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A comprehensive review on nutritive value, phytochemicals, and pharmacological activities of *Ocimum basilicum* var. *thyrsiflora*

Akankshya Sahu[1#], Gayatree Nayak[1#], Sanat Kumar Bhuyan[3*], Ruchi Bhuyan[2], Dattatreya Kar[2], Ananya Kuanar[1*]

[1]Centre for Biotechnology, Siksha 'O' Anusandhan University, Kalinga Nagar, Ghatikia, Bhubaneswar, Odisha, India, 751003
[2]Department of Medical Research, Health Science, IMS & SUM Hospital, Siksha 'O' Anusandhan University, Bhubaneswar, Odisha, India, 751003
[3]Institute of Dental Sciences, Siksha 'O' Anusandhan University, Bhubaneswar, Odisha, India, 751003
[#]1st and 2nd authors have an equal contribution.

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ABSTRACT

The genus *Ocimum* has many species belonging to the Lamiaceae family that are used to treat various diseases and disorders. *Ocimum basilicum* has been found to contain over 200 chemical components in different plant parts. The bioactive components showed the presence of α-linalool, camphor, limonene, thymol, citral, β-linalool, estragole, etc. *O. basilicum* exhibits anti-inflammatory, antioxidant, antiulcer, antiviral, hypoglycemic, hypolipidemic, antimicrobial, anticancer, wound-healing activities, etc. They have also been used to treat fevers, digestive issues, stomach cramps, nausea, gastritis, migraine, diarrhea. This review aims to provide information about the chemical compounds and biological activities of *O. basilicum* var *thyrsiflora* (Thai basil). To the best of our knowledge, this is the first review outlining the innovative ethnomedicinal approach to oral health care that, through its strong phytoconstituents, has the potential to improve modern medicine.

Implication for health policy/practice/research/medical education:
The findings revealed the presence of vitamins, protein, minerals, electrolytes, phytonutrients, and secondary metabolites such as flavonoids, phenolic compounds, etc. Essential oils and extracts have exhibited various pharmacological activities such as antifungal, antibacterial, antiviral, antioxidant, anti-inflammatory, anticancer, antiulcer, anti-dyspepsia, antigiardial, wound-healing, insecticidal, antiwormal, and cardiac stimulant effects on CNS, hypoglycemic and hypolipidemic effects, and inhibition in platelet aggregation. Hence, this plant has promising values for preparation of new drugs against these diseases.

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Introduction

For thousands of years, medicinal plants have been used for a wide range of prospects, including preserving food, pharmaceuticals, natural remedies, and alternative medicine. Compounds produced naturally instead of artificially are frequently assumed to biodegrade more easily and hence be more eco-friendly. Nowadays natural antimicrobial, antioxidants, cytotoxic, and nutrient agents have risen in popularity, and their use and good perception by consumers are increasing. In recent years, multiple drug resistance to pathogenic microbes have emerged in humans and plants, as a result of the widespread usage of commercial antimicrobial medicines used to treat infectious diseases (1).

Scientists have become increasingly interested in plant study, particularly in developed countries such as Europe and America. Approximately 60% of the world's population is estimated to depend on herbs and natural products for treatment, making it an integral source of pharmaceuticals (2).

The study of a wide spectrum of organic compounds that have been produced in plants is known as phytochemistry. Phytochemistry also determines the natural distribution, structure, biosynthesis, metabolism, and physiological

***Corresponding authors**: Sanat Kumar Bhuyan, Email: drsanat02@gmail.com; Ananya Kuanar, Email: ananyakuanar@gmail.com

activities of these compounds (3). Aromatic plants have a unique combination of volatile compounds characterized by sesquiterpenes and monosesquiterpenes, which play a key role in flavouring, fragrance and perfumery. In addition, they are distinguished by the existence of phenolic compounds, mainly phenylpropanoids and coumarins, in addition to essential oils (4). After the discovery of certain commercial synthetic antioxidants to be mutagenic, toxic, and carcinogenic, researchers have become more concerned about secondary biomolecules. Because of their antioxidant and antiradical properties, several plant species, including aromatic plants, have been studied (5-10).

A wide spectrum of climatic conditions and soil types are required for the good growth of the genus *Ocimum*. For example, saline and alkaline soils, moderately acidic pH, moderate to heavy rainfall, normal humidity, and high temperatures. It is most popular in China, Japan, Turkey, Iran and also found in South and Central America, tropical Asia, and Africa (11). The genus *Ocimum* is particularly well-known for its antioxidant properties (12).

Ocimum basilicum a valuable medicinal plant as well as a culinary herb in medicine. It has long been used to treat anxiety, cough, common cold, headaches, fevers, diabetes, migraine, and neuropathic problems. It is also used for heart problems, inflammatory diseases, depression, gastrointestinal diseases, insect bites, cramps, sinuses, and several neurological diseases (13). Moreover, the plant's flowering tops and leaves are apparent as a galactagogue, carminative, stomachic, and anti-inflammatory remedies in traditional medicine (14). In Vietnam, fever and malaria are cured by *O. basilicum*. Mucilaginous seed is used in medicine and in production of non-alcoholic beverages. The essential oil is used to control insects such as flies and bugs. Purple leaf ornamentals are fashionable and are most aromatic as green leaf varieties and can be utilized in the same way (15).

Ocimum basilicum is well recognized for its essential oil, which is accountable for the fragrance, aroma and condiment flavour (13). The plant also contains steroidal glycosides, cinnamic acid ester, acylated and glycosylated anthocyanins, triterpenoids, tannins, flavonoids, phenolic acids, for example, hydroxybenzoic acid, chicoric acid, p-coumaric acid, caffeic acid, protocatechuic acid, rosmarinic acid, vanillic acid, syringic acid, ferulic acid, and lithospermic acid B (16,17). Sweet basil oil has a significant commercial value because of the occurrence of phenylpropanoids such as chavicol, eugenol, and terpenoids (18).

According to pharmacological studies, several *O. basilicum* extracts contain antimicrobials, antioxidants (13), as well as antiviral (19), anti-inflammatory, hypolipidemic (20), anti-platelet aggregation, anti-carcinogenic, antiulcerogenic, and antithrombotic (21) properties. It also reduces LDL-cholesterol levels while increasing HDL-cholesterol levels in the blood, hence preventing cardiovascular disorders (22,23). Phenolic compounds' antioxidant properties are mostly related to their redox activities, which have the ability to absorb and neutralize free radicals, quench singlet and triplet oxygen molecules, and degrade peroxides. The antioxidant properties of most of these phytochemicals have been linked to lower cancer mortality rates in a diversity of human populations (24).

Extracts of *O. basilicum* (basil) from the roots, stems, flowers, leaves, and seeds have been used in a variety of medical treatments. Recent research has discovered that sweet basil extracts contain antibacterial effects against *Escherichia coli* and *Staphylococcus aureus*, antifungal effects against *Rhizopus solani* and *Aspergillus niger,* and antiviral effects against a few strains (25,26). The current study attempts to review the phytoconstituents and biological properties of extracts from *O. basilicum* var. *thyrsiflora* (Thai basil), with special reference to oral healthcare.

Taxonomic position

Ocimum basilicum var. *thyrsiflora* is commonly recognized as Thai basil. It belongs to the *Ocimum* genus, which comes from the Greek word "to smell," and the family Lamiaceae, popularly recognized as the mint family, with the following taxonomic position (Figure 1) (27).

Classical categorization in Ayurveda

Thai basil was used by Ayurvedic and Unani physicians to treat ringworm, rashes, and other skin problems in various forms. *Ocimum* has been used to study the phytoconstituents of essential oil (28). In addition to shrubs, the genus *Ocimum* contains around 150 species of plants (29,30). It is extensively utilized in the cosmetic, aromatherapy, perfumery, food, and pharmaceutical fields (31,32) and used worldwide due to its unique flavour profile, particularly in Mediterranean cuisine (22). In

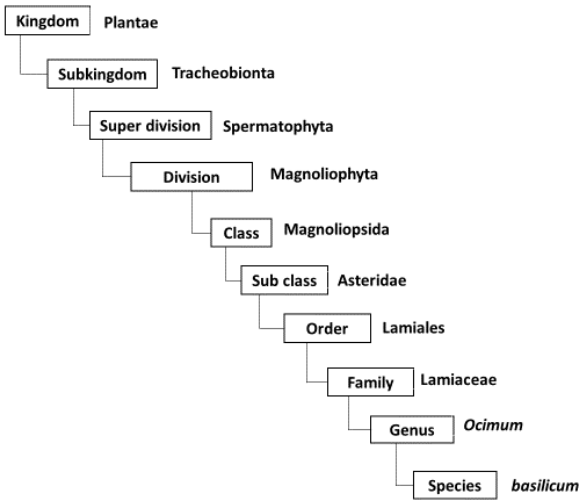

Figure 1. Taxonomic position of *Ocimum basilicum* var. *thyrsiflora* plant.

Mediterranean countries, *O. basilicum* infusions are popularly used in traditional medication to reduce plasma lipid concentration (33).

Ocimum is a genus of over 100 shrubs and herbs originated in tropical and sub-tropical areas and cultivated worldwide (34).

Botanical description

Ocimum basilicum var. *thyrsiflora* (Thai basil) is a delicate perennial herb, generally planted as an annual plant (Figure 2). Thai basil has shiny green, little serrated, narrow leaves with a sweet, anise-like aroma and gives a hint of licorice, and also a slight spiciness. It grows up to 45 cm (1 ft 6 in) tall and has a square purple stem like the stems of other mint plants. It has opposite and decussate leaves. Its flowers are shaped like a thyrse, as its scientific name suggests. The inflorescence is purple but the flowers are pink when open (Figure 3) (35).

Biogeography and ecology

Ocimum species grows well in a wide array of climatic conditions and soil types. Cultivation is suitable in alkaline and saline soils with a moderately acidic pH. Plant growth is enhanced by moderate to heavy rainfall, normal humidity, and high temperatures. *O. basilicum* grows in Central and South America, tropical Asia, and Africa, although it is especially popular in China, Japan, Turkey, and Iran (11). Figure 4 shows the distribution of *Ocimum basilicum var. thyrsiflora* in India (36).

Figure 2. *Ocimum basilicum* var. *thyrsiflora* plant.

Figure 3. Different parts, A) stem, B) flower, C) leaves, and D) seeds of Thai basil.

Therapeutic and potential applications in ethnomedicines

In various regions of Asia, *O. basilicum* is known as the goddess Tulsi, and is used in both medicine and orthodox Christian rituals in India (37,38). In the food industry, the traditional use of the plant has been reported as a flavouring agent and perfume (39). It is commonly cultivated in Iran, and it has been used as a medicine (40). In Asian beverages and desserts and traditional medicine, its seeds are used as a source of dietary fibre (41). It is also helped to treat cough, headache, dysentery, and skin problems (42). It is also found in Mediterranean foods, particularly in the south of Europe, for example, it is found in Greek and Italian cuisines (43). *O. basilicum* polysaccharides have long been utilized in traditional Chinese medication to treat cancer (44) and are still widely used in day-to-day life (45).

Nutritive value of *Ocimum basilicum*

Due to the presence of secondary metabolites for example essential oils, phenols, tannins, anthocyanins, steroids, and flavonoids, *O. basilicum* has long been recognized for its health benefits and has been applied in traditional medicine. The content of magnesium, potassium, and iron is high in *O. basilicum* (Table 1). Potassium and Magnesium, as two of seven essential macro minerals, boost cardiovascular health and nerve impulse transmission while also protecting against several chronic

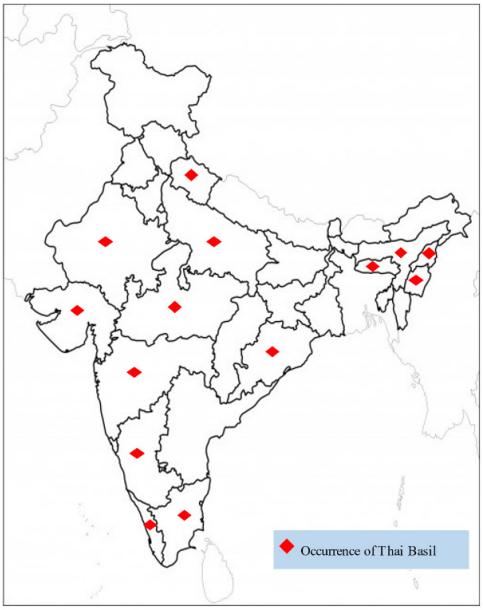

Figure 4. Distributions of *Ocimum basilicum* var. *thyrsiflora* in India.

Table 1. Nutritive constituent of fresh basil leaves in 100 g

Nutrient value	Nutritive elements
Phytonutrients	
3142 mcg	Carotene-β
46 mcg	Crypto-xanthin- β
5650 mcg	Lutein-zeaxanthin
Minerals	
177 mg	Calcium
385 mg	Copper
3.17 mg	Iron
64 mg	Magnesium
1.15 mg	Manganese
Vitamins	
5275 IU	Vitamin A
414.8 mcg	Vitamin K
18 mg	Vitamin C
0.80 mg	Vitamin E
0.209 mg	Pantothenic acid
68 mcg	Folates
0.902 mg	Niacin
0.155 mg	Pyridoxine
0.076 mg	Riboflavin
0.034 mg	Thiamin
Electrolytes	
295 mg	Potassium
4 mg	Sodium
23 kcal	Energy
2.65 g	Carbohydrates
3.15 g	Protein
1.60 g	Dietary fiber
0.64 g	Fat

disorders.

It is used as a diuretic and a digestive stimulant. It is rich in a variety of vital elements, including calcium, phosphorus, vitamin A, and vitamin C. It also includes a high concentration of carotenoids like β-carotene, which are transformed into vitamin A inside the body. Carotene is a potent antioxidant that provides much more benefits than vitamin A.

Polyphenols are abundant in basil. Polyphenols are a diverse group of chemicals that include phenolic acids, simple and complex flavonoids, and coloured anthocyanins. They inhibit peroxide oxidation in terms of pharmacological efficacy (46). Per 100 g of fresh material, sweet basil leaves contain water - 87 g, protein - 3 g, fat - 1 mg, carbohydrates - 5 g, fibre - 2 g, and ash - 2 g. Protein and fat content are high, but carbohydrates are low in the seeds.

Sweet basil is a famous savoury herb. Fresh and dried leaves are used in dishes and drinks to provide aroma, warmth, and sweetness, along with pungent and clove notes (47).

Phytochemical studies

Ocimum basilicum mainly contains around 20 compounds that have been identified by GC-MS, including estragole, 1,8-cineole, methyl eugenol, linalool, etc. *O. basilicum* also contains monoterpenes, including linalool, thymol, limonene, citral, α-linalool, camphor, β- and estragole. Methyl eugenol is one of the most abundant phytochemicals of *O. basilicum*. Radulović et al reported cichoric acid in fresh basil leaves (48). Phenolics are rich in crude extracts of various morphological parts of *Ocimum*. The presence of anthocyanins is responsible for the flower's deep purple pigmentation (49). 52.42% of linalool, 18.74% of methyl eugenol, and 5.61% of 1,8-cineol are major compounds identified by high-performance liquid chromatography (HPLC) in *O. basilicum* (48). Minor compounds are myrcene, borneol, and neral, present at 5%, 9%, and 8% w/w, respectively. HPLC was used to identify 14 distinct anthocyanins, 11 of which were cyanidin-based pigments and three of which were peonidin-based pigments (50). Perfumes and cosmetic products are also manufactured using this plant. *O. basilicum* extracts have potencies to inhibit the HIV-1 reverse transcriptase and platelet aggregation (51). Figure 5 shows phytoconstituents of essential oil of fresh *O. basilicum var. thyrsiflora* obtained by hydro distillation (52). Figure 6 shows their chemical structures.

Chemical constituents, extraction methods, and biological activities of *O. basilicum* are given in Table 2.

Pharmacological activities

In various regions of the world, *O. basilicum* has been extensively studied. It exhibits antifungal, antibacterial, antiviral, antioxidant, anti-inflammatory, anticancer, antiulcer, anti-dyspepsia, antigiardial, wound-healing, and insecticidal properties (Figure 7). It also has antiwormal activities, cardiac stimulant, CNS effects, hypoglycemic and hypolipidemic effects, and platelet aggregation inhibition properties.

Antimicrobial activities

Researchers have reported that *O. basilicum* has significant antibacterial activities. Its essential oils have been shown to have antibacterial activity against a number of gram-positive and gram-negative bacteria, mold, and yeast (104). In a study, different chemical extracts (methanol, ethanol, and hexane) of *O. basilicum* were tested for antibacterial effects *in vitro*. Ethanol extract inhibited the growth of 9 strains of the genera *Bacillus*, *Staphylococcus*, *Escherichia,* and *Acinetobacter* accounting for 6% of the total 146 bacterial strains tested. Hexane and methanol extracts exhibited antibacterial activity against 11% and 13% strains from 6 bacteria families, respectively, *Staphylococcus, Micrococcus, Escherichia, Brucella,*

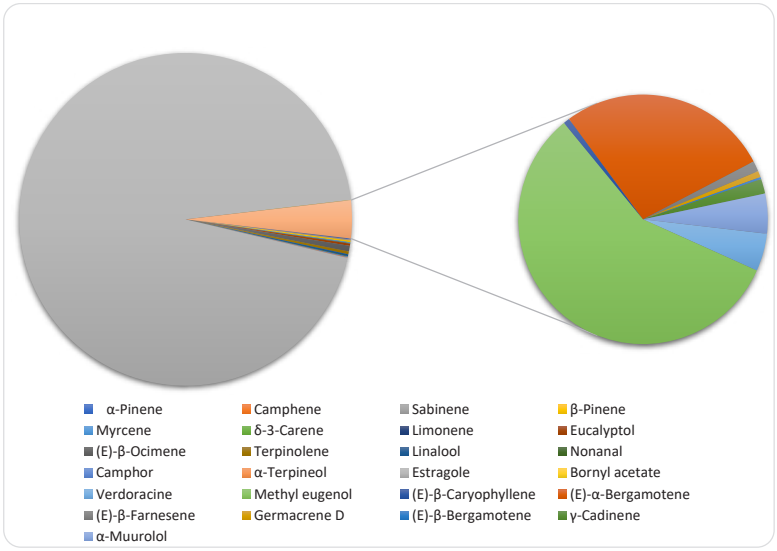

Figure 5. Phytoconstituents of essential oil of fresh *Ocimum basilicum* var. *thyrsiflora* obtained by hydro-distillation.

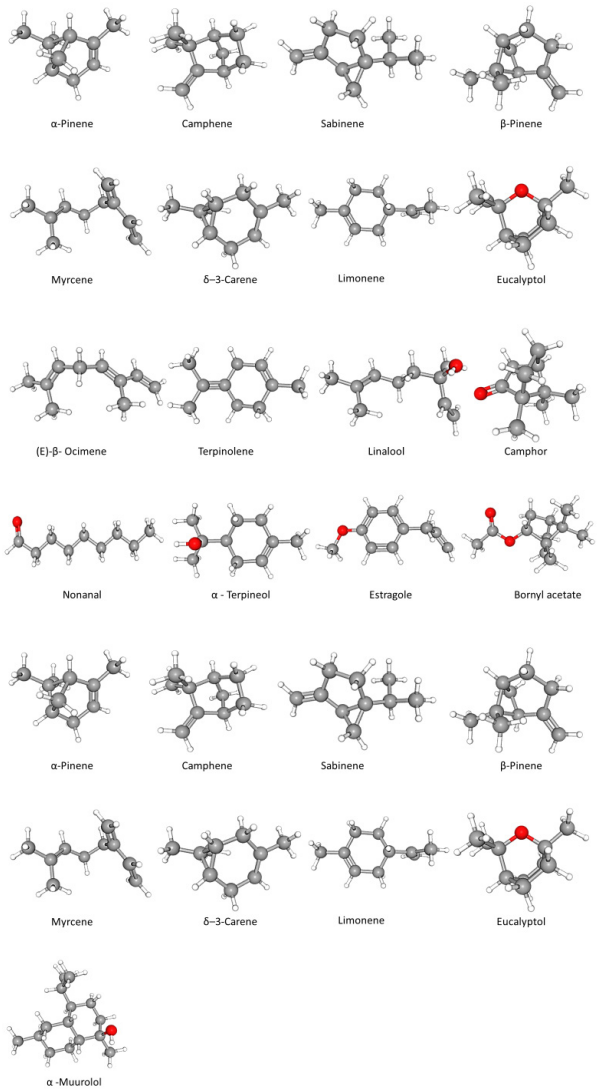

Figure 6. Chemical structures of phytoconstituents identified in *Ocimum basilicum* var. *thyrsiflora* essential oil (53).

*Bacill*us, and *Acinetobacter* accounting for 9% and 10% of the 146 bacterial strains studied. Three *Candida albicans* isolates were also inhibited by the methanol and hexane extracts (105.106).

Budka and Khan (107) discovered that essential oil of *O. basilicum*, *Thymus vulgaris* (thyme), and *Origanum vulgare* (oregano) had bactericidal activity against *Bacillus cereus* in rice-based diets. Only, methanol extracts of *O. basilicum* displayed antibacterial efficacy against *S. aureus*, *Listeria monocytogenes*, *Shigella* sp., *Pseudomonas aeruginosa,* and 2 different strains of *E. coli* reported in a similar study. Peppermint oil and two main ingredients (menthone and menthol), as well as sweet basil oil and its two main constituents (eugenol and linalool) were tested against *Sclerotinia sclerotiorum* (Lib.) and *Rhizopus stolonifer* (Ehrenb. ex Fr.). The essential oil components, specifically linalool, exhibited moderate antifungal activity, whereas eugenol had no effect (108).

In a study, the essential oil from *O. basilicum* was extracted by hydro-distillation process which was then analyzed using GC-MS. Fifteen compounds, representing 74.19% of the total oil, were with considerable antifungal activity against a few pathogenic fungi of plants (109).

Antiproliferative/anticancer activity

The essential oils of 17 Thai medicinal plants were examined for antiproliferative activity in murine leukaemia (P388) cell lines and human mouth epidermal carcinoma (KB). In comparison to the P388 cell line, basil oil showed the strongest antiproliferative action in the KB cell line. According to the findings, Thai medicinal plants could be used to treat cancer (110).

Anti-inflammatory activity

The anti-inflammatory action of *O. basilicum* L. crude methanolic extracts was established by the inhibition

Table 2. Biological activities, chemical constituents, and extraction methods of *Ocimum basilicum*

Chemical compounds	Methods of extraction	Biological activities	References
Menthol	Soxhlet solvent extraction	Local anesthetic	(54,55)
Linalool	Solvent-free microwave extraction, conventional hydro-distillation	Antinociceptive, Antihyperalgesic	(56,57)
Eugenol	Steam distillation	Anti-cancer, neuro-protective, local anesthetic	(58,59)
1,8-cineole	Hydro-distillation	Wound healing activity, Antiulcer	(60,61)
Methyl eugenol	Hydro-distillation	Anesthetic, anticonvulsant	(62,63)
Limonene	Solvent extraction	Anti-inflammatory, motor relaxant	(64,65)
β-Elemene	Glyco- and hydro-distillation	Anticancer, antineoplastic	(66,67)
α-Hergamotene	Cold maceration	Abiotic stress release	(68,69)
Bornyl acetate	Microwave extraction	Anti-inflammatory, analgesic	(70,71)
Camphor	Liquid-liquid extraction	Antipruritic, counterirritant	(72,73)
α-Copaene	Extraction by supercritical fluid	Cytotoxic, antigenotoxic, antioxidant	(74,75)
β-Caryophyllene	Extraction by supercritical fluid	Antibiotic, antioxidant, anti-carcinogenic	(76,77)
Chicoric acid	Extraction by solvent microwave	Immunostimulatory, antioxidant	(78,79)
Farnesene	Distillation by steam	Anti-insecticidal, antioxidant	(80,81)
β-Cadinene	Supercritical fractioned extraction	Antiproliferative, antinociceptive	(82,83)
Menthyl acetate	Solid-phase microextraction	Antibacterial, antioxidant	(84,85)
Germacrene	Solvent extraction	Anti-inflammatory, analgesic	(86-88)
α-Bisabolol	Extraction by supercritical carbon dioxide and in-situ	Anticancer, antibiotic, analgesic	(89-91)
δ-Gurjunene	Supercritical fluid extraction	Anti-inflammatory, antitumor, anti-oedematous	(92,93)
δ-Cadinene	Solid-phase microextraction	Antibacterial, antioxidant	(94,95)
Estragole	Hydro-distillation	Neuronal excitability	(96,97)
Neoisomenthol	Steam distillation	Nasal sensation	(98,99)
Guaiene	Steam distillation	Antidepressant, antiplatelet, antithrombotic	(100,101)
Pulegone	Liquid-liquid extraction	Antinociceptive	(102,103)

of main pro-inflammatory mediators and cytokines. A study found that methanol extract of *O. basilicum* aerial parts had a substantial anti-inflammatory effect against macrophages (RAW264.7), human chondrosarcoma (SW1353), and human primary chondrocytes1 (111).

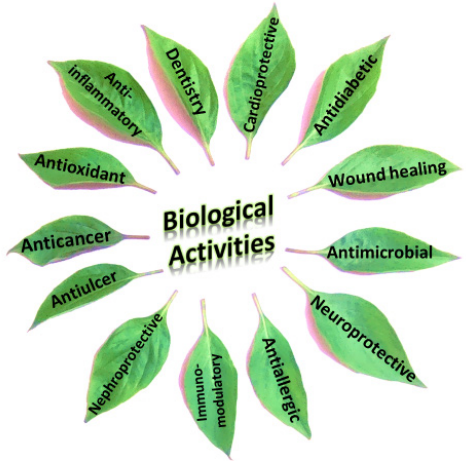

Figure 7. Possible role of *Ocimum basilicum* in different biological activities.

Antioxidant activity

Polyphenols of *O. basilicum* have been well known for their antioxidant properties. In one study, polyphenols isolated from methanol extract of *O. basilicum* were tested for antioxidant properties, and found to have the greatest antioxidant activity along with an outstanding synergistic activity on α-tocopherol (112). According to Kim et al, caffeic acid and rosmarinic acid were the strongest antioxidant components of *O. basilicum* (113).

Antiulcer activity

In a study, it was found that *O. basilicum* seed extracts had a notable antiulcer effect against ethanol-induced ulceration in animal models. In this experiment, rats were pretreated with 10% Tween 20® group-1), *O. basilicum* extract (group 2), and cimetidine (group 3). *O. basilicum* extracts and cimetidine exhibited expressively ($P < 0.05$) high inhibitory effects and reduction of submucosal oedema, gastric injury, and leucocytes infiltration compared to 10% Tween 20® (114).

Antiviral activity

In a study, apigenin, ursolic acid, and linalool were extracted from crude aqueous and ethanolic extracts of *O. basilicum*; they displayed antiviral effect against coxsackievirus B1 and enterovirus 71, among other viruses. Ursolic acid showed the strongest activity against HSV-1 and EV71, while apigenin had the highest activity against hepatitis-B, hepatitis-B antigen, ADV-3, HSV-2, and surface antigens; linalool had the strongest activity against AVD-II (115).

Hypoglycaemic effects

An aqueous extract of *O. basilicum* had a hypoglycemic effect in normal and streptozotocin-induced diabetic rats (116). *O. basilicum* expressively reduced blood glucose level in normal ($P<0.01$) and diabetic rats ($P<0.001$) after a single oral dose treatment. *O. basilicum* caused a significant drop in blood glucose levels ($P<0.001$) in diabetic rats after 15 days of repeated oral administration, but a less significant reduction ($P<0.05$) in normal rats. After 15 days of oral treatment, the main pro-inflammatory cytokines were suppressed, along with plasma insulin levels in both normal and diabetic rat; however, the body weight was constant.

Hypolipidemic effects

Ocimum basilicum contains polar compounds that may help reduce plasma lipid concentrations, which could help to prevent hyperlipidemia and associated cardiovascular disorders. An aqueous extract of basil had hypocholesterolemic and hypotriglyceridemic effects in hyperlipidemic rats administered by a high-fat diet/*O. basilicum* reduced total cholesterol level in plasma and liver ($P<0.02$, $P<0.05$, respectively), along with triglycerides in plasma and liver ($P<0$ .02, $P<0.01$, respectively). A similar finding was reported for plasma LDL-cholesterol concentrations ($P<0.02$). A similar study based on hypolipidemic effects of aqueous extract of *O. basilicum* revealed that the cholesterol ($P<0.001$) and triglyceride ($P<0.05$) levels considerably decreased after regular oral administration in diabetic rats (117).

Inhibitory effect on platelet aggregation

In a study, *O. basilicum* reduced platelet aggregation induced by thrombin and ADP in a dose-dependent manner showing its efficacy as an antithrombotic profile *in vivo* (22). Another study revealed that the aqueous extract of *O. basilicum* was investigated against the antiplatelet activity using thrombin and ADP as agonists. ADP-induced platelet aggregation was reduced by 113%, 28.2%, 30.5%, 44.7%, and 53%, while thrombin-induced platelet activation was abated by 15%, 23%, 40%, 38.4%, and 42% (20).

Wound-healing activity

The wound healing properties of the plant were investigated in rats with cutaneous excision wounds. Wounds were treated with honey along with alcohol leaf extract of *O. basilicum* and solcoseryl-jelly healed faster than wounds treated with honey alone (118).

Toxicity effect

On the toxicity of *Ocimum* species, there is limited information. *Ocimum* species toxicities seem to be very low; however, there are some potentially hazardous compounds like quercetin safrole, tryptophan, rutin, and caffeic acid (119).

Oral efficacy of *Ocimum* species

In dental medicine, herbal medicines have achieved high popularity for curing many oral infections and diseases such as lichen planus, leukoplakia, submucous fibrosis, mouth sores ulcer, dental caries, periodontitis, antibacterial and antifungal infections, etc. Species of *Ocimum* have multifaceted activities due to the presence of compounds like eugenol, linalool, ursolic acid, etc. *O. basilicum* has antibacterial activity against periodontal microbes, for example, *Streptococcus mutans, Aggregatibacter actinomycetemcomitans, and Porphyromonas gingivalis*. Essential oil from *O. basilicum* can kill oral carcinogenic and biofilm-forming microorganisms, such as *Lactobacillus* and *Streptococcus* species (120). *O. basilicum* is also used to relieve dental pain and reduce dental caries. The herbal medicine has antimicrobial properties that reduce periodontitis thereby killing periodontal pathogens. Commercially, these are used to make mouthwash, toothpaste, and a local drug delivery system to treat gingivitis, oral ulcers, and other oral problems (121).

Market available products from *Ocimum* species

Mostly the powder extracts of *O. basilicum* are used as an immunity booster. The different extracts of *O. basilicum* are used as a mouthwash, toothpaste, and gel to prevent microbial infections and inflammation in the gum, thereby maintaining a healthy oral status. Various skin products contain the active ingredients of basil to treat pimples and acne (e.g., facewash, face gel, face serum, oil, etc). Some examples of market available products of *Ocimum sanctum* (Holy basil) are given in Figure 8.

Ethnomedicinal value of *Ocimum basilicum*

Ocimum basilicum was discovered to be an essential medicinal plant used in the traditional healthcare system. Different observations were recorded by studying different plant parts used, modes of administration, different diseases treated, and therapeutic procedures for various diseases. Several diseases have been treated by *O. basilicum*, among which gastrointestinal diseases (22%) accounted for the highest percentage followed by skin infections (17%), respiratory problems (12%), cardiovascular diseases (10%), renal diseases (8%), oral

Figure 8. Market available products from *Ocimum* species.

infections, eye diseases (7%), muscular or skeletal and gynecological diseases (5%), insect bites (3%), and others (1%) (122).

Conclusion

Nowadays healthcare system is receiving more attention through some new innovative approaches in both developed and developing countries. Herbal medications could be a better and more effective alternative in healthcare. This review mainly focused on the distinct pharmacological properties and different chemical compounds present in *O. basilicum*. It has anti-inflammatory, antioxidant, antiulcer, hypoglycemic, hypolipidemic, antimicrobial, anticancer, wound-healing, and other properties. The pharmacological activities are determined by various chemical constituents and the amount present in them. According to various studies, *Ocimum sanctum* (holy basil) leaf extracts, essential oils, and leaf powder could inhibit dental plaques, caries, and periodontitis thereby preserving healthy gum and maintaining a normal healthy oral environment. So, researchers should give more attention to designing some new dental care innovations based on different biological activities and chemical constituents of *O. basilicum*.

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Authors' contribution

SB conceptualized. AS performed the data collection, analysis, validation, and preparation. RB supported the scientific discussions. GN, DK, and AK supported during the validation and preparation of the final manuscript. All authors read, reviewed, and approved the manuscript and edited English language.

Conflict of interests

Authors declare that there is no conflict of interest regarding the publication of this article.

Ethical considerations

Not available.

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References

1. Fair RJ, Tor Y. Antibiotics and bacterial resistance in the 21st century. Perspect Medicin Chem. 2014;6:25-64. doi: 10.4137/pmc.s14459.
2. Harvey A. Strategies for discovering drugs from previously unexplored natural products. Drug Discov Today. 2000;5(7):294-300. doi: 10.1016/s1359-6446(00)01511-7.
3. Harborne AJ. Phytochemical Methods a Guide to Modern Techniques of Plant Analysis. Springer Science & Business Media; 1998. p. 110.
4. Kaurinovic B, Popovic M, Vlaisavljevic S, Trivic S. Antioxidant capacity of *Ocimum basilicum* L. and *Origanum vulgare* L. extracts. Molecules. 2011;16(9):7401-14. doi: 10.3390/molecules16097401.
5. Gülçin I, Topal F, Çakmakçı R, Bilsel M, Gören AC, Erdogan U. Pomological features, nutritional quality, polyphenol content analysis, and antioxidant properties of domesticated and 3 wild ecotype forms of raspberries (*Rubus idaeus* L.). J Food Sci. 2011;76(4):C585-93. doi: 10.1111/j.1750-3841.2011.02142.x.
6. Akbar A, Kuanar A, Sandeep I, Kar B, Singh S, Mohanty S, et al. GC-MS analysis of essential oil of some high drug yielding genotypes of turmeric (*Curcuma longa* L.). Int J Pharm Pharm Sci. 2015;7(9):35-40.
7. Pattnaik PK, Kar D, Kuanar A, Sahu A, Mishra B. Molecular & biochemical characterization of selected elite accessions of ginger. Biocatal Agric Biotechnol. 2016;8:130-8. doi: 10.1016/j.bcab.2016.09.002.
8. Kar D, kuanar A, Panda MK, Pattnaik PK. Analysis of antimicrobial activities of different parts of *Symplocos racemosa*: an endangered medicinal plant of Eastern Ghats of India. Iran J Sci Technol Trans A Sci. 2018;42(3):1077-85. doi: 10.1007/s40995-016-0118-4.
9. Kar DA, Pattnaik PK, Pattnaik BI, Kuanar AN. Antimicrobial analysis of different parts extract in different solvent system of a waste weed-*Calotropis procera*. Asian J Pharm Clin Res. 2018;11(2):227-30.
10. Kar D, Panda MK. In vitro antioxidant potential of methanolic extract of *Symplocos racemosa* Roxb. Asian J Chem. 2017;29(10):2271-4. doi: 10.14233/ajchem.2017.20747.
11. Purushothaman B, Srinivasan RP, Suganthi P, Ranganathan B, Gimbun J, Shanmugam K. A comprehensive review on *Ocimum basilicum*. J Nat Remedies. 2018;18(3):71-85. doi:

10.18311/jnr/2018/21324.
12. Chanwitheesuk A, Teerawutgulrag A, Rakariyatham N. Screening of antioxidant activity and antioxidant compounds of some edible plants of Thailand. Food Chem. 2005;92(3):491-7. doi: 10.1016/j.foodchem.2004.07.035.
13. Bora KS, Arora S, Shri R. Role of *Ocimum basilicum* L. in prevention of ischemia and reperfusion-induced cerebral damage, and motor dysfunctions in mice brain. J Ethnopharmacol. 2011;137(3):1360-5. doi: 10.1016/j.jep.2011.07.066.
14. Sajjadi SE. Analysis of the essential oils of two cultivated basil (*Ocimum basilicum* L.) from Iran. DARU J Pharm Sci. 2006;14(3):128-30.
15. Aguilar NO, Tho PT, Oyen LP. *Ocimum basilicum* L. In: Plant Resources of South-East Asia. Leiden, Netherlands: Backhuys Publishers; 1999. p. 151-6.
16. Lee J, Scagel CF. Chicoric acid levels in commercial basil (*Ocimum basilicum*) and *Echinacea purpurea* products. J Funct Foods. 2010;2(1):77-84. doi: 10.1016/j.jff.2009.11.004.
17. Grayer RJ, Bryan SE, Veitch NC, Goldstone FJ, Paton A, Wollenweber E. External flavones in sweet basil, *Ocimum basilicum*, and related taxa. Phytochemistry. 1996;43(5):1041-7. doi: 10.1016/s0031-9422(96)00430-x.
18. Aly Taie HA, Abd-El Rahman Salama Z, Radwan S. Potential activity of basil plants as a source of antioxidants and anticancer agents as affected by organic and bio-organic fertilization. Not Bot Horti Agrobot Cluj Napoca. 2010;38(1):119-27. doi: 10.15835/nbha3813534.
19. Chiang LC, Ng LT, Cheng PW, Chiang W, Lin CC. Antiviral activities of extracts and selected pure constituents of *Ocimum basilicum*. Clin Exp Pharmacol Physiol. 2005;32(10):811-6. doi: 10.1111/j.1440-1681.2005.04270.x.
20. Amrani S, Harnafi H, Gadi D, Mekhfi H, Legssyer A, Aziz M, et al. Vasorelaxant and anti-platelet aggregation effects of aqueous *Ocimum basilicum* extract. J Ethnopharmacol. 2009;125(1):157-62. doi: 10.1016/j.jep.2009.05.043.
21. Berić T, Nikolić B, Stanojević J, Vuković-Gacić B, Knezević-Vukcević J. Protective effect of basil (*Ocimum basilicum* L.) against oxidative DNA damage and mutagenesis. Food Chem Toxicol. 2008;46(2):724-32. doi: 10.1016/j.fct.2007.09.102.
22. Tohti I, Tursun M, Umar A, Turdi S, Imin H, Moore N. Aqueous extracts of *Ocimum basilicum* L. (sweet basil) decrease platelet aggregation induced by ADP and thrombin in vitro and rats arterio--venous shunt thrombosis in vivo. Thromb Res. 2006;118(6):733-9. doi: 10.1016/j.thromres.2005.12.011.
23. Harnafi H, Serghini Caid H, el Houda Bouanani N, Aziz M, Amrani S. Hypolipemic activity of polyphenol-rich extracts from *Ocimum basilicum* in Triton WR-1339-induced hyperlipidemic mice. Food Chem. 2008;108(1):205-12. doi: 10.1016/j.foodchem.2007.10.062.
24. Asimi OA, Sahu NP, Pal AK. Antioxidant capacity of crude water and ethyl acetate extracts of some Indian spices and their antimicrobial activity against *Vibrio vulnificus* and *Micrococcus luteus*. J Med Plant Res. 2013;7(26):1907-15.
25. Nguefack J, Budde BB, Jakobsen M. Five essential oils from aromatic plants of Cameroon: their antibacterial activity and ability to permeabilize the cytoplasmic membrane of *Listeria innocua* examined by flow cytometry. Lett Appl Microbiol. 2004;39(5):395-400. doi: 10.1111/j.1472-765X.2004.01587.x.
26. Maisuthisakul P, Pasuk S, Ritthiruangdej P. Relationship between antioxidant properties and chemical composition of some Thai plants. J Food Compost Anal. 2008;21(3):229-40. doi: 10.1016/j.jfca.2007.11.005.
27. Natural Resources Conservation Service. United States Department of Agriculture. https://plants.usda.gov/home.
28. Chang SS, Ostric-Matijasevic B, Hsieh OA, Huang CL. Natural antioxidants from rosemary and sage. J Food Sci. 1977;42(4):1102-6. doi: 10.1111/j.1365-2621.1977.tb12676.x.
29. Lachowicz KJ, Jones GP, Briggs DR, Bienvenu FE, Palmer MV, Mishra V, et al. Characteristics of plants and plant extracts from five varieties of basil (*Ocimum basilicum* L.) grown in Australia. J Agric Food Chem. 1997;45(7):2660-5. doi: 10.1021/jf960791h.
30. Khazaei N, Esmaiili M, Emam Djomeh Z, Ghasemlou M, Jouki M. Characterization of new biodegradable edible film made from basil seed (*Ocimum basilicum* L.) gum. Carbohydr Polym. 2014;102:199-206. doi: 10.1016/j.carbpol.2013.10.062.
31. Marotti M, Piccaglia R, Giovanelli E. Differences in essential oil composition of basil (*Ocimum basilicum* L.) Italian cultivars related to morphological characteristics. J Agric Food Chem. 1996;44(12):3926-9. doi: 10.1021/jf9601067.
32. Zheljazkov VD, Cantrell CL, Tekwani B, Khan SI. Content, composition, and bioactivity of the essential oils of three basil genotypes as a function of harvesting. J Agric Food Chem. 2008;56(2):380-5. doi: 10.1021/jf0725629.
33. Bravo E, Amrani S, Aziz M, Harnafi H, Napolitano M. *Ocimum basilicum* ethanolic extract decreases cholesterol synthesis and lipid accumulation in human macrophages. Fitoterapia. 2008;79(7-8):515-23. doi: 10.1016/j.fitote.2008.05.002.
34. Liber Z, Carović-Stanko K, Politeo O, Strikić F, Kolak I, Milos M, et al. Chemical characterization and genetic relationships among *Ocimum basilicum* L. cultivars. Chem Biodivers. 2011;8(11):1978-89. doi: 10.1002/cbdv.201100039.
35. Thai basil. Available from https://en.wikipedia.org/wiki/Thai_basil.
36. *Ocimum basilicum* L. -- Species. Available from https://indiabiodiversity.org/species/show/230483.
37. Beatović D, Krstić-Milošević D, Trifunović S, Šiljegović J, Glamočlija J, Ristić M, et al. Chemical composition, antioxidant and antimicrobial activities of the essential oils of twelve *Ocimum basilicum* L. cultivars grown in Serbia. Rec Nat Prod. 2015;9(1):62-75.
38. Jelačić SĆ, Beatović DV, Prodanović SA, Tasić SR, Moravčević ĐŽ, Vujošević AM, et al. Chemical composition of the essential oil of basil (*Ocimum basilicum* L. Lamiaceae). Hem Ind. 2011;65(4):465-71.
39. da Silva Gündel S, Velho MC, Diefenthaler MK, Favarin FR, Copetti PM, de Oliveira Fogaça A, et al. Basil oil-nanoemulsions: development, cytotoxicity and evaluation of antioxidant and antimicrobial potential. J Drug Deliv Sci Technol. 2018;46:378-83. doi: 10.1016/j.jddst.2018.05.038.
40. Akbari GA, Soltani E, Binesh S, Amini F. Cold tolerance, productivity and phytochemical diversity in sweet basil (*Ocimum basilicum* L.) accessions. Ind Crops Prod. 2018;124:677-84. doi: 10.1016/j.indcrop.2018.08.048.

41. Hajmohammadi A, Pirouzifard M, Shahedi M, Alizadeh M. Enrichment of a fruit-based beverage in dietary fiber using basil seed: effect of carboxymethyl cellulose and gum tragacanth on stability. LWT. 2016;74:84-91. doi: 10.1016/j.lwt.2016.07.033.
42. Labra M, Miele M, Ledda B, Grassi F, Mazzei M, Sala F. Morphological characterization, essential oil composition and DNA genotyping of *Ocimum basilicum* L. cultivars. Plant Sci. 2004;167(4):725-31. doi: 10.1016/j.plantsci.2004.04.026.
43. Kaefer CM, Milner JA. The role of herbs and spices in cancer prevention. J Nutr Biochem. 2008;19(6):347-61. doi: 10.1016/j.jnutbio.2007.11.003.
44. Zhan Y, An X, Wang S, Sun M, Zhou H. Basil polysaccharides: a review on extraction, bioactivities and pharmacological applications. Bioorg Med Chem. 2020;28(1):115179. doi: 10.1016/j.bmc.2019.115179.
45. Li CL, Wang W, Zhang Y, Li JA, Lao FY. Research progress on extraction, separation and purification of polysaccharides from traditional Chinese medicine. China Pharm. 2016;27(19):2700-3.
46. Filip S. Basil (*Ocimum basilicum* L.) a source of valuable phytonutrients. Int J Clin Nutr Diet. 2017;3:118. doi: 10.15344/2456-8171/2017/118.
47. Basil Herb Nutrition Facts, USDA National Nutrient Data Base. Available from: http://www.nutrition-and-you.com/basil-herb.html. Accessed October 20, 2010.
48. Radulović NS, Blagojević PD, Miltojević AB. α-Linalool - a marker compound of forged/synthetic sweet basil (*Ocimum basilicum* L.) essential oils. J Sci Food Agric. 2013;93(13):3292-303. doi: 10.1002/jsfa.6175.
49. Lee J, Scagel CF. Chicoric acid found in basil (*Ocimum basilicum* L.) leaves. Food Chem. 2009;115(2):650-6. doi: 10.1016/j.foodchem.2008.12.075.
50. Phippen WB, Simon JE. Anthocyanins in basil (*Ocimum basilicum* L.). J Agric Food Chem. 1998;46(5):1734-8. doi: 10.1021/jf970887r.
51. Yamasaki K, Nakano M, Kawahata T, Mori H, Otake T, Ueba N, et al. Anti-HIV-1 activity of herbs in Labiatae. Biol Pharm Bull. 1998;21(8):829-33. doi: 10.1248/bpb.21.829.
52. Łyczko J, Masztalerz K, Lipan L, Lech K, Carbonell-Barrachina ÁA, Szumny A. Chemical determinants of dried Thai basil (*O. basilicum* var. *thyrsiflora*) aroma quality. Ind Crops Prod. 2020;155:112769. doi: 10.1016/j.indcrop.2020.112769.
53. PubChem website. Available from: https://pubchem.ncbi.nlm.nih.gov/.
54. Alvi MN, Ahmad S, Rehman K. Preparation of menthol crystals from mint (*Mentha arvensis*). Int J Agric Biol. 2001;3(4):527-8.
55. Galeotti N, Ghelardini C, Mannelli L, Mazzanti G, Baghiroli L, Bartolini A. Local anaesthetic activity of (+)- and (-)-menthol. Planta Med. 2001;67(2):174-6. doi: 10.1055/s-2001-11515.
56. Galhiane MS, Rissato SR, Chierice GO, Almeida MV, Silva LC. Influence of different extraction methods on the yield and linalool content of the extracts of *Eugenia uniflora* L. Talanta. 2006;70(2):286-92. doi: 10.1016/j.talanta.2006.02.040.
57. Kim KY, Lee HS, Min SS, Seol GH. Neuroprotective effect of (-)-linalool against sodium nitroprusside-induced cytotoxicity. Med Chem. 2015;5:178-82.
58. Khalil AA, ur Rahman U, Khan MR, Sahar A, Mehmood T, Khan M. Essential oil eugenol: sources, extraction techniques and nutraceutical perspectives. RSC Adv. 2017;7(52):32669-81. doi: 10.1039/c7ra04803c.
59. Pramod K, Ansari SH, Ali J. Eugenol: a natural compound with versatile pharmacological actions. Nat Prod Commun. 2010;5(12):1999-2006.
60. Wu H, Hendrawinata W, Yu Y, Gao X, Li Y, Bartle J, et al. Effect of hydrodistillation on 1,8-cineole extraction from mallee leaf and the fuel properties of spent biomass. Ind Eng Chem Res. 2011;50(19):11280-7. doi: 10.1021/ie201092h.
61. Rocha Caldas GF, Oliveira AR, Araújo AV, Lafayette SS, Albuquerque GS, Silva-Neto Jda C, et al. Gastroprotective mechanisms of the monoterpene 1,8-cineole (eucalyptol). PLoS One. 2015;10(8):e0134558. doi: 10.1371/journal.pone.0134558.
62. Pino Benitez N, Meléndez León EM, Stashenko EE. Eugenol and methyl eugenol chemotypes of essential oil of species *Ocimum gratissimum* L. and *Ocimum campechianum* Mill. from Colombia. J Chromatogr Sci. 2009;47(9):800-3. doi: 10.1093/chromsci/47.9.800.
63. Ding J, Huang C, Peng Z, Xie Y, Deng S, Nie YZ, et al. Electrophysiological characterization of methyleugenol: a novel agonist of GABA(A) receptors. ACS Chem Neurosci. 2014;5(9):803-11. doi: 10.1021/cn500022e.
64. Lopresto CG, Petrillo F, Casazza AA, Aliakbarian B, Perego P, Calabrò V. A non-conventional method to extract D-limonene from waste lemon peels and comparison with traditional Soxhlet extraction. Sep Purif Technol. 2014;137:13-20. doi: 10.1016/j.seppur.2014.09.015.
65. do Vale TG, Furtado EC, Santos JG Jr, Viana GSB. Central effects of citral, myrcene and limonene, constituents of essential oil chemotypes from *Lippia alba* (Mill.) N.E. Brown. Phytomedicine. 2002;9(8):709-14. doi: 10.1078/094471102321621304.
66. Sieniawska E, Sawicki R, Golus J, Swatko-Ossor M, Ginalska G, Skalicka-Wozniak K. *Nigella damascena* L. essential oil—a valuable source of β-elemene for antimicrobial testing. Molecules. 2018;23(2):256.
67. Li QQ, Wang G, Huang F, Banda M, Reed E. Antineoplastic effect of beta-elemene on prostate cancer cells and other types of solid tumour cells. J Pharm Pharmacol. 2010;62(8):1018-27.doi:10.1111/j.2042-7158.2010.01135.x.
68. Jadhav NM, Thergaonkar RS, Deodhar MA. Extraction of essential oil from flowers of *Mesua ferrea* Linn. GC-MS analysis and incorporation in cosmetic product. Int J Pharm Sci Res. 2016;7(12):5106-10. doi: 10.13040/ijpsr.0975-8232.7(12).5106-10.
69. Palmer-Young EC, Veit D, Gershenzon J, Schuman MC. The sesquiterpenes(E)-ß-farnesene and (E)-α-bergamotene quench ozone but fail to protect the wild tobacco *Nicotiana attenuata* from ozone, UVB, and drought stresses. PLoS One. 2015;10(6):e0127296. doi: 10.1371/journal.pone.0127296.
70. Fan S, Chang J, Zong Y, Hu G, Jia J. GC-MS analysis of the composition of the essential oil from *Dendranthema indicum* var. *aromaticum* using three extraction methods and two columns. Molecules. 2018;23(3):576. doi: 10.3390/molecules23030576.
71. Wu X, Xiao F, Zhang Z, Li X, Xu Z. [Research on the analgesic

effect and mechanism of bornyl acetate in volatile oil from *Amomum villosum*]. Zhong Yao Cai. 2005;28(6):505-7. [Chinese].
72. Nozal MJ, Bernal JL, Jiménez JJ, González MJ, Higes M. Extraction of thymol, eucalyptol, menthol, and camphor residues from honey and beeswax. Determination by gas chromatography with flame ionization detection. J Chromatogr A. 2002;954(1-2):207-15. doi: 10.1016/s0021-9673(02)00153-x.
73. Zuccarini P. Camphor: risks and benefits of a widely used natural product. J Appl Sci Environ Manag. 2009;13(2):69-74. doi: 10.4314/jasem.v13i2.55317.
74. Tam CU, Yang FQ, Zhang QW, Guan J, Li SP. Optimization and comparison of three methods for extraction of volatile compounds from *Cyperus rotundus* evaluated by gas chromatography-mass spectrometry. J Pharm Biomed Anal. 2007;44(2):444-9. doi: 10.1016/j.jpba.2006.10.026.
75. Türkez H, Celik K, Toğar B. Effects of copaene, a tricyclic sesquiterpene, on human lymphocytes cells in vitro. Cytotechnology. 2014;66(4):597-603. doi: 10.1007/s10616-013-9611-1.
76. Quispe-Condori S, Foglio MA, Rosa PT, Meireles MA. Obtaining β-caryophyllene from *Cordia verbenacea* de Candolle by supercritical fluid extraction. J Supercrit Fluids. 2008;46(1):27-32. doi: 10.1016/j.supflu.2008.02.015.
77. Legault J, Pichette A. Potentiating effect of beta-caryophyllene on anticancer activity of alpha-humulene, isocaryophyllene and paclitaxel. J Pharm Pharmacol. 2007;59(12):1643-7. doi: 10.1211/jpp.59.12.0005.
78. Lekar AV, Borisenko SN, Filonova OV, Vetrova EV, Maksimenko EV, Borisenko NI, et al. Extraction of caftaric and cichoric acids from *Echinacea purpurea* L. in subcritical water. Russ J Phys Chem B. 2013;7(8):968-75. doi: 10.1134/s199079311308006x.
79. Kuban-Jankowska A, Sahu KK, Gorska M, Tuszynski JA, Wozniak M. Chicoric acid binds to two sites and decreases the activity of the YopH bacterial virulence factor. Oncotarget. 2016;7(3):2229-38. doi: 10.18632/oncotarget.6812.
80. Green CP, Osborne P. Rapid methods for obtaining essential oil from hops. J Inst Brew. 1993;99(4):335-9. doi: 10.1002/j.2050-0416.1993.tb01172.x.
81. Sun Y, Qiao H, Ling Y, Yang S, Rui C, Pelosi P, et al. New analogues of (E)-β-farnesene with insecticidal activity and binding affinity to aphid odorant-binding proteins. J Agric Food Chem. 2011;59(6):2456-61. doi: 10.1021/jf104712c.
82. Marzouki H, Piras A, Marongiu B, Rosa A, Dessì MA. Extraction and separation of volatile and fixed oils from berries of *Laurus nobilis* L. by supercritical CO2. Molecules. 2008;13(8):1702-11. doi: 10.3390/molecules13081702.
83. Cascaes MM, Guilhon GM, de Aguiar Andrade EH, das Graças Bichara Zoghbi M, da Silva Santos L. Constituents and pharmacological activities of *Myrcia* (Myrtaceae): a review of an aromatic and medicinal group of plants. Int J Mol Sci. 2015;16(10):23881-904. doi: 10.3390/ijms161023881.
84. Rohloff J. Monoterpene composition of essential oil from peppermint (*Mentha* x *piperita* L.) with regard to leaf position using solid-phase microextraction and gas chromatography/mass spectrometry analysis. J Agric Food Chem. 1999;47(9):3782-6. doi: 10.1021/jf981310s.
85. Singh R, Shushni MAM, Belkheir A. Antibacterial and antioxidant activities of *Mentha piperita* L. Arab J Chem. 2015;8(3):322-8. doi: 10.1016/j.arabjc.2011.01.019.
86. Noge K, Becerra JX. Germacrene D, a common sesquiterpene in the genus *Bursera* (Burseraceae). Molecules. 2009;14(12):5289-97. doi: 10.3390/molecules14125289.
87. Del-Vechio-Vieira G, de Sousa OV, Miranda MA, Senna-Valle L, Kaplan MA. Analgesic and anti-inflammatory properties of essential oil from *Ageratum fastigiatum*. Braz Arch Biol Technol. 2009;52(5):1115-21. doi: 10.1590/s1516-89132009000500008.
88. Silvério MS, Del-Vechio-Vieira G, Pinto MA, Alves MS, de Sousa OV. Chemical composition and biological activities of essential oils of *Eremanthus erythropappus* (DC) McLeisch (Asteraceae). Molecules. 2013;18(8):9785-96. doi: 10.3390/molecules18089785.
89. Han GH, Kim SK, Yoon PK, Kang Y, Kim BS, Fu Y, et al. Fermentative production and direct extraction of (-)-α-bisabolol in metabolically engineered *Escherichia coli*. Microb Cell Fact. 2016;15(1):185. doi: 10.1186/s12934-016-0588-2.
90. Queiroz A, Cajaiba J. A sustainable process for (−)-α-bisabolol extraction from *Eremanthus erythropappus* using supercritical CO2 and ethanol as co-solvent. J Supercrit Fluids. 2016;110:39-46. doi: 10.1016/j.supflu.2015.12.011.
91. Kamatou GP, Viljoen AM. A review of the application and pharmacological properties of α-bisabolol and α-bisabolol-rich oils. J Am Oil Chem Soc. 2010;87(1):1-7. doi: 10.1007/s11746-009-1483-3.
92. Naseem MK, Younis A, Khan MA, Ahmad R. Gas chromatography-mass spectrometry of *Murraya exotica* essential oil extracted through different extraction techniques. J Anim Plant Sci. 2015;15(6):1730-6.
93. Muley BP, Khadabadi SS, Banarase NB. Phytochemical constituents and pharmacological activities of *Calendula officinalis* Linn (Asteraceae): a review. Trop J Pharm Res. 2009;8(5):455-65. doi: 10.4314/tjpr.v8i5.48090.
94. Nekoei M, Mohammadhosseini M. Chemical composition of the essential oils and volatiles of *Salvia leriifolia* by three different extraction methods prior to gas chromatographic-mass spectrometric determination: comparison of HD with SFME and HS-SPME. J Essent Oil Bear Plants. 2017;20(2):410-25. doi: 10.1080/0972060x.2017.1305918.
95. Scur MC, Pinto FG, Pandini JA, Costa WF, Leite CW, Temponi LG. Antimicrobial and antioxidant activity of essential oil and different plant extracts of *Psidium cattleianum* Sabine. Braz J Biol. 2016;76(1):101-8. doi: 10.1590/1519-6984.13714.
96. Andrade TC, De Lima SG, Freitas RM, Rocha MS, Islam T, Da Silva TG, et al. Isolation, characterization and evaluation of antimicrobial and cytotoxic activity of estragole, obtained from the essential oil of *Croton zehntneri* (Euphorbiaceae). An Acad Bras Cienc. 2015;87(1):173-82. doi: 10.1590/0001-3765201520140111.
97. Silva-Alves KS, Ferreira-da-Silva FW, Peixoto-Neves D, Viana-Cardoso KV, Moreira-Júnior L, Oquendo MB, et al. Estragole blocks neuronal excitability by direct inhibition of Na+ channels. Braz J Med Biol Res. 2013;46(12):1056-63. doi: 10.1590/1414-431x20133191.
98. Manuale DL, Betti C, Marchi AJ, Yori JC, Romeo

E. Synthesis of liquid menthol by hydrogenation of dementholized peppermint oil over Ni catalysts. Quim Nova. 2010;33(6):1231-4. doi: 10.1590/s0100-40422010000600002.
99. Eccles R, Griffiths DH, Newton CG, Tolley NS. The effects of menthol isomers on nasal sensation of airflow. Clin Otolaryngol Allied Sci. 1988;13(1):25-9. doi: 10.1111/j.1365-2273.1988.tb00277.x.
100. Gakuubi MM. Steam distillation extraction and chemical composition of essential oils of *Toddalia asiatica* L. and *Eucalyptus camaldulensis* Dehnh. J Pharmacogn Phytochem. 2016;5(2):99-104.
101. Swamy MK, Sinniah UR. A comprehensive review on the phytochemical constituents and pharmacological activities of *Pogostemon cablin* Benth.: an aromatic medicinal plant of industrial importance. Molecules. 2015;20(5):8521-47. doi: 10.3390/molecules20058521.
102. Alshishani AA, Saad B, Semail NF, Mohamad Salhimi S, Talib MK. Salting-out assisted liquid-liquid extraction method coupled to gas chromatography for the simultaneous determination of thujones and pulegone in beverages. Int J Food Prop. 2017;20(Suppl 3):S2776-S85. doi: 10.1080/10942912.2017.1373665.
103. de Sousa DP, Nóbrega FF, de Lima MR, de Almeida RN. Pharmacological activity of (R)-(+)-pulegone, a chemical constituent of essential oils. Z Naturforsch C J Biosci. 2011;66(7-8):353-9. doi: 10.1515/znc-2011-7-806.
104. Suppakul P, Miltz J, Sonneveld K, Bigger SW. Antimicrobial properties of basil and its possible application in food packaging. J Agric Food Chem. 2003;51(11):3197-207. doi: 10.1021/jf021038t.
105. Adigüzel A, Güllüce M, Şengül M, Öğütcü H, Şahin F, Karaman İ. Antimicrobial effects of *Ocimum basilicum* (Labiatae) extract. Turk J Biol. 2005;29(3):155-60.
106. Bunrathep S, Palanuvej C, Ruangrungsi N. Chemical compositions and antioxidative activities of essential oils from four *Ocimum* species endemic to Thailand. J Health Res. 2007;21(3):201-6.
107. Budka D, Khan NA. The effect of *Ocimum basilicum*, *Thymus vulgaris*, *Origanum vulgare* essential oils on *Bacillus cereus* in rice-based foods. EJBS. 2010;2(1):17-20.
108. Edris AE, Farrag ES. Antifungal activity of peppermint and sweet basil essential oils and their major aroma constituents on some plant pathogenic fungi from the vapor phase. Nahrung. 2003;47(2):117-21. doi: 10.1002/food.200390021.
109. Zhang JW, Li SK, Wu WJ. The main chemical composition and in vitro antifungal activity of the essential oils of *Ocimum basilicum* Linn. var. *pilosum* (Willd.) Benth. Molecules. 2009;14(1):273-8. doi: 10.3390/molecules14010273.
110. Manosroi J, Dhumtanom P, Manosroi A. Anti-proliferative activity of essential oil extracted from Thai medicinal plants on KB and P388 cell lines. Cancer Lett. 2006;235(1):114-20. doi: 10.1016/j.canlet.2005.04.021.
111. Raina P, Deepak M, Chandrasekaran CV, Agarwal A, Wagh N, Kaul-Ghanekar R. Comparative analysis of anti-inflammatory activity of aqueous and methanolic extracts of *Ocimum basilicum* (basil) in RAW264.7, SW1353 and human primary chondrocytes in respect of the management of osteoarthritis. J Herb Med. 2016;6(1):28-36. doi: 10.1016/j.hermed.2016.01.002.
112. Jayasinghe C, Gotoh N, Aoki T, Wada S. Phenolics composition and antioxidant activity of sweet basil (*Ocimum basilicum* L.). J Agric Food Chem. 2003;51(15):4442-9. doi: 10.1021/jf034269o.
113. Kim HJ, Chen F, Wang X, Rajapakse NC. Effect of methyl jasmonate on secondary metabolites of sweet basil (*Ocimum basilicum* L.). J Agric Food Chem. 2006;54(6):2327-32. doi: 10.1021/jf051979g.
114. Abdulla MA, Ahmed KA, Al-Bayaty FH, Masood Y. Gastroprotective effect of *Phyllanthus niruri* leaf extract against ethanol-induced gastric mucosal injury in rats. Afr J Pharm Pharmacol. 2010;4(5):226-30.
115. Chiang LC, Ng LT, Cheng PW, Chiang W, Lin CC. Antiviral activities of extracts and selected pure constituents of *Ocimum basilicum*. Clin Exp Pharmacol Physiol. 2005;32(10):811-6. doi: 10.1111/j.1440-1681.2005.04270.x.
116. Zeggwagh NA, Sulpice T, Eddouks M. Anti-hyperglycaemic and hypolipidemic effects of *Ocimum basilicum* aqueous extract in diabetic rats. Am J Pharmacol Toxicol. 2007;2(3):123-9. doi: 10.3844/ajptsp.2007.123.129.
117. Harnafi H, Aziz M, Amrani S. Sweet basil (*Ocimum basilicum* L.) improves lipid metabolism in hypercholesterolemic rats. E Spen Eur E J Clin Nutr Metab. 2009;4(4):e181-e6. doi: 10.1016/j.eclnm.2009.05.011.
118. Salmah I, Mahmood AA, Sidik K. Synergistic effects of alcoholic extract of sweet basil (*Ocimum basilicum* L.) leaves and honey on cutaneous wound healing in rats. Int J Mol Med Adv Sci. 2005;1(3):220-4.
119. Anonymous, Medicinal Plants for Livestock, *Ocimum basilicum*, *O. americanum* and *O. micranthum*. Cornell University Animal Science, 2010. http://www.ansci.cornell.edu/plants/medicinal/basil.html.
120. Fernandes T, D'souza A, Sawarkar SP. *Ocimum sanctum* L: promising agent for oral health care management. In: Natural Oral Care in Dental Therapy. Wiley; 2020. p. 259-69.
121. Patil A, Gunjal S, Latif AA. Tulsi: a medicinal herb for oral health. Galore Int J Health Sci Res. 2018;3(4):37-9.
122. Bhat GM, Majeed H, Islam MA, Rather TA, Bakshi M, Shahkhan FA, et al. Indigenous medicinal practices of *Ocimum basilicum* L. in rural Kashmir. J Pharmacogn Phytochem. 2020;9(5):1876-81.