indian Journal of Physiology and Pharmacology*, 47(1), 115-119.
Shahrani, M., Rafieian-Kopaei, M., 2009. Comparison of morphine and tramadol effects on phagocytic activity of mice peritoneal phagocytes *in vivo*. *International Immunopharmacology*, 9(7-8), 968-970.
Shikhsamani, H., Fallah-Hoseini, A., Shojaii, H.D., Goushegir, A., Abdollahi Fard, M., 2011. Antidiabetic Plants of Iran. *Acta Medica Iran*, 49(10), 637-642.
Singh, D., Chaudhuri, P.K., 2018. A review on phytochemical and pharmacological properties of Holy basil (*Ocimum sanctum* L.). *Industrial Crops and Products*, 118, 367-382.
Singh, N., Verma, P., Pandey, B.R., Bhalla, M., 2012. Therapeutic potential of *Ocimum sanctum* in prevention and treatment of cancer and exposure to radiation: An overview. *International Journal of Pharmaceutical Sciences and Drug Research*, 4(2), 97-104.
Singh, R., Chandra, R., Bose, M., Luthra, P.M., 2002. Antibacterial activity of *Curcuma longa* rhizome extract on pathogenic bacteria. *Current Science*, 83, 737-740.
Siva, M., Shanmugam, K.R., Shanmugam, B., Venkata, S.G., Ravi, S., Sathyavelu, R. K., Mallikarjuna, K., 2016. *Ocimum sanctum*: a review on the pharmacological properties. *International Journal of Basic and Clinical Pharmacology*, 5, 558-565.
Sofowora, A., 1993. Medicinal plants and traditional medicine in Africa Spectrum Books LTD. Ibadan, Nigeria, pp, 191-289.
Sofowora, A., 1993. Medicinal plants and traditional medicine in Africa. Spectrum Books LTD. Ibadan, Nigeria, 289-320.
Sood, S., Narang, D., Dinda, A.K., Maulik, S.K., 2005. Chronic oral administration of *Ocimum sanctum* Linn. augments cardiac endogenous antioxidants and prevents isoproterenol-induced myocardial necrosis in rats. *Journal of Pharmacy and Pharmacology*, 57(1), 127-133.
Subapriya, R., Nagini, S., 2005. Medicinal properties of neem leaves: a review. *Current Medicinal Chemistry-Anti-Cancer Agents*, 5(2), 149-156.
WCSP (World Checklist of Selected Plant Families), 2016. *Azadirachta indica*. Royal Botanic Gardens, Kew. Retrieved 14 December 2016 – via the Plant List.
Yamani, H.A., Pang, E.C., Mantri, N., Deighton, M.A., 2016. Antimicrobial activity of Tulsi (*Ocimum tenuiflorum*) essential oil and their major constituents against three species of bacteria. *Frontiers in Microbiology*, 7, 681.
Zorofchian Moghadamtousi, S., Abdul Kadir, H., Hassandarvish, P., Tajik, H., Abubakar, S., Zandi, K., 2014. A review on antibacterial, antiviral, and antifungal activity of curcumin. *BioMed Research International*, 2014, 186864.

Reviewed by:

Ahmed A. J. MAHMOOD: University of Mosul, Mosul, IRAQ
Emine OKUMUS: Van Yuzuncu Yil University, Van, TURKEY