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The healing potential of *Ocimum gratissimum*: An integrative review of its ethnomedicinal uses, phytochemistry, and pharmacological relevance

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Abstract
Medicinal plants have played a crucial role in shaping human civilization, serving as the foundation of healthcare practices across cultures and historical periods. They have long been used as primary sources of therapeutic agents, and even today, many modern pharmaceuticals are derived from these plants, underscoring their continued relevance in medicine. For thousands of years, medicinal herbs have been utilized not only to treat various diseases but also to preserve food, enhance flavor, and prevent the spread of infections, highlighting their multifaceted role in human health and daily life.
Among these valuable plants, *Ocimum gratissimum*, commonly known as clove basil or African basil, is widely distributed across India and renowned for its significant therapeutic potential. The plant contains a rich diversity of bioactive compounds, including essential oils, flavonoids, alkaloids, tannins, phenolic compounds, terpenoids, and glycosides, which collectively contribute to its extensive pharmacological activities. Owing to these bioactive constituents, *O. gratissimum* is extensively used as a nutritional supplement and flavoring agent in both traditional and modern preparations throughout tropical, subtropical, and warm temperate regions.
Pharmacological studies have demonstrated that *O. gratissimum* exhibits a wide spectrum of biological activities, including antimicrobial, anti-inflammatory antidiabetic, antihelminthic, antidiarrheal, antiurolithiatic, antioxidant, antimutagenic, insecticidal, and anticancer effects. Despite its promising therapeutic profile, there is a pressing need for well-designed human clinical studies to establish its safety, efficacy, and optimal dosage, which would support its integration into evidence-based clinical applications. This review article aims to discuss the historical and traditional uses of *Ocimum gratissimum*, its bioactive constituents, therapeutic benefits, and to consolidate current knowledge regarding its botanical characteristics and ecological significance.

Keywords: *Ocimum gratissimum*, medicinal plants, bioactive compounds, pharmacological activities, traditional medicine, therapeutic potential

Introduction
The use of medicinal plants in traditional and complementary medicine for the treatment, management, and prevention of various ailments dates back to the earliest stages of human civilization [1, 2]. It is estimated that approximately 80% of the global population relies primarily on ethnomedicine or herbal remedies for healthcare and disease management [3, 4].
The increasing preference for herbal medicines over conventional pharmaceuticals is largely due to the proven efficacy of their active constituents as natural healing agents, along with their accessibility, affordability, availability, and generally low or non-toxic effects [5, 6].
In recent years, medicinal plants and their bioactive constituents have attracted considerable attention from researchers for their potential in preventing and managing chronic and life-threatening diseases [7, 8] including cancer, diabetes, stroke, and arthritis [9]. They have also been explored as alternative therapeutic options for psychiatric disorders [10] and to address the healthcare needs of aging populations [8]. Today, medicinal plants not only serve in the treatment of various diseases but also act as critical sources for the discovery of novel drugs in both traditional and modern medical systems. Notably, several widely used pharmaceutical drugs such as quinine, digoxin, aspirin, and morphine were derived from medicinal plants including *Cinchona officinalis, Digitalis purpurea, Salix alba, and Papaver somniferum*, respectively [11].

Fig 1: *Ocimum gratissimum*

Ocimum gratissimum (Fig 1) commonly known as clove basil, is an important aromatic and medicinal plant belonging to the family Lamiaceae. It grows both in the wild and under cultivation across numerous tropical and subtropical regions worldwide. Also referred to as Nimma Tulasi, the plant is widely distributed in India and South Africa, thriving in tropical climates. This traditional medicinal herb is rich in a variety of phytochemical constituents and has been extensively studied for its wide range of physiological and therapeutic properties. Research has identified several bioactive compounds in *O. gratissimum*, including flavonoids, polyphenols, and volatile oils such as eugenol, thymol, and geraniol. The plant exhibits multiple pharmacological activities, including vasorelaxant, anti-inflammatory, antimycotoxigenic, and antioxidant effects.

Plants display remarkable biochemical versatility, enabling them to produce complex organic molecules that are not directly involved in their primary metabolic or growth processes. These compounds, referred to as secondary metabolites, are now more accurately described as phytochemicals [12]. Phytochemicals are naturally occurring, biologically active compounds derived from plants, demonstrating significant therapeutic and disease-preventive potential. Their benefits are largely attributed to their antioxidant properties, which protect cellular components from oxidative damage caused by free radicals and reactive oxygen species (ROS) key contributors to disease development, food spoilage, and deterioration. Medicinal plants have been integral to healing practices since ancient times, long before the emergence of modern pharmaceuticals.

Different plant parts including leaves, flowers, stems, roots, seeds, fruits, and bark are used in various forms of herbal medicine. Their therapeutic efficacy is linked to their phytochemical content, which elicits specific physiological effects in humans. Major classes of these compounds include alkaloids, tannins, flavonoids, and phenolic compounds. *Ocimum gratissimum* Linn. (Labiatae) is primarily cultivated for its essential oils, concentrated mainly in the leaves and stems. These oils, rich in eugenol, thymol, citral, geraniol, and linalool, display strong antifungal activity. Studies have also revealed its antinociceptive (pain-relieving) effects. Both the whole plant and its essential oil are widely utilized in traditional medicinal systems in Africa and India, while the oil also serves as a natural insect repellent [13].

O. gratissimum possesses potent antimicrobial and germicidal properties, making it a valuable ingredient in toothpastes, mouthwashes, and topical formulations. It is traditionally employed as a gargle to relieve sore throat and tonsillitis, and also functions as an expectorant and cough suppressant. Its extracts have been shown to be effective against gastrointestinal helminths in both humans and animals. Due to its carminative properties, it alleviates digestive disturbances and is additionally used as an emetic and in the management of hemorrhoids. Furthermore, *O. gratissimum* is applied in the treatment of rheumatism, paralysis, epilepsy, fever, diarrhea, sunstroke, influenza, gonorrhea, and mental disorders. In southern Nigeria, it is also used as a culinary spice and flavoring agent.

As a member of the Lamiaceae family, *Ocimum gratissimum* is a herbaceous species native to tropical regions, particularly India and West Africa. The plant is recognized by several regional names, including Vriddhu Tulasi (Sanskrit), Ram Tulasi (Hindi), and Nimma Tulasi (Kannada). It holds great significance in traditional healing systems across cultures for both therapeutic and culinary purposes. The leaves and flowers are especially rich in essential oils, often used in the preparation of teas and infusions. In folk medicine, *O. gratissimum* is applied in managing respiratory tract infections, diarrhea, headache, skin and eye ailments, pneumonia, cough, fever, and conjunctivitis.

In India, the whole plant is traditionally used as a natural remedy for sunstroke, headache, and influenza, exhibiting diaphoretic, antipyretic, and anti-inflammatory properties. Additionally, the leaf infusion of *O. gratissimum* is employed as a pulmonary antiseptic, antitussive, and antispasmodic preparation [14].

This study aims to provide a comprehensive and updated overview of the medicinal uses, bioactive phytochemicals, and essential oils, as well as the pharmacological activities of *O. gratissimum.* Moreover, the paper emphasizes the plant's therapeutic potential and identifies existing gaps in current knowledge, thereby encouraging further research into its efficacy and potential commercialization for the management of various human diseases.

2. Taxonomy and botanical description

Table 1: Taxonomy classification of *Ocimum gratissimum* [15]

Domain	Eukaryota
Kingdom	Plantae
Subkingdom	Tracheobionta
Super Division	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Asteridae
Order	Lamiales
Family	Lamiaceae
Genus	Ocimum L
Species	Gratissimum

Table 2: Common names of *Ocimum gratissimum* in India [15]

Languages	Local names
Hindi	Ram tulsi, Ban tulsi, Jangli tulsi, Laung tulsi, Banjari
Sanskrit	Ajaka, Vriddha Tulasi
Kannada	Rama Tulasi
Marathi	Ajavala, Tanatulasu
Tamil	Elumichan Tulasi, Peruntulasi, Elumiccam tulaci
Telugu	Nimma Tulasi
Malayalam	Kattu thulasi, Anathulasi, Karpoorathulasi

2.2 Synomyms

Clove basil, African basil, Wild basil, Shrubby basil, Tea bush, Tree basil, Rama tulsi, Van tulsi etc.

2.3 Description on Morphological and Microscopic Characteristics of *Ocimum gratissimum*:

Morphology

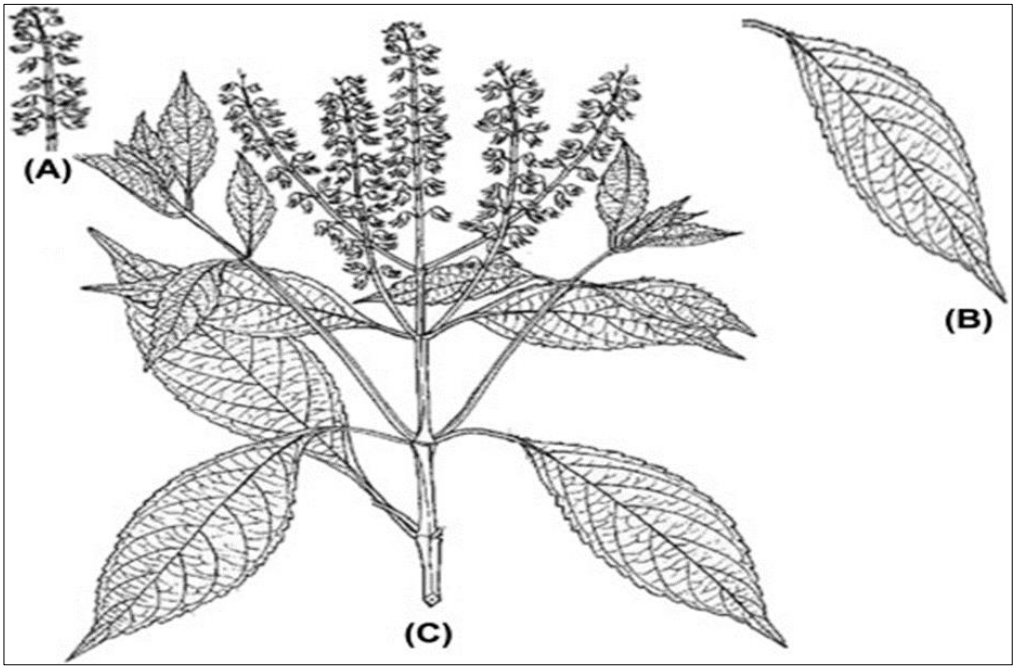


Fig 2: Morpholical structure of (A) Seeds and Flowers, (B) Leaf, (C) Aerial part

In biology, morphology refers to the analysis of a plant's physical characteristics, including its size, structure, form, and how its individual parts interact. It highlights the key biological aspects that define a plant's shape and spatial arrangement. One such plant is basil, a fragrant herbaceous species scientifically identified as *Ocimum gratissimum*. This plant is characterized by its upright growth, standing between 1-3 cm tall. It possesses (Fig 2) a spherical stem, quadrangular branches, and a woody base [16].

STEM

The stem of *O. gratissimum* is notably rounded and quadrangular, with a rigid structure that becomes woody at the base. The epidermis near the base tends to peel off in strips, and the stem is typically highly branched [16].

Leaves

Its leaves are arranged in opposite pairs in a decussate pattern, and each is attached to the stem by a pubescent petiole measuring 2-5 cm in length. The leaf blades are

elliptical to oval, measuring between 1.5-2.5 cm long and 0.6-12 cm wide, with coarsely separated margins [17].

Flowers

O. gratissimum produces greenish-yellow flowers arranged in simple or short branched racemes. The floral axis is quadrangular and densely covered with hairs. The style is bifid, and the upper part of the calyx is purple, whereas the corolla and stamens are white, and the anthers are yellow. Each flower is accompanied at its base by a sessile, oval-shaped bract, measuring 3-12 mm in length and 1-7 mm in width [17].

Fruit

As for its fruit, *Ocimum gratissimum* develops four small, sub-globular, dry nutlets, each around 1.5 mm long, rough, and brown in color. These nutlets are enclosed in spherical capsules approximately 2 mm in diameter. This sub-woody plant can grow from 1 to 2 meters, and in some cases, up to 3 meters tall. It is widely known for its strong aromatic scent [17].

Seed

The seeds of basil are small and reddish-black. Although the outer pericarp does not become mucilaginous in water, the seeds of *O. gratissimum* (OGSs) have been researched for use as disintegrants or suspending agents. When they come into contact with water, they form a mucilaginous layer due to their high water absorption capacity, showcasing the swelling potential of OGSs [16].

Microscopy

On both surfaces of the leaf, the epidermal cells exhibit irregular contours. Diacytic stomata and abundant secretory glands are present, along with simple pluricellular hairs located on the leaf veins. In cross section, the leaf shows a monostratified epidermis (beam), followed by a layer of palisade parenchyma in the sub-epidermal region, then spongy parenchyma, and finally the lower monostratified epidermis [18].

Powder Microscopy: A powder analysis was performed by Lic Dinah Garcinia (1998) [19], during which the following features were observed (Fig 3).

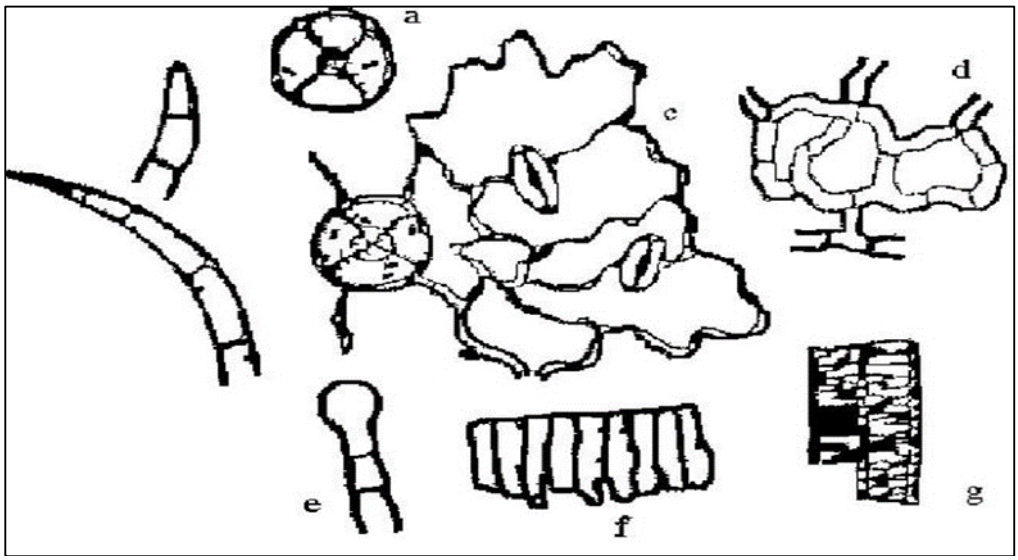


Fig 3: Powder microscopy of *Ocimum gratissimum* shows the following features

a) Presence of peltate and non-glandular uniseriate pluricellular hairs.
b) Glandular trichome observed from the top, exhibiting four radiating cells.
c) Fragment of epidermis containing glands and stomata.
d) Section showing mesophyll tissue of the leaf.
e) Multicellular glandular hair with a stalk.
f) Palisade parenchyma cells.
g) Reticulate tracheary elements

Table 3: Comparitive Morphological study of some Ocimum Species [20]

parameter	*Ocimum gratissimum*	*Ocimum americanum*	*Ocimum basilicum*	*Ocimum sanctum*
Colour	Light green	Green to yellowish green	Green or occasionally purple	Green to purple
Odour	Aromatic	Aromatic	Mildly aromatic	Warm aromatic and sharp
Taste	Oily and sharp,tingling taste resembling cloves,pungent	Characteristic, mint-like flavour	Characteristic	Warm, pungent, aromatic and sharp
Height	1-1.5m	30-60cm	60-80cm	20-60cm
Herb Description	Stem and branches green	Branched herb with sub-quadrangular, striated branches and light puff-coloured stem	Erect, strongly aromatic, nearly glabrous branching herb with soft spreading hairs	Highly branched], stems and branches purplish, sub-quadrangular, woody, covered with soft spreading hairs

3. Geographical source and habit

3.1 Geographical source and Location

Geographical Source: *Ocimum gratissimum* is indigenous to tropical regions of Africa, India, and Southeast Asia.

Geographical Location: *Ocimum gratissimum* is a perennial, aromatic shrub commonly distributed across tropical areas including Brazil, India, Vietnam, Rwanda, Nigeria, Cameroon, Togo, Ivory Coast, Kenya, Benin, and South Africa [21].

3.2 Habit and Distributi

Ocimum gratissimum typically thrives in disturbed habitats surrounding human settlements, such as coastal scrublands, lakeshores, savannas, submontane forests, and along roadsides and stream banks, occurring at elevations from sea level up to 2300 m. It is also commonly cultivated in home gardens as an ornamental or hedge plant. In India, it flourishes in plains, valleys, and both dry and moist deciduous forests.

Within the Lesser Antilles, the plant is regarded as a widespread and relatively common herb, frequently naturalized in open, wet habitats at low to mid-elevations. It often behaves as a weed along roadsides, wastelands, and pastures across many Pacific islands [22].

The native range of *O. gratissimum* includes tropical Africa, India, and Southeast Asia, but it is now cultivated and naturalized in China, South America, the Caribbean, Australia, New Zealand, and several Pacific and Indian Ocean islands. On some of these islands, particularly in the Pacific and Caribbean regions, it is considered an invasive species (Fig 4) [17].

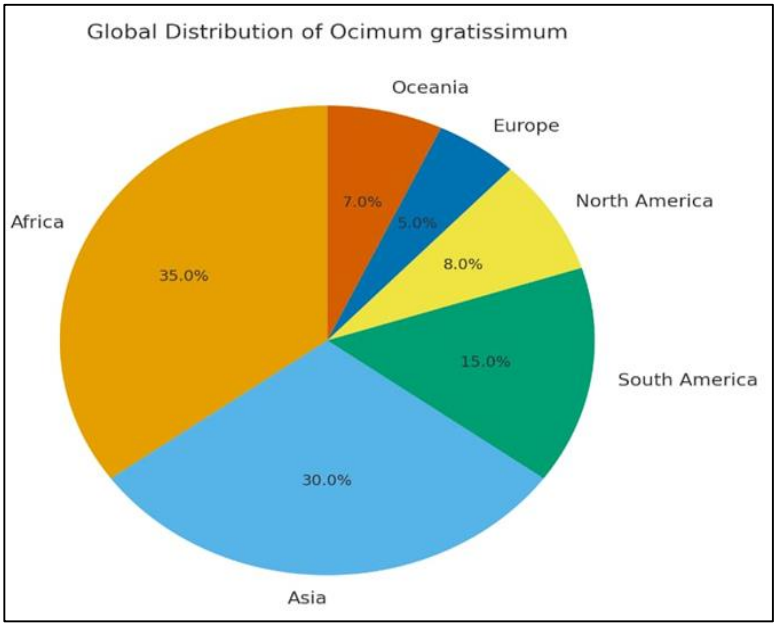


Fig 4: Global distribution of *Ocimum gratissimum*

3.3 Cultivation:

- **Land Preparation:** Before cultivation, the land should be well-leveled and divided into manageable plots. During soil preparation, it is advisable to incorporate 15 t/ha of farmyard manure along with the recommended basal fertilizers, ensuring they are evenly mixed into the soil to promote fertility and uniform growth [23].
- **Soil Condition:** *Ocimum gratissimum* grows best in rich, well-drained loamy soil that is slightly acidic, with a pH range of 5.5-6.5. The ideal temperature range for its growth lies between 17 °C (minimum) and 39.2 °C (maximum). Well-drained soil promotes vigorous vegetative growth, while waterlogging can cause root rot and stunted development [23].
- **Climate:** The plant prefers humid conditions with moderate to high rainfall. It thrives under long daylight periods and mild temperatures, which are favorable for plant growth and essential oil production. *O. gratissimum* can grow up to 900 meters above sea level and shows tolerance to mild frost and drought. Although oil yield is lower in partial shade, the plant can still survive and grow under such conditions [23].
- **Propagation and Planting Time:** Propagation of Tulsi is primarily through seeds. However, due to extensive cross-pollination, seed quality tends to deteriorate over successive generations. Therefore, fresh seeds from pedigree stock should be used for maintaining crop quality.The nursery is usually raised in the third week of February, and transplanting is carried out around mid-April [23].
- **Harvesting:** Harvesting of Tulsi should be carried out with great care to avoid any form of contamination. After harvest, all surfaces and equipment that come into contact with the plant should be thoroughly cleaned to maintain purity. For achieving maximum essential oil yield and superior oil quality, the crop should be harvested at full bloom [23].

4. Ecological Adaptations

In several countries, *Ocimum gratissimum* is cultivated as a hedge plant. It serves as an excellent supplementary crop during periods of famine, owing to its ability to grow in diverse soil types, including nutrient-poor soils, demonstrating remarkable ecological adaptability [24]. Under water stress conditions, the nitrogen content in the plant tends to increase, likely due to the mobilization of minerals to the leaves, which supports the synthesis of amino acids and proteins, thereby enhancing the plant's resistance to drought [25].

A decrease in potassium and calcium levels has also been reported, possibly resulting from the redistribution of these

elements to the roots, where they function as osmoprotectants. Additionally, ascorbic acid breakdown under stress conditions contributes to drought tolerance [25]. Field experiments conducted under varying conditions daily watering with sunlight, five-day watering with sunlight, daily watering under natural shade, and five-day watering under natural shade revealed that water stress leads to a reduction in plant height and leaf area, while essential oil content increases under shade and water stress but declines under full sunlight [26].

Further studies confirm the plant's tolerance to UV-B radiation, resulting in elevated flavonoid, ascorbate, and proline levels, without negatively affecting the antioxidant capacity of the leaves [27]. Pot experiments demonstrate that under water stress, there is a reduction in saponin content, an increase in tannin levels, and no significant change in flavonoid concentration [25]. Likewise, carbohydrate, moisture, dry matter, and crude fat contents decrease, whereas ash, crude protein, and crude fiber contents increase, with the calorific value of the leaves remaining unchanged [28].

Moreover, plants subjected to water stress and inoculated with arbuscular mycorrhizal fungi (AMF) exhibit a notable rise in essential oil yield, chlorophyll pigments, and total phenolic compounds, while proline accumulation occurs specifically under water stress conditions [29].

5. Phytochemical Properties of *O. gratissimum*

5.1 Qualitative analysis for phytochemicals

Table 4

Phytochemicals	Presence/Absence
Alkaloids	Present
Cardiac glycoside	Absent
Anthraquinone	Present
Gums mucilage	Present
Proteins	Present
Amino acids	Present
Tanins	Present
Phenolic compound	Present
Triterpenoids	Present
Steroids	Present
Sterols	Present
Saponins	Present
Flavones	Present
Flavonoids	Present
Thiol group	Absent

5.2 Phytochemicals in methanolic and aq. leaf extract of *O. gratissimum*

Table 5

Table (4, 5): Results of the phytochemical analysis of *Ocimum gratissimum* [30]

Phytochemicals	Methanolic extract	Aqueous extract
Alkaloids	Present	Absent
Saponins	Absent	Present
Tannins	Present	Present
Phlobatannins	Present	Present
Anthraquinones	Absent	Present
Steroids	Present	Present
Terpenoids	Present	Present
Flavonoids	Present	Present
Cardiac glycosides		
1. With steroids	Present	Present
2. With deoxy	Absent	Present

5.3 Mineral constituents

Mineral Constituents of *O. gratissimum*: The mineral composition of *O. gratissimum* leaves is influenced by soil characteristics and geographic location. Essential minerals such as potassium, calcium, magnesium, iron, manganese, zinc, copper, and sodium, which are vital for human health, have been reported in the leaves of *O. gratissimum* [31-33].

- **Potassium:** *O. gratissimum* leaves are particularly rich in potassium, making them an excellent dietary source of this mineral [34]. Both leaves and stems contain substantial potassium, along with copper, iron, manganese, and zinc, which can be beneficial for hypertensive patients. Potassium is essential for proper heart and smooth muscle function, supporting normal digestive and muscular activity [32]. Studies have shown potassium concentrations in *O. gratissimum* leaves of 81.63±0.05 mg/100g [32] and 1479.88 ± 0.01 mg/100g [35], indicating that these leaves can serve as a valuable potassium source when used as a condiment [36, 31].
- **Calcium:** Calcium is essential for maintaining blood calcium levels and promoting bone growth. Studies have reported calcium concentrations in *O. gratissimum* leaves as 60.12 ± 0.43 mg/100g and 4523 mg/100g [32,

[37], indicating that condiments made from the leaves can serve as good sources of calcium.

- **Sodium:** Sodium plays a crucial role in condiments, functioning as an antibacterial agent and preservative by reducing water activity. Sodium chloride also enhances flavor by influencing enzyme activity and biochemical pathways. Due to its affordability and versatility, salt is widely used in the food industry [38]. However, excessive sodium intake has been linked to cardiovascular disease and hypertension [39]. Consequently, there is a trend towards reducing or replacing sodium with alternatives such as phosphorus or potassium chloride and improving salt's physical form to lower intake while maintaining flavour [40].
- **Iron:** *O. gratissimum* leaves contain notable iron levels, with an average of 18.03 mg/100g. Iron content can vary depending on the sampling location [34] and has been confirmed in further studies as 0.312±0.067 mg/kg [31]. Iron is essential for red blood cell production and oxygen transport, making the leaves a valuable addition to foods as a condiment vegetable.
- **Zinc:** Zinc is a crucial micronutrient required for growth, immune function, and enzyme regulation. It is also used in agriculture and metal handling to prevent oxidation, while deficiency can result in hair loss, memory impairment, delayed wound healing, and physical weakness [41-45]. In vegetable condiments, zinc can reduce caking and provide nutritional supplementation, and around 8% of plant proteins exhibit zinc-binding activity, highlighting its role in various biochemical processes [46, 47]. Zinc regulates enzyme activity, enhances antioxidant enzyme function, and minimizes cadmium accumulation in plants, contributing to food safety [48-50].

Zinc derived from *O. gratissimum* has diverse applications. Leaf extracts have been used to produce zinc oxide (ZnO) nanoparticles with antibacterial effects against Staphylococcus aureus and Escherichia coli [51, 52] and can inhibit corrosion in zinc-aluminum alloys, indicating potential as a non-toxic corrosion inhibitor [53]. Ayurvedic literature also reports trace levels of zinc along with other essential elements such as iron, copper, and manganese, contributing to the plant's medicinal properties [54]. These findings underscore the importance of zinc from *O. gratissimum* in nutrition, nanotechnology, and medical applications, while also supporting the development and quality of vegetable condiments.

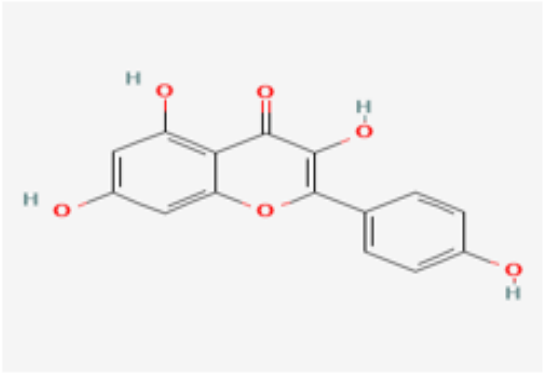
5.4 Chemical constituents

Table 6: Chemical constituents of *O.gratissimum*

Part of the Plant	Chemical Constituents
Leaves	Alkaloids, tannins, glycoside, saponins, resins, cardiac glycoside, steroidal terpens and flavonoids [55]
Leaves	Saponins, phenols, phlobatannins, and anthraquinones [56]
Leaves	Tannins, terpenoids in the methanolic and ethanolic extracts; terpenoids in petroleum ether and chloroform extracts; carbohydrates in alcoholic extracts [57]
Aerial plant parts	Monoterpenes, sesquiterpenes, and aliphatic compounds, with p-cymene, γ-terpinene, α-thujene, and β-myrcene. p-cymene/thymol and p-cymene chemotype [58]
Aerial parts	Trans-methyl isoeugenol, cis-ocimene, germacrene-D, and β-caryophyllene [59]
Leaves	Volatile oils, methyleugenol, cis-ocimene, germacrene-D, transcaryophyllene and pinene [60]
Leaves	Four phenolic substances were identified: L-caftaric acid, L-chicoric acid, eugenyl-β-D-glucopyranoside and vicenin-2 [61]
Leaves	Eugenol, cis-ocimene, γ-muurolene, (Z,E)-α-farnesene, α-trans-bergamotene and β caryophyllene [62]
Leaves	Gamma-terpinene, beta-phellandrene, limonene and thymol [63]
Leaves	Sinapic acid, rosmarinic acid, luteolin, apigenin, nepetoidin A, xanthomicrol, nevadensin, hymenoxin, salvigenin, apigenin 7,4,-dimethyl ether, palmitic acid, basilimoside, 2-α, 3-β-dihydroxy olean-12-en-28-oic acid, methyl acetate and oleanolic Acid [64]

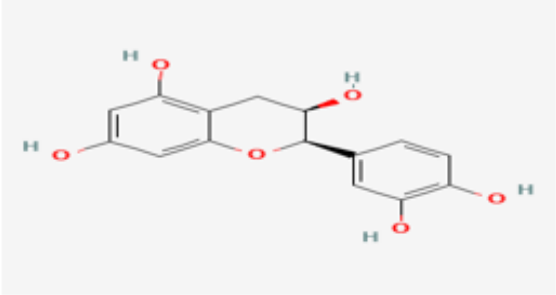
5.5 Chemical structures and bioactivity of some compounds isolated from *O. gratissimum*

Kaempferol



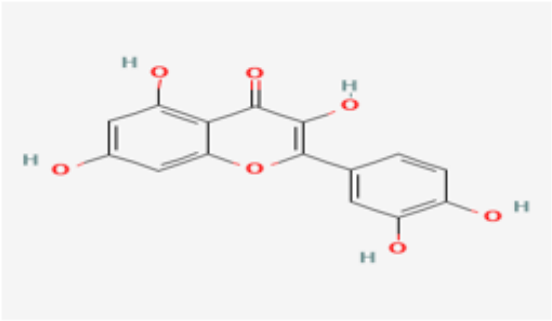
Antioxidant, anti-inflammatory, antimicrobial, anticancer, cardioprotective, neuroprotective, antidiabetic, anti-osteoporotic, estrogenic/antiestrogenic, anxiolytic, analgesic and antiallergic activities

Epicatechin



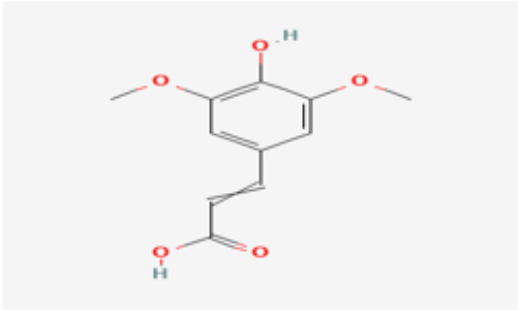
Antiangiogenic, anti-diabetic, antioxidant and anticancer effects [66].

Quercetin



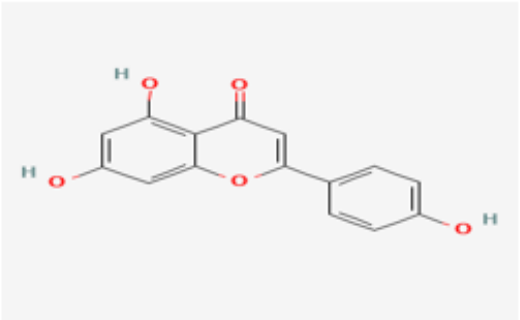
Antidiabetic, anti-inflammatory, antioxidant, antimicrobial, anti-Alzheimer's, antiarthritic, cardiovascular, and wound-healing effects [67].

Sinapic acid



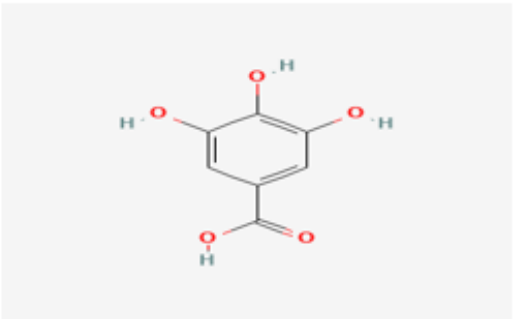
Exhibits antioxidant, anti-inflammatory, anticancer, antimutagenic, antiglycemic, neuroprotective, and antibacterial activities [68].

Apigenin



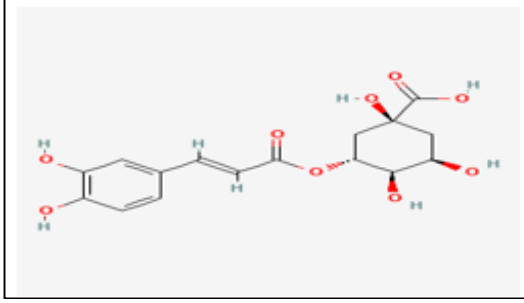
Anti-inflammatory, antioxidant, antibacterial and antiviral activities and blood pressure reduction [69].

Gallic acid



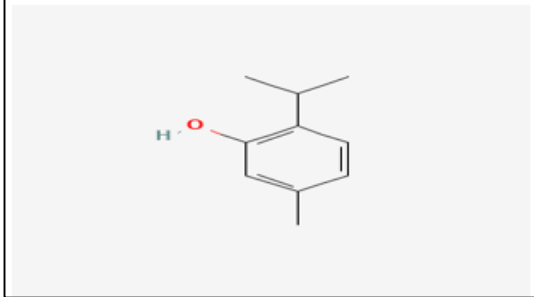
Antioxidant, anti-inflammatory, and antineoplastic, hepatoprotective and anti hyperglycaemic properties [70-72].

Chlorogenic acid



Antioxidant activity, antibacterial, hepatoprotective, cardioprotective, anti-inflammatory, antipyretic, neuroprotective, anti-obesity, antiviral, anti-microbial, anti-hypertension [73].

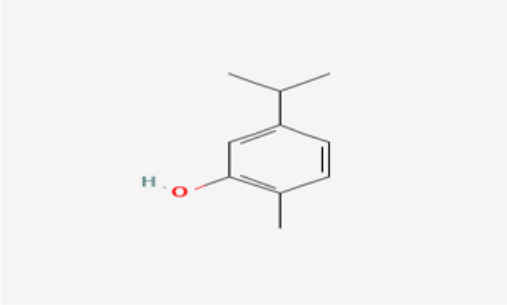
Thymol



Antiseptic, antibacterial, antifungal, anthelmintic, antiviral, antioxidant, expectorant, antispasmodic, carminative, diaphoretic, sedative, anti-rheumatic, and even anti-cancer, anti-hyperlipidemic and anti-hyperglycemic action.

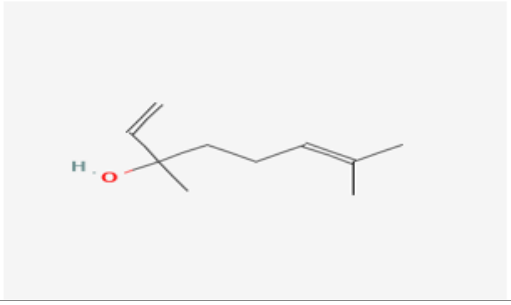
[74-79]

Carvacrol



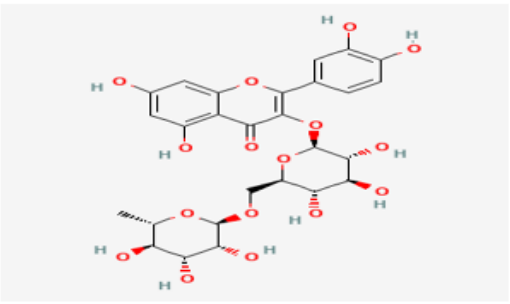
Antimicrobial, antioxidant, and anticancer, analgesic, antispasmodic, antiinflammatory, angiogenic, antiparasitic, antiplatelet, Ache inhibitory, insecticidal, antihepatotoxic and hepatoprotective activities [80, 81].

Linalool

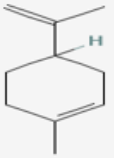


Antimicrobial and insect-repellent properties, anti-inflammatory activity, antihyperlipidemic, antidepressant, neuroprotective and anticancer properties [82-84].

Rutin



Antioxidant, cytoprotective, vasoprotective, anticarcinogenic, neuroprotective and cardioprotective activities [85-87].

Limonene		
		Anti-inflammatory, antioxidant, antinociceptive, anticancer, antidiabetic, antihyperalgesic, antiviral, and gastroprotective effects, relief of heartburn and gastroesophageal reflux [88, 89].

6. Etanobotanical and Traditional Uses

6.1 Vegetable Condiment:

Ocimum gratissimum is recognized as a condiment vegetable commonly utilized in culinary practices as a sauce or spice to enhance flavor [15]. The chemical composition of *O. gratissimum* meets daily nutritional requirements, and its rich mineral content contributes to a balanced human diet [90]. Its leaves are widely used as a local condiment and serve as an excellent source of essential minerals such as calcium, magnesium, and potassium [32]. Traditionally, *O. gratissimum* has also been incorporated into various dishes as a flavoring ingredient. When properly extracted, its bioactive compounds find potential applications in the food, pharmaceutical, and medical industries.

With its unique flavor-enhancing properties, therapeutic potential, and nutritionally beneficial composition, *O. gratissimum* is classified as a condiment vegetable [91]. It is frequently employed as a spice and seasoning agent in food preparation due to its characteristic clove-like aroma and taste [34]. The plant also contains bioactive compounds that are valuable in pharmaceuticals, food additives, and natural colorants [92]. Notably, phytochemicals such as eugenol, limonene, ocimene, and rosmarinic acid contribute to its distinctive flavor profile [93].

Because of the mineral and phytochemical composition of its leaves, *O. gratissimum* can be used as a condiment vegetable to enrich food with both flavor and essential nutrients [94]. Moreover, the presence of bioactive secondary metabolites suggests therapeutic potential, including possible applications in diabetes management. Thus, incorporating *O. gratissimum* leaves into meals not only enhances taste but also promotes a nutrient-rich diet. In addition, its antibacterial, anti-inflammatory, and antioxidant properties further support its traditional use as a valuable condiment.

6.2 Traditional uses

It possesses antidiabetic, antiseptic, antidiarrhoeal, antitussive, antihelmintic, antipyretic, anti-inflammatory, antispasmodic, and antimicrobial properties and is also employed in the treatment and management of various ailments such as stomach and kidney disorders, upper respiratory tract infections, pneumonia, epilepsy, fever, convulsions, diarrhea, headache, and influenza [95-102].

7. Reported Pharmacological Activities

7.1 Activities

Antinociceptive Activity

O. gratissimum has long been used in traditional medicine for alleviating pain-related disorders. The study employed the hot plate and formalin tests to investigate the pain-relieving (antinociceptive) activity of *O. gratissimum* essential oil and two of its main bioactive constituents, eugenol and myrcene, in mouse models. The essential oil at a dose of 40 mg/kg, as well as eugenol and myrcene at 10 mg/kg, significantly reduced pain perception during both the neurogenic and inflammatory phases of the formalin test [103].

Anti-Diabetic Activity

[103]Observed that the aqueous leaf extract of *O. gratissimum* is effective in reducing blood sugar levels in cases of type 1 diabetes. Additional studies explored its impact on immune responses and functions in nicotine-exposed macrophages (10 mM), highlighting its immunomodulatory role. Treatment with a 10 g/mL aqueous extract notably suppressed nicotine-induced nitric oxide (NO) production and iNOS II expression. The extract also demonstrated protective effects by inhibiting Th1 cytokine activity and promoting Th2 responses in nicotine-treated mice peritoneal macrophages.

Anti-Protozoal Activity

Research conducted by [103, 104] evaluated the antiprotozoal potential of *O. gratissimum* leaves and stems through *in vitro* studies against *Trypanosoma brucei* and *Plasmodium falciparum* during their pre-bloom and full-bloom stages. The extracts exhibited the strongest inhibitory effect against *Trypanosoma brucei*, suggesting significant antiprotozoal properties. Both *in vitro* and *in vivo* findings revealed that parasite survival varied with extract concentration lower doses (12.5 and 25 mg/mL) prolonged survival compared to higher concentrations (50, 75, and 100 mg/mL). Furthermore, after a four-day suppression period, the essential oil of *O. gratissimum* displayed pronounced antimalarial activity at doses of 200, 300, and 500 mg/kg, indicating its potential use in malaria therapy and prevention.

Wound-Healing Activity

[104] Reported that *O. gratissimum* exhibits strong wound-healing potential by restoring cell function and protecting against UV-C-induced inhibition of skin cell proliferation and migration. A formulation containing 2% *O. gratissimum* oil with honey as a surfactant showed excellent antibacterial activity. The study also found that the antibacterial efficacy of Ocimum oil depends on the overall electrical charge of the surfactant during formulation. The synergistic effects of 2% Ocimum oil in honey, along with honey's known healing properties, suggest its effective use as a natural topical antiseptic for wound management.

Anti-Infertility Activity

[104] Reported that *Ocimum gratissimum* may play a beneficial role in the management of erectile dysfunction by influencing penile and testicular tissue activity in rats. When methanolic and oil extracts of *O. gratissimum* leaves were administered at doses of 250 mg and 500 mg for 14 and 28 days, no negative effects on male reproductive performance were observed. Furthermore, an aqueous extract of *O. gratissimum* demonstrated anticancer potential due to its antioxidant capacity when tested on human osteosarcoma cells, contributing to the expanding evidence supporting its use in cancer therapy. Bioactive compounds from plants, including those in *O. gratissimum*, are known to exhibit strong anticancer properties.

Antioxidant Property

Highlighted that the therapeutic benefits of *Ocimum gratissimum* are primarily associated with its antioxidant and anti-inflammatory actions. Leaf extracts of the plant are rich in antioxidant vitamins such as ascorbic acid and alpha-tocopherol. Studies have shown that phenolic and flavonoid compounds protect cells from oxidative damage caused by free radicals, helping to prevent stress-related cellular injury. These phytochemicals are largely responsible for the plant's combined antioxidant and anti-inflammatory effects [105,106].

Bio-Pesticides

Ocimum gratissimum essential oil at a concentration of 1 L/mL exhibited strong repellent and toxic fumigation activity against *Tuta absoluta*. When combined with modified montmorillonite clay, the oil achieved a 95-100% insect mortality rate, which gradually declined by 60% after 30 days but remained effective for up to 70-80 days. In addition, cinnamic acid esters derived from *O. gratissimum* displayed significant insecticidal activity against adult *Tribolium castaneum* at a concentration of 26.92 mg/mL [107].

Anxiolytic Activity

[107,108] Noted that anxiety is a widespread mental health disorder affecting both children and adults, often characterized by tension, restlessness, and distress. Administration of 200 and 400 mg/kg of methanolic or petroleum ether extracts of *O. gratissimum* prolonged the onset of tonic and clonic seizures and reduced mortality in experimental models. These results suggest that the extracts act on gamma-aminobutyric acid (GABA) receptors, similar to benzodiazepines and other conventional anxiolytic drugs.

Anti-Cancer Activity

[107,108] Evaluated the anticancer effects of *O. gratissimum*, demonstrating that its aqueous extract possesses potent antioxidant activity and cytotoxic effects on human osteosarcoma cells. In mice models induced with Mahlavu cells, treatment with 12.5-300 g/mL of *O. gratissimum* extract significantly reduced basement membrane breakdown, angiogenesis, and the activity of matrix metalloproteinases (MMP-2 and MMP-9). Administration of 200 mg/kg extract inhibited tumor development by regulating the ERK signaling pathway, reducing aerobic glycolysis, and promoting apoptosis. These effects collectively limited tumor progression and breast cancer growth. Moreover, when MCF-7 human breast cancer cells were treated with *O. gratissimum*, activation of the mTOR/Akt/AMPK signaling pathway was observed, resulting in cytotoxic and apoptotic effects.

Anti-Microbial Activity

[109] Examined the antibacterial potential of *O. gratissimum* leaf extracts against major pathogenic bacteria including *Staphylococcus aureus, Escherichia coli, Salmonella typhi,* and *Salmonella typhimurium*, all of which are linked to diarrheal infections. Extracts tested included cold-water (CWE), hot-water (HWE), and steam-distilled (SDE) preparations. Among these, only the SDE showed inhibitory activity, with minimum inhibitory concentrations ranging from 0.1% for S. aureus to 0.01% for *E. coli* and *S. typhimurium.*

Anti-Fungal Activity

[110] Emphasized the importance of discovering safe and efficient antifungal agents for treating dermatophytosis. Plant-based preparations remain a promising alternative. *In vitro* testing using agar dilution revealed that *O. gratissimum* leaf extracts including hexane, chloroform fractions, essential oil, and eugenol displayed significant antifungal activity against *Microsporum canis, M. gypseum, Trichophyton rubrum*, and *T. mentagrophytes.*

Anti-Bacterial Activity

[111] Found that the essential oil (EO) of *Ocimum gratissimum* exhibited strong antibacterial action against *Staphylococcus aureus* at a concentration of 0.75 mg/mL. Minimum inhibitory concentrations (MICs) for *Shigella flexneri, Salmonella enteritidis, Escherichia coli, Klebsiella species*, and *Proteus mirabilis* were between 3 and 12 mg/mL. However, inhibition of *Pseudomonas aeruginosa* was not achieved even at concentrations of 24 mg/mL or higher.

Anti-Diarrheal Activity

[112] Investigated the antidiarrheal potential of *O. gratissimum* leaf aqueous extract and found that it significantly reduced castor oil-induced diarrhea in rats. This was demonstrated by a noticeable decrease in the number of wet feces among treated animals. Phytochemical screening identified tannins, steroids, triterpenoids, and carbohydrates as the major constituents. These results indicate that the extract's antidiarrheal action may result from inhibition of intestinal motility, likely through muscarinic receptor suppression.

7.2 Dose

There is currently no standardized clinical data available to determine an exact dosage for African basil. Traditionally, a common home remedy involves consuming 10-12 fresh Tulsi leaves with one teaspoon of grated ginger and 7-8 dried kalimirch (black pepper) [113].

In folk medicine, the clove basil plant (*Ocimum gratissimum*) has been widely utilized to manage several health conditions, including cancer, diabetes, inflammation, anemia, diarrhea, pain, and microbial infections caused by bacteria and fungi [114]. This perennial aromatic shrub grows across all continents. Its juice is traditionally used to relieve dizziness, headaches, colds, and coughs, while infusions are known to act as a tonic and pectoral in Cameroon. In Nigeria, *O. gratissimum* is recommended for treating

diarrhea, respiratory problems, and parasitic worm infestations. It is also used to relieve pneumonitis, fever, headaches, eye infections, and skin disorders. In Togo, plant infusions are used to manage coughs (as and antitussive), while the fresh leaf juice is considered effective for treating diarrhea and dysentery [115].

In the Benin Republic, aqueous macerations from the aerial parts of the plant are used for conditions such as pelvic pain, digestive issues, candidiasis, dysmenorrhea, vomiting, hemorrhoids, and diarrhea. The stem decoction is also used for treating hepatitis, cough, asthma, and wound infections.

Extensive pharmacological studies have supported the plant's diverse therapeutic applications, highlighting its anesthetic, anti-stress, anti-inflammatory, anthelmintic, antidiarrheal, antimutagenic, anti-ulcer, gastroprotective, hepatoprotective, sedative, and antifungal activities.

Additionally, *O. gratissimum* is a common ingredient in toothpaste, mouthwash, and topical antiseptic formulations. Research further indicates that its extracts could serve as supportive therapy for patients with acquired immunodeficiency syndrome (AIDS) and human immunodeficiency virus (HIV). It is also valued as a febrifuge, an effective rinse for sore throats and tonsillitis, and an additive in traditional antimalarial preparations. Both humans and animals suffering from intestinal helminths have shown improvement when treated with *O. gratissimum* extracts [113].

7.3 Side effects

Tulsi contains eugenol a compound also found in cloves and balsam of Peru. While small doses of eugenol can protect the liver against toxin-related injury, excessive intake may result in liver damage, nausea, diarrhea, increased heart rate, or convulsions [116].

Pregnancy Warning

Pregnant women are strongly advised to avoid Tulsi. This aromatic herb, a member of the Lamiaceae family, may adversely affect both the mother and the fetus. Reports from the Times of India suggest that it can cause uterine contractions, potentially leading to miscarriage [113].

Diabetic Patients

While Tulsi has been shown to help stabilize blood sugar levels, individuals taking antidiabetic medications should avoid its concurrent use, as it may cause hypoglycemia (abnormally low blood sugar). Moreover, animal studies reported by NCBI indicate that Tulsi might impact fertility in both males and females by reducing sperm count and decreasing the weight of reproductive organs, such as the testis, adrenal glands, prostate, uterus, and ovaries [113].

Blood-Thinning Properties

Tulsi exhibits mild blood-thinning properties. Although it serves as a natural alternative for those avoiding synthetic drugs, individuals already taking anticoagulant or antiplatelet medications should refrain from using it to prevent excessive bleeding [113].

Potential Liver Damage

The high eugenol content in Tulsi, though beneficial in moderation, can be harmful when consumed excessively. Overuse may lead to liver toxicity, nausea, diarrhea, rapid heartbeat, and convulsions [113].

Dental Caution

Chewing Tulsi leaves directly is not recommended, as they contain mercury, which can cause tooth discoloration. It is better to swallow the leaves whole. According to the Times of India, Tulsi leaves are naturally acidic, and prolonged chewing can disturb the alkaline environment of the mouth, leading to enamel erosion and tooth sensitivity [113].

7.4 Toxicology

Conflicting results have been reported regarding the potential toxic effects of orally administered *O. gratissimum* on hematological parameters such as red blood cell count, hemoglobin levels, platelets, and neutrophils in animal studies. However, its impact on human blood parameters remains uncertain. In experimental models, the essential oil of *O. gratissimum* was found to be non-toxic in mice, exhibiting a high acute median lethal dose [117].

8. Conclusion

The medicinal importance of Ocimum has made it a cornerstone in Ayurvedic practice. Holy basil, commonly called Tulsi or basil, is widely used in Ayurvedic remedies and is often referred to as an "elixir of life" because it is believed to support longevity. Its leaves serve as a natural aid for digestion when chewed after meals and are also used as a remedy for coughs.

O. gratissimum demonstrates a broad spectrum of pharmacological effects, including antimicrobial, antibacterial, antifungal, antiviral, antimalarial, anesthetic, antiprotozoal, and anthelmintic activities. Beyond these, it also exhibits anti-diabetic, anti-fertility, anti-inflammatory, and anti-stress properties, and research indicates its potential in treating breast cancer. Traditionally, it has been used to manage insect bites, eye and skin conditions, respiratory infections, diarrhea, and fever.

This review compiles recent studies on the chemical composition (phytochemistry) and diverse therapeutic uses of *Ocimum gratissimum*, highlighting its extensive potential in both traditional and modern medicine.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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