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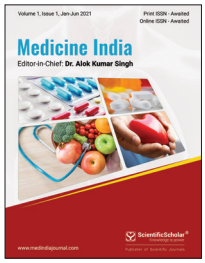

Review Article

Exploring the therapeutic potential of *Ocimum gratissimum* extracts against microbial infections: A Comprehensive review

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ABSTRACT

The escalating challenge of microbial resistance to conventional antimicrobial drugs has spurred a quest for alternative treatments, with plant-based extracts emerging as promising candidates. Over recent decades, plants and their extracts have been harnessed for various purposes, including medicinal applications, flavoring agents, food preservation, and disease prevention. *Ocimum gratissimum*, a locally abundant plant, has garnered attention for its multifaceted therapeutic and nutritional properties. *O. gratissimum*, commonly known as clove basil, has a rich history of culinary and medicinal use. Its essential oils are prized for their diverse applications, from culinary flavorings to toiletries and cosmetics additives. Extracts derived from *O. gratissimum* leaves have demonstrated efficacy against various ailments. Water extracts of the leaves exhibit anti-malarial properties, alleviate catarrh and stomach pain, and possess anticonvulsant and antitussive effects. Conversely, oil leaf extracts showcase potent antibacterial, antiseptic, and antifungal activities. This comprehensive review explores the therapeutic potential of *O. gratissimum* extracts, shedding light on their diverse pharmacological properties and potential applications in combating microbial infections. By harnessing the bioactive compounds present in *O. gratissimum*, novel avenues for addressing the growing threat of antimicrobial resistance may be unveiled. Further research is warranted to elucidate the mechanisms underlying the observed effects and optimize the utilization of *O. gratissimum* extracts in clinical settings.

Keywords: Microorganisms, O*cimum gratissimum*, Antibacterial, Antimicrobial, Phytochemical, Essential oil

INTRODUCTION

The exponential increase in microbes resisting antibiotics in the past few years has necessitated the need for an alternative natural drug to treat some microbial-caused ailments. According to Khan and Saurabh, 2011,[1] plant extracts or chemicals from plants became the foundation of pharmaceutical production – natural blueprinting for new drug creation. Therefore, this review summarizes the major studies done so far and includes important and forward-looking suggestions.

Due to the lack of contemporary medicine in some parts of the world and poverty, the World Health Organization has reported that 80% of the world's population is using conventional medicine as first aid and primary health care (Denyer *et al*., 2008).[2] The use of chemically-based medicines, which are often referred to as synthetic drugs, in the treatment of different bacterial

ailments, results in long-term complications and adverse effects on the recipient (Umar *et al*., 2016).[3] The use of chemically based drugs for bacterial treatment leads to long-term complications in individuals and possesses serious side effects because the chemical constituents of most of these drugs are cytolytic/cytotoxic when used in large doses and can also be carcinogenic. The cost of these synthetic drugs is also a major turn-off.

The use of naturally grown plants as a substitute for chemically synthesized drugs is important in the prevention of negative side effects and toxicity. Exploration of spices, flavors, and therapeutic plants began with our precursors several years back. It is presently a well-known subject that is of interest to life researchers due to the issues of medication obstruction and the cost of medications. Researchers in Africa and other nations are investigating plants that are utilized in conventional medication (Nnaemeka *et al*., 1991).[4]

Ocimum gratissimum

In tropical areas such as India and West Africa, *O. gratissimum* is commonly known. It is widely known in coastal and savannah areas of Nigeria (Effraim *et al*., 2003).[5] This plant is herbaceous and belongs to the Labiatae family. It is popularly called scent leaf, which is popularly used as a spice for soup or food preparation in Western Nigeria due to its aroma (Akinjogunla *et al*., 2009).[6] The plant's flowers are rich in common essential oils (EOs) and are likewise used for infusion and tea (Rabelo *et al*., 2003).[7] This plant also manages diarrhea, high fever, and epilepsy (Effraim *et al*., 2003).[5] Mental illness could be treated using these leaves in the savannah areas (Akinmoladun *et al*., 2007).[8] The Ibos use *O. gratissimum* to treat born naval to make the surfaces germ-free and treat flu and fungal infections (Ijeh *et al*., 2005).[9] The plant's roots are said to be used as a sedative for children in the Brazilian tropical forest inhabitants (Freire *et al*., 2006).[10] The people of sub-Saharan African and Kenyan communities use these plants equally for various purposes. Blocked nostrils can be cleared by sniffing the leaves between the plants. They rubbed the leaves between palms and sniffed to clear blocked nostrils, also to treat abdominal pains, coughs, fever, barrenness, ear infections, convulsions, and sore eyes (Adebolu and Oladimeji, 2005; Matasyoh *et al*., 2007).[11,12] Leave extract can also be used as a mosquito repellant (Ojewumi *et al*., 2022).[13] The people of India use the whole plant for the management of influenza, headache, and sunstroke, and due to its anti-inflammatory activity, it can also serve as a diaphoretic and antipyretic (Kumar and Prajapati, 2003; Ngassoum *et al*., 2003).[14,15] Plant EO can be mixed together as skin disinfectants and treat pimples, bubbles, and minor injuries (Orafidiya *et al*., 2006).[16] *O. gratissimum* plant is known to be used for both nutritional and medicinal purposes (Ojewumi *et al*., 2021a; b).[17,18]

It was reported by Ijeh *et al*. (2005)[9] that the mixture of the leaves of *Xylopia aethiopica* and *O. gratissimum* is utilized in the tears of ladies during puerperium. The presence of alkaloids, tannins, phytates, flavonoids, and Oligosaccharides explains the phytochemical evaluation of *O. gratissimum*. Silva *et al*. (2005)[19] reported that the leaf water extracts of *O. gratissimum in vitro* are very potent in various human pathogenic dermatophytes.

Description

The base of the plant is usually woody, with an average height of about 1–3 m. *O. gratissimum* leaves are usually 3–9 cm wide and 5–13 cm long. The plant has a lime-green scented leaves (USDA, 2008).[20]

Plate 1 a and b show the *O. gratissimum* plant and the leaf, respectively.

History

Plants are widely known to be one of the most profitable resources in both traditional and modern medicine for chemically based drugs (Hammer *et al*., 1999).[21] Medicinal use of plant products dates back to the beginning of human civilization. Some chemical substances are responsible for the medicinal importance of some plants that release physiological properties in man. Common constituents (bioactive) are tannins, alkaloids, flavonoids, and phenolic compounds. Most of the abundant in the plants are incorporated into food and herbs (Okwu, 1999).[22] Medicinal plant-based drugs are simple and effective because they exhibit broad-spectrum activity. Our ancestors invented the findings on herbs, spices, and medicinal plants a thousand years ago, and these are now a popular course that excites life scientists due to drug resistance and the cost of chemically based drugs. The use of herbs and spices in treating various ailments has been an ancient practice (Adams and Moss, 1999).[23]

Plate 1: (a) *Ocimum gratissimum* plant. (b) *O.gratissimum* leave. Source: (Kin *et al*., 2018).[24]

Medicinal values

Insect and mosquito repellent

O. gratissimum contains larvicide, which inhibits an insect's growth at the larval life stage. Commonly found products of these larvicidal are camphor, cineole, and limonene. These leaves and others serve as a natural repellent for mosquitoes, houseflies, bugs, and other crawling and flying insects (Kin *et al*., 2018; Ojewumi *et al*., 2017a; 2018a; b).[24-27]

Anti-inflammatory properties

O. gratissimum has some anti-inflammatory properties that can be used in pain relief drugs, such as Ibuprofen and aspirin. When these leaves are extracted, it is discovered that it is an effective cure for ulcer pains, ear infections, fever, etc. (Amengialue *et al*., 2013; Okoye *et al*., 2014; Babatunde *et al*., 2019).[28-30]

Treatment of respiratory disorders

Fluid extracts of leaves effectively affect markers of irritation, including kinases in protein, interleukins, and leukocytes/eosinophils in the experimental respiratory hypersensitivity models (*in vitro* tries assessing impacts on aviation route epithelial cells, *in vivo* examinations in rodents) and along these lines can be utilized in overseeing breathing issues (Jiao *et al*., 2013).[31]

Reduce blood level

They contain cinnamic acid, which aids in improving circulation and regulation of blood sugar levels, and can also be used in improving the breathing sequence of an individual with respiratory problems (Abhay *et al*., 2014).[32]

Remedy for stomach disorders

This leaf has been found to take care of stomach upset, including gastroenteritis; just by mere chewing, the leaf can cure cold or flu symptoms. Boiling these leaves with the addition of ginger and honey is effective for treating cough, fever, asthma, bronchitis, and influenza. Drinking from squeezed leaves would help with stooling (Okoye *et al*., 2014).[29]

Antispasmodic effect

Aqueous extract from the leaf has an antispasmodic effect used to treat ailments such as convulsions and seizures. This extract, when boiled, can be taken as a tonic and, when gargled, could help with sore throat (Orafidiya *et al*., 2004).[33]

Antimicrobial and antibacterial properties

The antimicrobial and antibacterial property of the leaf enables it to be used as a food preservative. The antimicrobial properties make it possible for it to be used to treat infections such as tooth decay, mouth infections, oral infections, fungal infections, and bad breath. Studies also show that *O. gratissimum* has antibacterial properties against *Salmonella* Enteritidis, *Staphylococcus aureus,* and *Escherichia coli* (Nakamura *et al*., 1999; Ojewumi *et al*., 2021c).[34,35]

Fight against sickle cell anemia

Due to the anti-sickling properties of ursolic acid found in *O. gratissimum*, the compound fights against the production of abnormal, sickle-shaped red blood cells (Tshilanda *et al*., 2015).[36]

Protect from cardiovascular diseases

Heart-friendly compounds in the leaf, such as magnesium, are good for lowering cholesterol levels and aids blood circulation. According to Li *et al*., 2012[37] water extract of *O. gratissimum* reduced the effect of induced cardiac abnormalities linked with liver fibrosis in rats. It was also revealed that scent leaf extract could help protect and reverse toxicity and blood pressure changes linked with exposure to cobalt-chloride in rats.

Adverse effect of *O. gratissimum*

This leaf has little or no side effects when taken as a food quantity. However, an extract taken orally as medicine can result in the following effects (Li *et al*., 2012).[37]

1. Bleeding disorders: The oils from this plant can hinder the blood clotting process, causing a continuous flow of blood and increased bleeding. Patients undergoing surgery can suffer from a high loss of blood, or patients with a bleeding disorder
2. Low blood pressure: There are tendencies of the leaf extract to lower an individual's blood pressure. This can cause an increase in lowered blood pressure
3. Pregnancy: Although *O. gratissimum* is used as an aroma-therapy massage, pregnant women are warned against it as it can result in miscarriage or stillbirth.

Extraction methods

Several new and old methods have been used to extract EO from different parts of various plants, which include the supercritical carbon dioxide (CO_2) extraction method, aqueous enzymatic, steam distillation extraction method, water distillation extraction method, and microwave-assisted

hydrodistillation extraction method (Ojewumi *et al*., 2018c; 2019a; b).[38-40]

Supercritical CO_2 method of extraction

Supercritical CO_2 extraction is one of the most recent ways of extracting oils from potential plant parts; although not cost-effective, it yields good oil quality. CO_2 becomes supercritical at 33°C, which is neither gas nor liquid; instead, it possesses gas and liquid properties. Since CO_2 is inert, it does not chemically interact with the oil produced.

Steam distillation extraction method

Steam distillation is another good technique used to extract oils from various plant parts, where the potential plant is put in a container and steam is forced over it. When heated up, the steam assists with delivering the aromatic organic atoms from the plant since the steam powers open up the jackets wherein the oils are kept.

Water distillation extraction method

The water distillation extraction method is known to be one of the oldest extraction methods [Figure 1]. It is the most suitable method for fresh and dry plant samples; heat does not damage them. This method is carried out by heating water at the top of the vessel at the same position where the plant is placed. The EO is usually transported by vapor and accumulates in water due to the difference in density when it gets to the collecting vessel called "The Florentine Container."

Microwave-assisted hydrodistillation extraction method (MAHD)

MAHD is a more advanced method used in the extraction of crude oils from various plant parts [Figure 2] (Golmakani and Rezaei, 2008; Filly *et al*., 2014).[41,42] The production of high-yield and good-quality EOs, shorter extraction time, and faster extraction rate with fewer solvents have been associated with this method.

Maceration

The maceration extraction method is used in the wine-making process and is now adopted and used for medicinal plant research. The maceration method involves soaking the plant sample, whether powdered or coarse, in a jar with a solvent and kept at ambient temperature for three days with regular agitation (Organization *et al*., 2008).[43] The aim is to soften and open the plant walls to release soluble phytochemicals. It is then strained using the filtration method after 3 days.

Related sample leaves

Mentha spicata (spearmint)

Mentha spicata is a rhizomatous, herbaceous, and perennial plant of about 35–100 cm tall, with hairy to hair less hair tall stems, underground fleshy wide-spreading rhizome with medium-sized leaves. (Ojewumi *et al*., 2017a).[25]

Both freshly plucked and dried plants are frequently used in the food, cosmetic, and pharmaceutical industries (Bensabah *et al*., 2013).[44] Having strong antioxidant properties, these plants are a rich source of polyphenols. Plate 2 shows the stem with leaves of a scent leave.

Moringa oleifera

Moringa oleifera belongs to the *Moringaceae* family. Since this plant possesses various amazing healing properties, it is widely known as "Miracle Tree" (Ojewumi *et al*., 2018a).[26] Due to its various applications, isolation of its bioactive constituents from different parts of the leaf is usually carried out (Guevara *et al*., 1999).[45]

Phytochemicals

These organic, naturally occurring synthetic mixtures present in plants offer people more medical benefits than those credited to macronutrients and micronutrients (Hasler and Blumberg, 1999).[46] Laboratory animals are often used to determine the structure of phytochemicals in experimental model systems such as cell cultures *in vitro* or *vivo* experiments (Molyneux *et al*., 2007).[47] *O. gratissimum* is high in flavonoids, alkaloids, glucosides, tannins, oligosaccharides, and EOs such as thymol and eugenol, which are responsible for its anti-malaria, antibacterial, and antidiabetic properties (Oboh *et al*., 2009).[48] It is commonly used in traditional medicine to treat illnesses such as fever,

Plate 2: Scent leave (Source: Ojewumi *et al*., 2017a).[25]

cough and respiratory disease, kidney stones, sore throat, epilepsy, and dermatitis (Jimoh *et al*., 2008).[49] According to Cheng (2003),[50] *O. gratissimum* contains all the necessary phytochemical constituents [Tables 1 and 2] [Figure 3].

Other common leaves with their phytochemical properties are listed in Table 3.

Secondary metabolites

Alkaloids

The natural compounds are highly variable and contain many structural frameworks. Alkaloids are very much needed in the production of many drugs (McNaught *et al*., 1997).[51] They are grouped mainly into cyclopeptide and peptides alkaloids, proto-, true-, polyamine-, and pseudo-alkaloids. It is known that most alkaloids are poisonous in high doses or pharmacologically active. However, some of them are also found in our daily food and are referred to as purine alkaloids. Cheng (2003)[50] research said that alkaloids can decrease blood pressure and balance the nervous system in the case of mental illness.

Flavonoids

These polyphenol compounds contribute to the yellow pigments found in orange petals and in nature. They are known to possess antiviral and antiallergic properties. Flavonoids help in the anti-inflammatory problem in both chronic and acute inflammation (Bohm and Koupai-Abyazani, 1994).[52]

Mineral content

Some essential elements in plants show their medicinal values and their different combinations help cure various ailments. These elements include Sodium (Na), Magnesium (Mg), Potassium (K), Iron (Fe), Copper (Cu), and Calcium (Ca).

Mg

It can be administered intravenously to decrease the chance of atrial fibrillation and also to helps regulate heart rhythm (Holleman *et al*., 1988).[53] In the experiment carried out by Alexander (2016),[54] magnesium was discovered to be one of the most abundant elements with a 1.712 ± 0.537 mg/kg concentration.

Na

The role of this element is to maintain the fluid balance within body cells and in the proper functioning of both muscles and nerve impulses. Milbury and Richer, in 2008,[55] reported that an average adult needs about 3–4 g daily Na, but modern dietary habits take in 6–20 g daily.

Ca

The role of calcium is to maintain strong teeth and bone, more significant parts of human blood and extracellular fluids also need lots of calcium (Holleman *et al*., 1988).[53]

Fe

Iron in plants shows that they are essential for the transportation of oxygen and the production of red blood cells in the body (Bahl and Bahl, 2006).[56]

Cu

In addition to energy metabolism, another function of copper is the release of iron from cells into the body's plasma (Bahl and Bahl, 2006).[56]

Microorganisms

Staphylococcus aureus

S. aureus is a Gram-positive pathogen for both animals and humans, causing various degrees of diseases ranging from severe diseases such as endocarditis, bacteremia, pneumonia, and septic arthritis to superficial skin infections. *S. aureus* is of the family *Staphylococcaceae*. Mammalian species, including human beings, are most affected. *S. aureus* is easily transmitted due to its wide species range, including transmission between humans and animals (Spaulding *et al*., 2013).[57] Plate 3 shows a cross-sectional picture of *S. aureus*.

Streptococcus pneumoniae

S. pneumoniae is a Gram-positive bacterium which is the cause of the majority of community-acquired pneumonia.

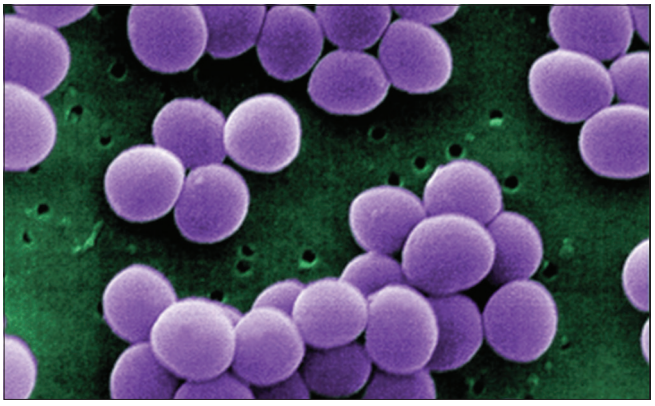

Plate 3: *Staphylococcus aureus* (Source: Spaulding *et al*., 2013).[57]

This organism is located in the human respiratory tract, showing a symbiosis relationship with humans. Nevertheless, infection by pneumococcus is not only dangerous, causing pneumonia, but also causes otitis media, bronchitis, meningitis, and septicemia. The alpha-hemolytic property of *S. pneumoniae* means that red blood cells can be broken down by producing hydrogen peroxide (H_2O_2) (van der Poll and Opal, 2009).[58] Plate 4 shows a cross-sectional picture of *S. pneumoniae.*

Plate 4: *Streptococcus pneumoniae* (Source: van der Poll and Opal, 2009).[58]

Escherichia coli

E. coli is a type of bacteria that is popularly found in the intestines. Most of these types of *E. coli* are not harmful and can even help digestion processes. They are also primarily responsible for food poisoning in their hosts, commonly found in fecaloid matter. It is frequently found in fecaloid matter (Kotloff *et al*., 2013).[59] *E. coli* causes urinary tract infections and Pneumonia from different types of bacteria. About 75–95% of urinary tract infections are caused by this bacterium. Shiga [toxin-producing *E-coli*] is a toxin caused by *E.coli* that makes a person sick, damaging the intestine lining. A much-known bad strain is 0157:H7, which causes severe sickness, vomiting, bloody diarrhea, and abdominal pains. One can get infected by *E. coli* through untreated milk, vegetables, ground meat and fruit, other food, beverages, water, other people, and animals. Plate 5 shows a cross-sectional picture of *E. coli.*

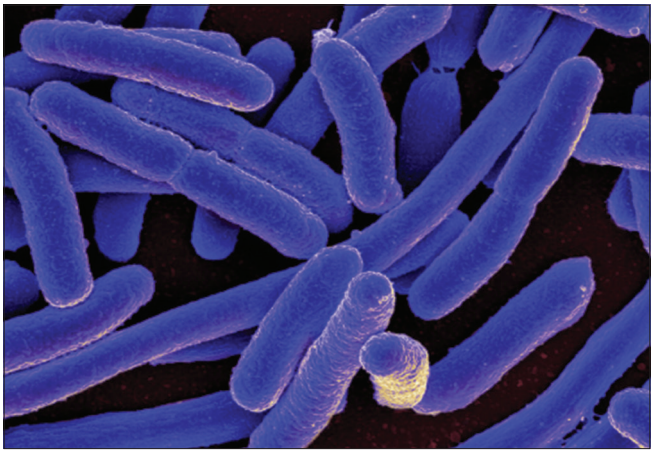

Plate 5: *Escherichia coli* (Source: Kotloff *et al*., 2013).[59]

Salmonella typhimurium

This organism can cause contamination in any living thing. It is regularly related to the consumption of animal products. *S.* Typhimurium can move people through crude or half-cooked contaminated food, such as eggs and meat. In poultry, *S.* Typhimurium is passed from flying creatures like birds to birds, mostly through droppings. When they are butchered for eating, the microbes move from their gut to the fleshy parts of their body and can likewise be transferred from the winged creature's ovaries to their eggs. *S.* Typhimurium causes gastroenteritis (aggravation of the gut part), prompting stomach cramps and fever. These side effects may last as long as 7 days. Notwithstanding, anti-infection agents or different medicines might be required if individuals cannot ward off the disease themselves due to a fundamental condition, such as a compromised immune system. Plate 6 shows a cross-sectional picture of *S.* Typhimurium.

Plate 6: *Salmonella* yphimurium (Source: Nakamura *et al*., 1999).[34]

Salmonella typhi

S. typhi affects only cause diseases in human beings, for example, typhoid fever. It is widespread in some developing countries with poor hygiene and sewage-

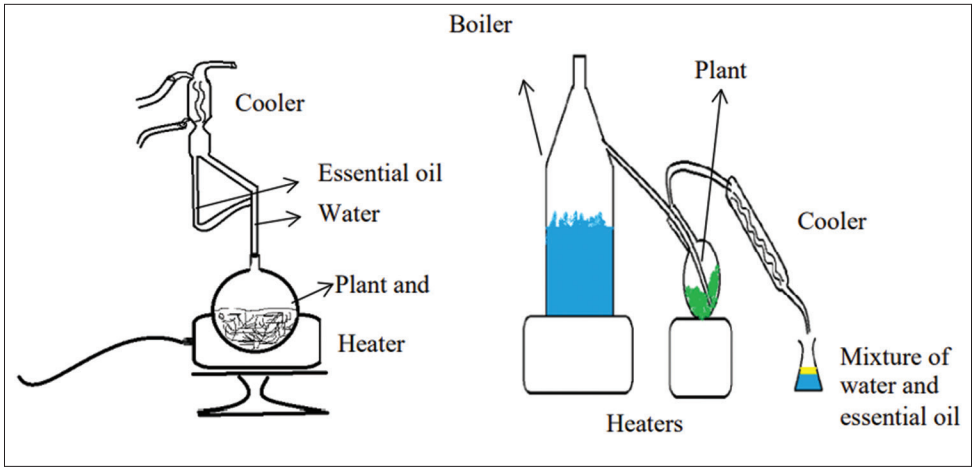

Figure 1: Steam and water distillation method. Source: (Akdağ and Öztürk, 2018).[60]

Table 1: Biologically active compound extracted from *Ocimum gratissimum*.

Plant Section	Constituents	Compound Components	References
Plant	EO	Methyl chavicol, Thymol, eugenol.	(Nadkarni, 1996)[61]
Plant	EO	Gratissimol	(Satyavati *et al.*, 1987)[62]
Seed	Mucilage	Pentoses, lipids, hexoses, uronic acid.	(Tharanathan and others, 1975)[63]
Plant	Phytochemical evaluation	Alkaloids, oligosaccharides, tannins, flavonoids.	(Matasyoh *et al.*, 2007)[12]
Leaves	EO	Eugenol, methyl eugenol, trans-caryophyllene, famesene, camphor, cis-ocimene, trans-ocimene, pinene, germacrene-D and I-bisabolene.	(Matasyoh *et al.*, 2007)[12]
Leaves	EO	Eugenol, bisabolene and thymol.	(Lemos *et al.*, 2005)[64]
Seed	EO	Thymol and eugenol.	(Iwalokun *et al.*, 2003)[65]
Plants	EO	Thymol, ɣ terpene, p-cymene and trans sabienene hydrate	(Kéita *et al.*, 2000)[66]
Plants	EO	1,8 cineole, Eugenol, methyl eugenol, linalool, methyl chavicol	(Lawrence and others, 2011)[67]
Aerial parts	EO	Eugenol, sabinene, cubenene, limonene, methyl eugenol, β-caryophyllene, camphene, famesene,α-pinene, p-cymeme, fenchone, linalool, T-cadinol, ɣ-eudesmol, β-bisobolie, α-humelene and β-elemene	(Pandey *et al.*, 2000)[68]
Aerial parts	EO	Eugenol	(Faria *et al.*, 2006)[69]
Leaves	EO	Citral, Linalool, thymol, ethyl cinnamate, eugenol	(Dubey *et al.*, 1997)[70]
Leaves	EO	limonene, Thymol, terpinolene, ɣ-terpinene, p-cymene, and 1,8-cineole	(Jirovetz *et al.*, 2005)[71]
Aqueous extract	Phytochemical evaluation	Carbohydrates, Tannis, Steroids, triterpenoids	(Offiah and Chikwendu, 1999)[72]
Leaves	EO	Oleanolic acid.	(Njoku *et al.*, 1997)[73]

EO: Essential oil

Table 2: *Ocimum gratissimum* phytochemical screening.

Constituents	Results	HPLC
Tannis	+	+
Flavonoids	+	+
Saponins	+	+
Terpenoids	+	+
Glucosides	+	+
Steroids	+	+
Alkaloids	+	+
Plobatannis	+	+

Source: (Alexander, 2016).[54] HPLC: High-pressure liquid chromatography, +: Present

contaminated water. Typhoid fever symptoms include loss of appetite, tiredness, and stomach pains. In the absence of immediate treatment, *S.* typhi infection may lead to liver damage, internal bleeding, holes in the gut, and typhoid fever. Typhoid can be fatal in up to 20% if not treated appropriately. Stool and blood samples are ways typhoid can be diagnosed. *S.* typhi is carried in the blood of people with this typhoid, and the bacteria are passed out in their blood or feces. Vaccination is recommended when traveling to a country where typhoid is rampant. Plate 7 shows a cross-sectional picture of *S,* Typhi.

Klebsiella pneumonia

K. pneumoniae is bacteria that naturally live in the intestine and feces. The bacteria are not threatening when inside the intestine but can be threatening when they spread to other organs, leading to severe problems. Part of the body *K. pneumonia* can affect the bladder, brain, liver, eyes, blood, and wounds. When the immune system is weak, conditions caused by long-term antibiotic use increase the chances of getting this infection. Plate 8 shows a cross-sectional picture of *K. pneumonia*.

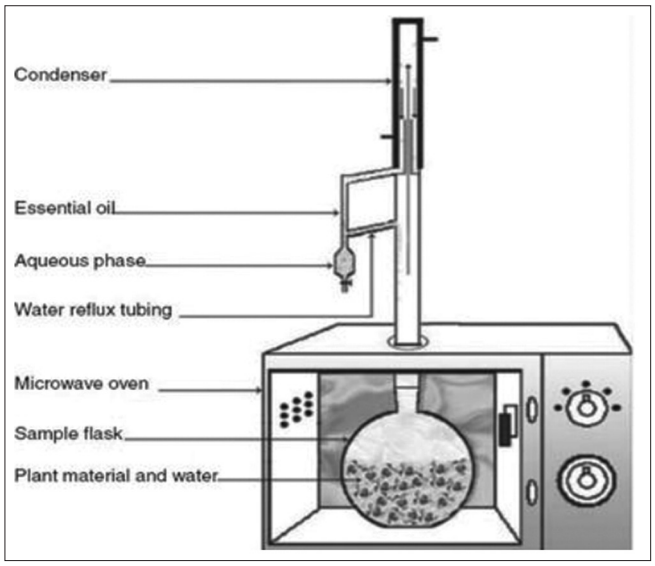

Figure 2: Microwave extraction method. Tshilanda, 2015[36]

Gas chromatography-mass spectrometry (GC/MS) analysis

GC/MS is a two-compartment instrumental method comprising a GC which is attached (coupled) to an MS, by which blends of complex synthetic substances are isolated, recognized, and evaluated (Al-fekaiki *et al*., 2021).[74] This instrument is used majorly to identify proof and quantitation of volatile and non-volatile compounds in complex blends. Nonetheless, the ability to find the nature and chemical structure of identified compounds that are already separated needs to be clarified, which requires a spectroscopic detection system (Stashenko and Martinez, 2014).[75]

Antibacterial activity

O. gratissimum extract antibacterial activity

Kolawole, *et al.* (2018)[76] reported that *O. gratissimu*m had a higher antibacterial effect compared to that of V. *amygdalina* and also phytonutrients (alkaloids, flavonoid, tannin, and steroid) compared with the extract obtained from the leaf of *V. amygdalina*. The antimicrobial property of *O. gratissimum* exhibited a higher zone of inhibition on the tested organisms.

Consequently, it is essential to look for alternative sources of antibiotics since the pathogenic microbes are beginning to develop resistance against antibiotics (Agarwal *et al*., 2012).[77]

Table 3: Other common leaves with their phytochemical properties.

S. No.	Organic Name	Common Names	Medicinal Value	Phytochemicals
1.	*Amaranthus hybridus* (L) (*Amaranthaceae*) is a Flowering perennial plant with about 12 species, reddish flowers bearing seeds, simple leaves, and dense green.	Pigweed, African-spinach	These leaves are cooked and eaten as an astringent.	alkaloids, flavonoids, phenols, saponins, tannins, phytic acid.
2.	*Azadirachita indica*. (*Lamiaceae*) This is found in the mahogany family in the form of a tree. It has evergreen leaves, small white flowers, and hard, cracked bark.	Neem, Dogo-near	Root extracts and bark are antibacterial, Antifungal, antihelminthic, and Sedative. Leaf can be used as decoration and infusion for chickenpox and malaria. Twig chewed for toothache.	Saponin, Steroids, Tannins, Flavonoids, Cyanogenic, Glycosides
3.	*Corchorus olitorius* (*Tilaeceae*) is a herbaceous plant with simple evergreen leaves, stems, yellowish flowers and fruits inside pods.	Bush okra, Ahihara, Kerenkere.	Extract from the leaf with water dilution is for fevers, menstrual regulation flow, a purgative, and a Tonic.	Cardiac- glycosides, tannins, flavonoids, anthraquinones.
4.	Curcubita pepo (Cucubitaeae) is a perennial plant with all parts edible. It is a climber, pollinated by insects, large green fruits with many seeds and evergreen leaves.	Pumpkin, Anyu, Anyi.	Treatment of urinary tract infections, rheumatism, benign prostatic hyperplasia, serves as a nourisher, gout, improves the flow of milk in new mothers, in postpartum swelling, and as an Aphrodisiac agent	Vitamins E, steroids, And B, Zn, Cu, P, K, Mg, Fe, folic acid, Niacin, riboflavin, thiamin, and pantothenic acid. Fatty acid

Source: (Adachukwu and Yusuf, 2014)[78]

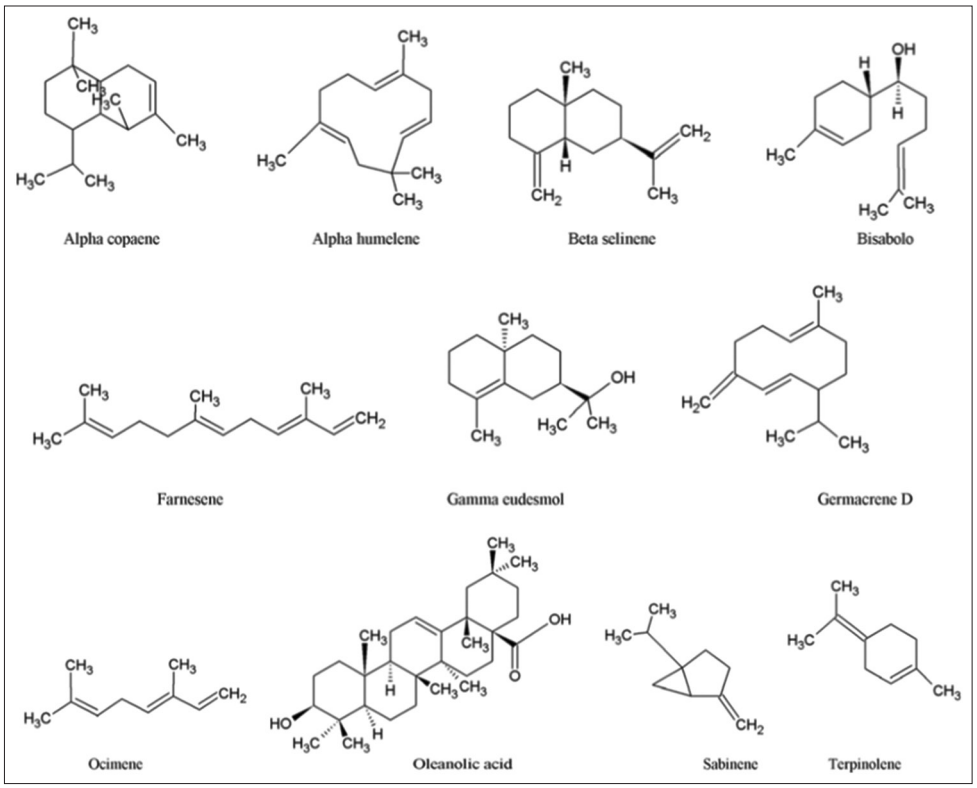

Figure 3: Illustration of active compounds obtained from *Ocimum gratissimum.* (Source: Akinyemi *et al*., 2005).[79]

Plate 7: *Salmonella* typhi (Source: Nakamura *et al*., 1999).[34]

Various plant extracts have been discovered to possess healing properties. These properties provide bactericidal and bacteriostatic effects on bacteria (Effraim *et al*., 2000; Alo *et al*., 2012).[80,81] The results showed that cold water extract of *V. amygdalina* showed inhibition zone diameter (15 mm) only against S. typhi, which supports the research of Ogbulie *et al.* (2007).[82] Likewise, the hot water of *V. amygdalina* restrained the growth of *E. coli* and *S.* typhi with the diameter (15 and 20 mm), respectively, which tallies with the findings of Ogbulie

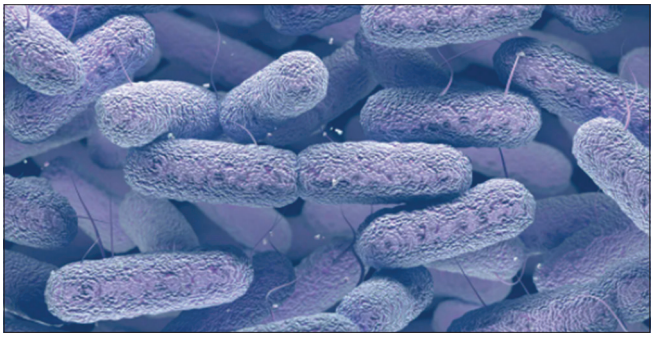

Plate 8: *Klebsiella pneumonia* (Source: Korvick *et al*., 1991).[83]

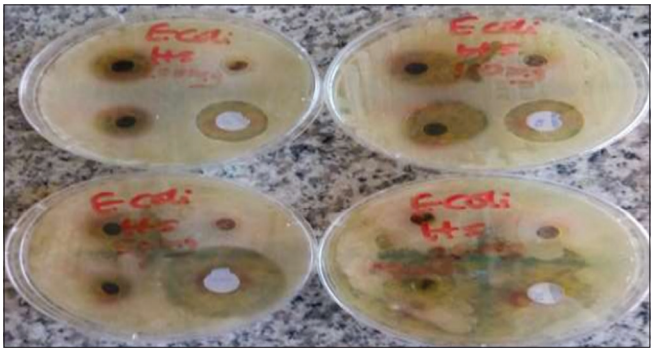

Plate 9: Antibacterial activity on *Escherichia coli* (Source: Kin *et al*., 2018).[24]

et al., 2007.[82] Ethanolic extract held back the growth of *E. coli* and S. typhi with the inhibition zone diameter of 23 and 13 mm, respectively, and it is related to the research findings of Ogbulie *et al*., 2007.[82] Furthermore, it was documented by Okigbo and Mmeka (2008)[84] that the *V. amygdalina's* ethanolic and aqueous extract was able to inhibit that *E. coli* (Madubunyi *et al*., 1995)[85] confirmed but opposed to (Ashebir and Ashenafi, 1999)[86] on the observation on plants capability to inhibit *E. coli*. The methanolic extract of *V. amygdalina* suppressed/inhibited the growth of *E. coli* and *S. typhi* with the diameter inhibition zone (23 and 20 mm), supporting Akinpelu's (1999)[87] research that states that *V. amygdalina* leaf of 60% was potent at 25 mg/mL against *E. coli* and *S. typhi* isolates. However, in this experiment, *V. amygdalina* showed no inhibition growth against *K. pneumonia*. Subsequently, *O. gratissimum*, cold water extract did not inhibit the growth of all the tested organisms, while only inhibiting the growth of *E. coli* with the zone of inhibition diameter (120 mm), which negates the research done by (Adebolu and Oladimeji, 2005).[11] Thus, *O. gratissimum* inhibited *S. typhi* and *E. coli* with inhibition zone diameters of 20 m m and 21 mm, respectively [Plate 9], which supports the research work of (Nwinyi *et al*., 2018)[88] that reported that ethanol extracts of *O. gratissimum* have a higher antibacterial activity against *E. coli*. Moreover, the methanolic extract of *O. gratissimum* only inhibited S. typhi with an inhibition zone diameter (23 mm). Hence, *O. gratissimum* did not inhibit the growth of *K. pneumoniae*. Furthermore, Ogbulie *et al*. (2007) [82] research negates that the cold and hot water extracts of *A. malagueta* only inhibited the growth of *E. coli* at 19 mm and 21 mm, respectively. At the same time, the ethanolic extract of *A. malagueta* could only inhibit the growth of *S.* typhi with the inhibition zone diameter at 14 mm, contrary to Ogbulie *et al*., 2007[82] findings. *E. coli* was only inhibited in the methanolic extracts with an inhibition zone diameter of 12 mm. In conclusion, no plant extracts from this research could inhibit the growth of *K. pneumoniae*.

Akinyemi *et al*. (2005)[79] carried out an extensive test on the stem bark parts. Stem back extract showed antimicrobial properties to both ethanolic and aqueous extract of *O. gratissimum*. At lower concentrations, they function as bacteriostatic, and at higher concentrations, as bactericidal. The minimum inhibitory concentration and minimal concentration of bactericides were discovered to be between 18.2–24.0 g/mL and 30.4–37.0 µg/mL, respectively. In other words, their results offer a scientific basis for the traditional use of water and ethanol extracts of *O. gratissimum* against Methicillin-resistant *S. aureus* associated diseases (Akinyemi *et al*., 2005; Nakamura *et al*., 1999).[34,79]

CONCLUSION

Plants and their extracts should be encouraged to treat and manage various infections (bacteria and fungi), such as neonatal meningitis and pneumonia, which are majorly caused by microorganisms such as *Klebsiella, E. coli*, Pneumonia, and *S. aureus*. Consuming *O. gratissimum* can protect human vital organs from injury caused by toxic agents. This review shows that EO from *O. gratissimum* can promote good health, and formulation from it may be useful in the clinical management of some ailments such as mental illness, wounds, ulcers, fungal infections, fever, cold, catarrh, epilepsy, high fever, and diarrhea. It also confirmed using different parts of plant extract in cooking and folk medicine. However, further studies are required on its toxicity and dosage. Clinical trials can also be done using white albino rats or domestic pigs, followed by trials involving human beings.

Author contributions

MEO was the major contributor to the writing of the manuscript, DEB and OOO edited the manuscript, and TGO and EOO collated previous work done. All authors read and approved the final manuscript.

Ethical approval

The Institutional Review Board approval is not required.

Declaration of patient consent

Patient's consent was not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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