Ocimum Species: Ethnomedicinal Uses, Phytochemistry and Pharmacological Importance

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ABSTRACT

Plant species belonging to the Ocimum genus are among the most popular medicinal plants and are being used for several purposes in ethnomedicine. Ocimum is universally cultivated; however, the geographical distribution highlights three major centers of Ocimum diversity: the tropical areas of America, the tropical region of Asia, and the tropical and subtropical regions of Africa. Ocimum species have been employed traditionally for several medicinal purposes, including antioxidant, antibacterial, hypoglycaemic, hepatoprotective, antiviral, and other medicinal purposes. Though scientists have carried out studies and chronicled the pharmacological potentials of Ocimum species, documents containing these data seem to be disassembled, making it difficult to really distinguish the pharmacologically beneficial species from those that are not and also to get comprehensive information about the medicinal species in this genus. Hence, this review aims to outline classified information on the ethnopharmacology, phytochemistry, and pharmacological importance of some Ocimum species that have been different researchers have reported. In carrying out this review, the literature search was done via relevant databases including PubMed, Springer, Web of Science, Science Direct, Embase, SciFinder, Google Scholar, and Scopus. The species reviewed are the most widely used from the Ocimum genus in traditional medicine, and they are also the most researched for intended use in conventional therapeutic practice. Literature reveals that these species contain several compounds responsible for the numerous pharmacological activities elicited by them, including antimalarial, anticancer, anti-diabetic, anti-inflammatory, and antioxidant effects.

KEYWORDS: Ocimum species; Ethnomedicine; Pharmacological potential

INTRODUCTION

In the past few years, scientists and researchers have focused mainly on natural products searching for potent and safer agents for curative, prophylactic, and other medicinal purposes.¹ This has led to extensive scientific studies on suspected medicinal plants and other natural products.² Scientific chronicles have shown that remarkable success has evolved from this trend, as several pharmacological agents currently in use were developed from natural products (including plants).³

Plant species belonging to the Ocimum genus are among the most popular medicinal plants and are being used for several purposes in ethnomedicine. Of the entire genus stemming from the subfamily Nepetoideae (under the family Lamiaceae), Ocimum (also known as Basil) is the most important.⁴ The name Ocimum was derived from the word “Ozo” (Greek), which means smell.⁵ Due to its enormous use in traditional medicine and pharmaceutical industry and perfumery purposes, it is also referred to as the “king of herbs.”⁶ According to the report documented by Pushpangadan and Bradu, the genus Ocimum with over 160 species, is said to be the largest genera belonging to the Lamiaceae family.⁷ About 65 of the species are native to Ocimum, while the others are considered synonyms.¹,⁷ Ocimum is universally cultivated; however, the geographical distribution highlights three important centers of Ocimum diversity. These are the tropical areas of America, the tropical region of Asia, and Africa’s tropical and subtropical regions. The African tropical rain forest has the highest...
number of Ocimum species. The main species of Ocimum with documented pharmacological activity include Ocimum gratissimum, Ocimum basilicum, Ocimum sanctum, Ocimum americanum, and Ocimum Kilimandscharicum. These species have been reported traditionally to possess different culinary and medicinal activities. In different parts of the world, people employ plant species from this genus for several medicinal purposes such as antioxidant, antibacterial, hypoglycaemic, hepatoprotective, antiviral, and several other medicinal purposes. Though scientists have carried out studies and chronicled the pharmacological potentials Ocimum, documents containing these data seem to be disassembled, making it difficult to really distinguish the pharmacologically beneficial species from those that are not and also to get comprehensive information about the medicinal species in this genus. Hence, this review aims to outline classified information on the ethnopharmacology, phytochemistry, and pharmacological importance of some Ocimum species that have been different researchers have reported.

In carrying out this review, the literature search was done via relevant databases, including PubMed, Springer, Web of Science, Science Direct, Embase, SciFinder, Google Scholar, and Scopus. The keywords used for the search include Ocimum, Ocimum species, phytochemical, phytochemistry, pharmacological activity, pharmacological evaluation of extracts, fractions, or isolated compounds from Ocimum. The study's selection and inclusion were based on publications done in the English language only. All selected manuscripts were analyzed for relevance to the topic, reported plant species, isolated chemical compounds, and evaluated biological activities.

**Ethnopharmacology of Ocimum species**

Literature shows that traditionally, plant species belonging to the Ocimum genus are widely employed to treat and manage several ailments, including mental illness, diarrhea, measles, gonorrhea, rheumatism, paralysis, high fever, influenza, epilepsy, abdominal pains, cold, and cough. In addition, they are also used as antipyretic, antihelmintic, antiemetic, and antimalarial agents traditionally. The specific documented tradomedical application of the different species belonging to the Ocimum genus are summarized in table 1 below.

**Table 1. The tradomedical uses of different Ocimum species**

| Species           | Region                        | Parts                        | Traditional Uses                                                                                                                                                                                                 | References |
|-------------------|-------------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Ocimum americanum | China, India, Thailand, Nigeria, Cameroon, Mali, Guinea | Leaves                       | It is used for treating coughs, bronchial catarrh, ulcers, haemorrhoids, tuberculosis, stomach pains, ear and eye ailments. It is also used to lower high blood pressure and treat constipation, stomach ache, diabetes, diarrhea, dysentery, and haemorrhoids. | [15 - 19] |
| Ocimum basilicum  | Cameroon, Egypt, Nigeria, Guinea, Mali, Rwanda | Leaves                       | They were used for prophylaxis and treating cardiovascular disorders, diabetics, aches and pains, cough, headache, kidney malfunctions, and diarrhea. It is also used to treat skin infections, snake bites, and insect stings and as a sedative. | [20- 23] |
| Ocimum gratissimum| India, China, Nigeria, New Zealand, Australia | Leaves, stem, root, and flowers | It is used as an antidiabetic, anti-septic, antidiarrhoeal, antitussive, antihelmintic, antipyretic, anti-inflammatory, antispasmodic, and antimicrobial agent, also used for the treatment and management of various stomach and kidney ailments, upper respiratory tract infection, pneumonia, epilepsy, fever, convulsion, diarrhea, headache, and influenza. | [27 - 34] |
| Ocimum Kilimandscharicum | India, Thailand, Ethiopia, Tanzania, Kenya, Uganda, Sudan, Ethiopia | Leaves                       | It is employed to treat cough, cold, measles, abdominal pain, measles, diarrhea, and diarrhea. In addition, it is used as an insect repellent and for storage pest control. | [35 - 37] |
| Ocimum sanctum    | Asia, Africa, Malaysia, Australia, United Arab Emirates | Leaves                       | It is used traditionally to manage and treat several ailments such as headache, fever, cough, common cold, flu, sore throat, colic pain, asthma, diarrhea, digestive disorders, bronchitis, influenza, insomnia, hepatic diseases, arthritis, and malaria fever. It is also used as an antidote for scorpion sting and snakebite | [38 - 40] |
Phytochemical Studies

Ethnomedicinal plants contain complex plant chemicals, also known as phytochemicals. These phytochemicals are made up of several compounds. The enormous information revealed by the ethnomedicinal applications of Ocimum species spurred a scientific investigation into its chemical constituents. These studies have led to the identification and isolation of various phytochemicals from different plant parts of Ocimum species. These include alkaloids, terpenoids, organic acids, tannins, flavonoids, coumarins, quinones, polyphenols, saponins, and their derivatives.

Ocimum americanum: Phytochemical analysis carried out by Dhole et al. [41] showed that Ocimum americanum is rich in alkaloids, phenolic compounds, tannins, lignin, saponins, flavonoids, terpenoids, and anthraquinone. Alcêlia et al. [42] also gave a similar report, and as well documented compounds such as α-pinene, Camphene, sabinene, β-pinene, and other compounds which have been identified and isolated from its essential oil.

Ocimum basilicum: Sanni et al. [43] and Ismail[44] reported carbohydrates, tannins, cardiac glycosides, flavonoids, terpenes, and steroids in Ocimum basilicum leaves. Using a GC-MS, Andrew et al. [45] carried out a chemical analysis that showed α-Pinene, β-Myrccene, 4-Hexen-1-ol acetate, and other important bioactive compounds in its essential leaf oil. Sarfaraz et al. [46] also documented the presence of these compounds in a report on their analysis.

Ocimum gratissimum: A phytochemical report documented by Offiah and Chikwendu[47] revealed tannins, steroids, triterpenoids, and carbohydrates in Ocimum gratissimum. Prabhut et al. [48] also showed alkaloids, tannins, flavonoids, and oligosaccharides. Pandey and Chowdhury, [49] Matasyoh et al., [50] Kéita et al.,[51] and Jirovetz et al. [52] have also documented specific compounds which have been isolated from Ocimum gratissimum, this has been summarized in table 2, and some of the structures shown in figure 1.

Ocimum Kilimandscharicum: According to a report by Tewari et al., [53], alkaloids, glycosides, saponins, flavonoids, phenols, carbohydrates, steroids, protein, and amino acids are among the phytochemicals present in Ocimum Kilimandscharicum. In their work, Charles and Simon[54] isolated seventeen compounds from its essential oil, including α-pinene, Camphene, β-pinene, and Eugenol [table 2].

Ocimum sanctum: In a research work published by Xia et al., [55], carbohydrates, terpenoids and alkaloids were present in the ethanolic extract of Ocimum sanctum. Similarly, Devendran and Balasubramanian[56] also reported the presence of flavonoids, cardiac glycosides, steroids, saponin and tannins, and carbohydrates terpenoids and alkaloids. Furthermore, using a GC-MS, analysis of the hydroalcoholic extract showed several compounds, including Eugenol and Caryophyllene.

Reported compounds isolated from the various Ocimum species have been outlined in table 2, while some of the structures are shown in figure 1.

Table 2. Compounds isolated from different Ocimum species

| Species             | Compounds Isolated                                                                 | Reference       |
|---------------------|-----------------------------------------------------------------------------------|-----------------|
| Ocimum americanum   | α-pine ne, Camphene, Sabinene, β-pine ne, β-mircene, Limonene, 1,8 cineole, linalool oxide, Fenchone, Linalool, Camphor, Borneol, 4-terpineol, α-Terpineol, cis-piperitol, Estragrole, Eugenol, β-selinen, β-caryophyllene, bicyclomacarene, β-bisabolene. | [42]             |
| Ocimum basilicum    | α-Pinene; β-Myrcene; 4-Hexen-1-ol acetate; 4 Eucalyptol; cis-Linaloloxide; 1,6-Octadien-3-ol, 3,7-dimethyl; Methyl ethyl cyclopentane; L-Menthone; L(-)-menthol; Estragrole; N-Cyno-3-methylbut-2-enamine; Citral; Cyclohexene, 4-methyl-1(1-methylene thyl); Phenol, 2,3,5-trimethyl; Eugenol; Formic acid, cyclohexyl ester; Copae; cis-7,10,13,16-Docosatetraenoic acid, methyl ester; Neosolongifolene; trans-α-Bergamotene; Alloaromadendrene; Humulene, beta-copaene; beta-Bisabolone; cis-murola-3,5-diene; cis-alpha-Bisabolene; Nerolidol; trans-4-Methoxyccinnamaldehyde; Benzeneacetic acid, alpha.-hydrox; Phenylethanolamine; 3-Methyl-2-phenylindole; N-Benzyl-N-ethyl-p-isopropylbenzamide | [45 - 46]         |
| Ocimum gratissimum  | Eugenol, methyl eugenol, cis-ocimene, trans-ocimine, pinene, camphor, germacrene-D, trans-caryophyllene, farnesene and l-bisabolone, Thymol, methyl chavicol, linalool, limonene, methyl eugenol, β-caryophyllene, farnesene, α-terpineol, methyl isoegenol, geraniol, α-copaene, bisabolol, fenchone, cubenen, Camphene, T-cadanol, sabinene, myrcene, β-bisabolone, α-humelene and β-elemene. | [47-52]          |
| Ocimum Kilimandscharicum | β-pinene, Myrcene, 1,8-cineole, Limonene, Terpen-r4-ol, α-terpineol, Bornyl acetate, α-pine ne, Camphene, Eugenol, β-caryophyllene, α-humulene, Linalool, Camphor, γ-murolene, Germacrene B, Epi-a-cadinol | [53-54]          |
| Ocimum sanctum      | Eugenol; Cyclohexane, 1,2,4-triethyl- ; Caryophyllene; 10-Heptadecen-8-ynoic acid; Cyclopentane, cyclopropyldiene - ; ZZ-4,16-Octadecadien-1-ol acetate; Benzene methanamine, N,N-α,4- tetramethyl - ; 3,8'-trimethoxy-3-piperidyl-2,2'-binaphthalene1,1',4,4'-tetroe; Octadecane, 1,1-dimethoxy - ; Pentanedinitrile, 2-methyl- | [55-56]          |
Ocimum basilicum

According to Politeo et al. and Ramesh et al., Ocimum basilicum is rich in antioxidants compounds and hence has high antioxidant activity.[74 - 75] Dwivedi et al. stated that the Solvent extracts of the plant elicit significant activity at the cellular level, including inhibition of HIV-1 reverse transcriptase and anti-aggregatory effect on blood platelets.[76] Clinical studies reported by Siurin et al. and Nature et al. revealed that Ocimum basilicum volatile oil has characteristic antioxidant activities.[77 - 78] Bravo et al. also reported the protective activity of the ethanolic extract of Ocimum basilicum against mutagenesis and oxidative DNA damage, accompanied by a decrease in cholesterol synthesis accumulation of lipid in human macro-phages.[79] A report by Wannissorn et al. and Ahmet et al. reveals that Ocimum basilicum exhibits antibacterial effect against several bacteria, including C. perferingens, Salmonella spp., C. jejuni, and E. coli.[80 - 81] Also, Opalchenova and Obreshkova revealed that the plant aerial parts volatile oil elicit significant activity against drug immune clinical isolates of Pseudomonas, Enterococcus, and Staphylococcus.[82] Patel et al. have documented the significant antimicrobial effects of Ocimum basilicum from their study.[83] In vitro studies by Yamasaki, et al. revealed that Ocimum basilicum exhibits marked inhibitory actions against cytopathogenicity induced by HIV-1 in MT-4 cells.[84] Renzulli et al. reported that rosmarinic acid (a compound present in Ocimum basilicum) has significant inhibitory activity against inflammatory processes. In vitro studies reveal that rosmarinic reduces the production of oxygen species and inhibits protein and DNA synthesis induced by mycotoxins, hence preventing cell death.[85] In vitro study on P388 and KB cell lines by Manosroi et al. revealed that the essential oil Ocimum basilicum elicited moderate anti-proliferative activity compared to the standard drug 5-fluorouracil.[86] Mohan et al. reported the hypolipidemic and hypoglycemic activity of aqueous extract of Ocimum basilicum in laboratory rats. They observed a marked reduction in serum lipid, lipid peroxidation products, blood glucose level, and improvement in glucose tolerance.[87]

Ocimum gratissimum

The antibacterial and antifungal efficacy of Ocimum gratissimum has been reported in various studies.[88 - 89] Pharmacological study of the aqueous extract revealed it has an analgesic and anti-inflammatory activities of the leave-in laboratory mice.[70] According to Sinittha et al., Ocimum americanum elicits an immune-modulatory effect[71], while Lenise et al. have also documented its anesthetic activity. [72] Aluko et al. carried out a study to evaluate the hepatoprotective activity of Ocimum americanum leave in laboratory rats with paracetamol–induced liver damage and reported having a hepatoprotective effect.[73]
Typhi, V. cholera, and N. gonorrhea.[93] It has an excellent synergic activity with ampicillin, eliciting highly significant antibacterial effects against E. coli and P. mirabilis, and also possesses similar synergic activity with nystatin and ketoconazole, eliciting significant antifungal effect against C. Albicans.[94] The anti-diarrheal activity of the leaf extract was established in a study by Irori et al., which used the disc diffusion and tube dilution methods to ascertain its effect against bacteria S. Typhi, E. coli, S. dysenteriae, P. shigelloides, and A. sobria, and it proved to be a significant antibacterial agent.[95] Pratheeba et al. also revealed that the chloroform leaf extract had an excellent insecticidal effect against filariasis causing mosquito vector Culex quinquefasciatus.[96] The plant leaves have been shown to possess a broad-spectrum antibacterial activity against P. mirabilis, E. coli, and S. aureus.[97] The methanolic leaf extract has been reported to be active against nicotine toxicity due to its ability to decrease free radical generation and lipid-protein damage, and antioxidant activity.[98] The aqueous leaf extract has been reported to show significant hypoglycaemic effect, reducing lipid MDA, LDL-cholesterol, and triacylglycerol levels[99] and caused a marked decrease in the plasma glucose level in laboratory rats in the streptozotocin-induced diabetic model.[100] The aqueous leaf extract has been observed to inhibit proliferation, chemotaxis, induction of COX-2 protein and morphogenesis, and decrease the size of breast cancer tumors.[101] The dichloromethane leaf extract in an in vitro study inhibited myeloid leukemia[102]; hence, it may help treat human cancer. The methanolic crude leaf extract has been documented to be having haematinic and hemopoietic activity in laboratory rats.[103] An increase in erythrocytes, hemoglobin packed cell volume, thrombocytes, and neutrophils count, as well as increase in platelet distribution width, mean platelet volume, and platelet-large cell ratio (P–LCR) have been observed to be elicited by the leaf extract.[104] Reduction in the serum total protein and urea level, packed cell volume, neutrophils, hemoglobin, and increased uric acid, in total acid, prostatic acid, phosphatases, leucocytes, and lymphocytes have also been reported to be elicited by the plant.[105] Its leaf essential oil has been reported to show both fungistic and fungicidal activity at different concentrations against A. alternata, S. rolfsii and C. capsici.[106] Ocimum kilimandscharicum

Hakkim et al. evaluated the antioxidant potential of the Methanolic leaf extract of Ocimum kilimandscharicum using an in vitro model. They reported it to exhibit a moderate activity compared to butylated hydroxyl anisole (BHA). [107] Mwangi et al. also experimented to examine the antioxidative activity of the alcoholic leaf extract of Ocimum kilimandscharicum in mice using the tail-flick model. The outcome revealed it to be a significant antioxidant agent. [108] Based on their in-vitro antiplasmodial study using dichloromethane extract of leaves and twigs of Ocimum kilimandscharicum, Owuor et al. reported significant activity against both chloroquine-resistant and chloroquine-sensitive Plasmodium parasites, [109]. In contrast, Runyoro et al. reported that the oil elicited larvicidal activity on Culex quinquefasciatus larvae. [110] Using castor-oil-induced diarrhoea model and castor oil-induced enteropooling assay in rats; and charcoal meal test/intestinal motility test in mice, Serin et al. demonstrated that the aqueous leaf extract has significant anti-diarrheal activity. [111] Kumar et al. also reported the significant antimicrobial activity of volatile oil of the whole plant of Ocimum kilimandscharicum against Gram-negative bacteria (E. coli, E. cloacae, Vibrio cholera, S. dysenteriae, P. aeruginosa, Klebsiella sp), [112] while Shinde et al. also reported its effectiveness against Gram-positive bacteria (S. aureus, S. epidermidis, S. mutans, S. viridans, B. subtilis, M. luteus). [113] Monga et al. also reported the antimalanoma and radioprotective effect of alcoholic aqueous extract in mice.[114] Jambere et al. carried out a laboratory test on the leaves of Ocimum kilimandscharicum against the following insects Rhzoceptorha Dominica, Sitophilus zeamais, Sitotroga cereaellae in maize and sorghum grains to evaluate its insecticidal activity. The reported experimental outcome showed it to be an effective insecticidal agent. [115] Mahesh et al. have also documented the significant wound healing activity of the aqueous extract as a result of the experiment they carried out on laboratory rats, using the excision, incision, and dead space wound model.[116] Ocimum sanctum

Ocimum sanctum has been chronicled and described to be having several pharmacological activities. Rahman et al. reveals that Ocimum sanctum shows antimicrobial activity against a wide range of bacteria, including Staphylococci sp., E. coli, Shigella sp., S. aureus, Enterobacteria sp., P. aeruginosa, S. Typhi, Staphylococci sp., C. Albicans, K. pneumonia, M. tuberculosis, and M. pyogenes. [117] According to an in vitro study by Farivar et al., Ocimum sanctum extract proved to be an effective anti-tuberculosis agent. [118] Khan et al. reported that aqueous, hexane, chloroform, n-butanol extracts, and essential oil of Ocimum sanctum showed significant antifungal activity against several fungi A. solani, C. guillermondii, C. capsici, Curvularia sp., F. solani, H. oryzae and A. flavus.[119 - 120] Kelm et al. also reported that the methanolic, hydroalcoholic, and aqueous extracts of Ocimum sanctum elicit significant antioxidant activity, both in vitro and in vivo. [121] According to Geetha et al., Oral intake of the Ocimum sanctum significantly protects the liver and aortic tissue from hypercholesterolemia-induced peroxidative damage.[122] Siva et al. documented that the Oral administration of Ocimum sanctum extract significantly reduced blood sugar levels.
in streptozotocin-induced and glucose-fed hyperglycemic diabetic rats. A different study by Gholap and Kar also showed that Ocimum sanctum reduced the serum concentration of cortisol and glucose and elicited antiperoxidative activity.[123] Aruna et al., in their study, revealed that Ocimum sanctum leaves significantly reduced the squamous cell hematoma incidences and carcinoma in experimental rats. [124] The result from a study by Ganasoundari et al. revealed that Ocimum sanctum aqueous leaf extract inhibited hydroxyl (OH) radical-induced deoxyribose degeneration significantly. They also showed the synergic activity WR-2721 and Ocimum sanctum, which produced a better effect against OH radical activity when compared with the individual agents alone. [125] Shetty et al. experimented with evaluating the activity of Ocimum sanctum aqueous leaf extract on tumor necrosis factor-Alfa (TNF-Alfa) in laboratory rats, using the excision model. The result showed that the Ocimum sanctum extract increased the rate of epithelization and wound contraction, hence a significant wound healing effect. [126] In the antiulcer study carried out by Govind et al. in rats using aspirin, indomethacin, alcohol (ethanol 50%), histamine, reserpine, serotonin, or stress-induced ulcers models, the oil of Ocimum sanctum showed significant antiulcer activity. [127] Mediratta et al. reported that steam distilled leave extract of Ocimum sanctum caused a modification in laboratory rat humoral immune response. This could be attributed to antibody production, the release of mediators of hypersensitivity reactions, and tissue responses to mediators in the target organs.[128] Godhwani et al., in a separate experiment, also demonstrated the immunomodulatory effect of Ocimum sanctum using widal and sheep erythrocyte agglutination tests. [129] Sridevi et al. showed that Ocimum sanctum has significant benefits when employed in the treatment of asthma and other related conditions. They also reported that Ocimum sanctum has the potential to cause mast cell stabilization, suppression of IgE, and inhibition of release of inflammatory mediators; hence, it may be the cause of these effects. [130] According to Ravindran et al., the Ocimum sanctum normalizes noise stress-induced alteration in neurotransmitter levels due to, and this is proof of its anti-stress activity. [131] Asha et al. showed the significant antihelmintic activity of Ocimum sanctum essential oil using the Caenorhabditis elegant model.[132] Different extracts of stem and leaves of Ocimum sanctum were subjected to experimental studies for anticonvulsant activity by maximal electroshock model using phenytoin as standard. It was observed that ethanol and chloroform extract of leaf and stem produced significant preventive effects against toxic convulsions induced by trans corneal electroshock. [133] Ocimum sanctum has also been shown to have a robust cardioprotective effect against myocardial agents. Sood et al. revealed that Ocimum sanctum elicited significant protection against isoproterenol-induced myocardial necrosis in laboratory rats by increasing the activity of endogenous antioxidants. [134] Joshi et al. reported that Ocimum sanctum L. alcoholic extract ameliorated scopolamine-induced amnesic effect as well as memory deficits caused by aging in laboratory mice. Ocimum sanctum both increased significantly step-down latency (SDL) and acetylcholine esterase inhibition. This may be useful in the treatment of dementia, Alzheimer’s disease, and other cognitive disorders.[135] Ocimum sanctum has been documented to have a significant antidote effect against dog bite, snake bite, scorpion bite, and insect bites.[136] **CONCLUSION** Ocimum species have been employed traditionally for therapy globally. The species reviewed are the most widely used from the Ocimum genus in traditional medicine, and they are also the most researched for intended use in conventional therapeutic practice. These species contain several compounds responsible for the numerous pharmacological activities elicited by them, including antimalarial, anticancer, antidiabetic, anti-inflammatory, and antioxidant effects.

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