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Research Article

A COMPREHENSIVE REVIEW OF PHYTOCHEMISTRY AND PHARMACOLOGICAL ACTIVITIES OF *OCIMUM SANCTUM LINN.'S* ANTIBACTERIAL, ANTIMICROBIAL, AND THERAPEUTIC POTENTIALS

[1]V. Madan Mohan Rao, [2]Y. Shanti Prabha, [3]Phool Gend Kumar, [4]Sanjay Dey, [5]P. Balaraju and [6*]D. Veera Nagendra Kumar

[1]Department of Botany, Government Degree College, Chintalapudi, Andhra Pradesh-534460
[2]Department of Zoology, Dr. VSK Government Degree College (Autonomous), Visakhapatnam, Andhra Pradesh-530003
[3] Department of Zoology, Brahmanand PG College, Kanpur Nagar Uttar Pradesh- 208001
[4] Department of Zoology, Ananda Mohan College, Kolkata, West Bengal- 700009
[5] Department of Botany, Government Degree College, Husnabad, Telangana- 505467
[6*]Department of Zoology, Government College for Men (Autonomous), Kadapa, Andhra Pradesh-516004

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ABSTRACT

Incorporating Ayurvedic principles into your daily routine, including consuming adaptogenic herbs, has the potential to effectively address many chronic diseases that are major contributors to global mortality. Tulsi, also known as Holy Basil or *Ocimum sanctum* Linn., holds a revered status in ancient healing systems like Ayurveda for its medicinal properties. With a wide range of pharmacological benefits, including antimicrobial and antibacterial effects, this review delves into the phytochemical makeup and therapeutic potential of *O. sanctum*. By meticulously searching scientific databases such as PubMed, Scopus, Web of Science, and Google Scholar both in vitro and in vivo experiments were analyzed alongside existing reviews. Key bioactive compounds such as eugenol, ursolic acid, rosmarinic acid, carvacrol, and linalool present in the plant contribute to its antibacterial properties against pathogens like Pseudomonas aeruginosa, *Klebsiella pneumoniae, Escherichia coli,* and *Staphylococcus aureus*. Additionally, *O. sanctum* exhibits hepatoprotective, immunomodulatory, wound-healing, anti-inflammatory, and antioxidant properties. The plant's therapeutic and antibacterial attributes support its integration into modern plant-based treatments while honoring its historical medicinal use. This study shows that *O. sanctum* L. has therapeutic benefits based on the pharmacological research included.

Keywords: *Ocimum sanctum*, Phytochemistry, Therapeutic potential, Antioxidant, Antibacterial, Medicinal plants.

INTRODUCTION

For centuries, various plant parts like roots, stems, leaves, flowers, seeds, and barks have been utilized as natural remedies for treating various illnesses. Plants remain a valuable source of medicinal compounds, particularly in developing nations, where they are plentiful, cost-effective, and free from adverse effects. *Ocimum sanctum* Linn., commonly known as Holy Basil or Tulsi, is widely cherished in India and Southeast Asia. This plant holds significant importance in ancient healing traditions like Ayurveda, Siddha, and Unani due to its spiritual significance and extensive medicinal properties, as noted in studies by Pattanayak *et al*. (2010) and Mondal *et al*. (2009).

Ocimum sanctum, belonging to the Lamiaceae family, is an herbaceous plant recognized for its fragrant leaves containing essential oils and various phytochemicals. It has a long history of medicinal use in treating respiratory ailments, skin infections, digestive disorders, and mental health conditions. Recent studies have confirmed its potent antimicrobial and antibacterial qualities, reinforcing its traditional therapeutic reputation (Jamshidi & Cohen, 2017;

*Corresponding Author: Dr. D. Veera Nagendra Kumar, Department of Zoology, Government College for Men (Autonomous), Kadapa, Andhra Pradesh, Email: veeranagendrakumar@gmail.com.

Prakash & Gupta, 2005). The plant's diverse phytochemical composition, which includes flavonoids like orientin and vicenin, terpenoids, phenolic acids such as rosmarinic acid and caffeic acid, tannins, alkaloids, and essential oils like eugenol, linalool, and methyl eugenol, contributes to its wide range of medicinal properties. Studies have shown that these bioactive compounds (Geeta *et al*., 2001; Shinde *et al*., 2012) possess strong antibacterial effects against both Gram-positive and Gram-negative pathogenic bacteria (Kelm *et al*., 2000; Singh *et al*., 2011). Additionally, *O. sanctum* demonstrates anti-inflammatory, antioxidant, immunomodulatory, hepatoprotective, antidiabetic, adaptogenic, and wound-healing properties, further emphasizing its therapeutic potential in treating various infectious and chronic conditions (Manikandan *et al*., 2007; Siva *et al*., 2008). These qualities underscore the plant's importance as a versatile therapeutic agent with multiple targets. This review aims to provide a thorough examination of *O. sanctum*'s phytochemical and pharmacological landscape, with a focus on the plant's antibacterial and antimicrobial properties. In order to demonstrate the importance of *O. sanctum* in contemporary drug development and to outline future directions for phytopharmaceutical research, we seek to connect traditional knowledge systems with contemporary biomedical research through the synthesis of in vitro, in vivo, and clinical findings.

Methodology

This brief review was conducted by searching through various databases, such as PubMed, GBIF, and Google Scholar. The review aimed to include relevant studies related to Pharmacological Activities of *Ocimum sanctum Linn.'s* Antibacterial, Antimicrobial, and Therapeutic Potentials. It is important to consider more recent research for a comprehensive understanding of this topic.

Phytochemistry of *Ocimum sanctum* Linn.

Tulsi, also known as Holy Basil or *Ocimum sanctum* Linn., is packed with a variety of phytochemicals that contribute to its diverse pharmacological benefits. Through the combined action of terpenoids, alkaloids, flavonoids, phenolic acids, and essential oils, Tulsi offers a range of potent biological effects that are key to its healing properties.

Traditional Uses

Tulsi, also known as "the elixir of life," is revered in Ayurveda and Siddha systems of medicine for its myriad health benefits. Its various parts are utilized to treat a range of ailments such as colds, headaches, coughs, and fever. Tulsi is also used as a remedy for conditions like bronchitis, asthma, skin diseases, and digestive disorders. In addition, chewing tulsi leaves can help alleviate ulcers and mouth infections (Prajapati *et al*., 2003), while adding a few leaves to water or food can purify and eliminate germs. This sacred herb is known for its ability to enhance immunity and protect against various infections, including viruses, bacteria, fungi, and protozoa. Furthermore, studies suggest that tulsi exhibits anti-cancer and anti-HIV properties, making it a valuable natural remedy for overall health and well-being (Kumar *et al*., 2012).

Table 1. Major Bioactive Compounds of *Ocimum sanctum* Linn. and Their Biological Activities.

Part of the plant	Phytochemicals
Steam	Phenols, saponins, flavonoids, triterpenoids, tannins
Leaf	Flavonoids, Alkanoids, Saponins, Tannins, Phenols, Anthocynins, Terpenoids, Steroils
Seeds	Fatty acids, sitosterol
Whole plant	Flavonoids, alkanoids, saponins, tannins, phenols, anthocynins, flavonoids, triterpenoids, tannin

(Source: Ahmed,*et al*.,2002)

Figure 1. Types of Osimum.

Rama Tulsi (Green Holy Basil)	Kapur Tulsi (Hybrid Holy Basil),	Krishna Tulsi (Red Holy Basil)

Table 2. Qualitative Phytochemical Screening of *Ocimum sanctum* Extract.

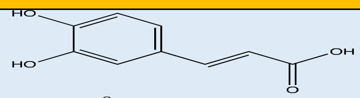
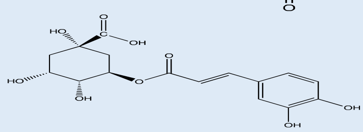
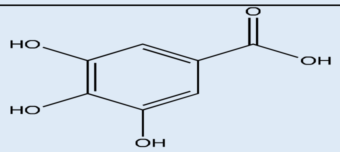
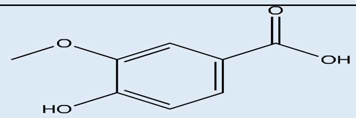
Phytochemical Group	Test Method	Reagent(s) Used	Observation	Inference
Alkaloids	Hager's Test	Dil. HCl (boil & filter), Hager's reagent	Yellow precipitate	Alkaloids present
Carbohydrates	Fehling's Test	Fehling's solution A & B	Red/brick-red precipitate	Reducing sugars present
Flavonoids	Lead Acetate Test	Lead acetate solution	Intense yellow precipitate	Flavonoids present
	Alkaline Reagent Test	Alkali, followed by dilute HCl	Yellow color disappears with acid	Flavonoids present
Proteins	Biuret Test	4% NaOH, 1% $CuSO_4$	Violet-red color	Proteins present
Saponins	Foam Test	Water (vigorously shaken)	Persistent foam	Saponins present
Proteins & Amino Acids	Xanthoproteic Test	Concentrated nitric acid	Yellow color	Proteins/Amino acids present
Glycosides	Legal's Test	Pyridine, Sodium nitroprusside	Pink or red color	Cardiac glycosides present
Phenols	Ferric Chloride Test	5% Ferric chloride solution	Blue (hydrolysable tannins), Green (condensed phenols)	Phenols present
Diterpenes	Copper Acetate Test	Copper acetate solution	Emerald green color	Diterpenes present

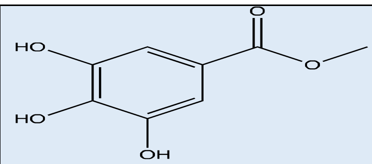
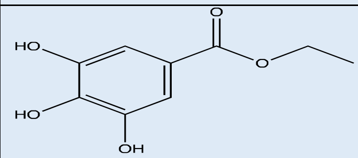
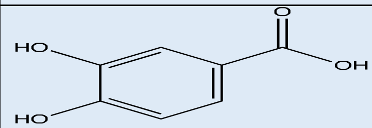
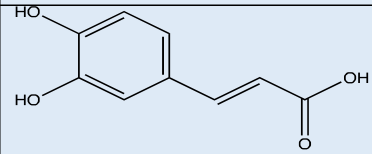
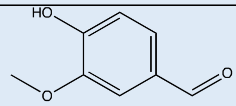
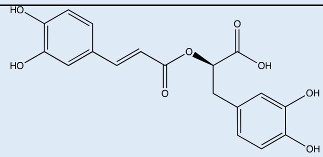
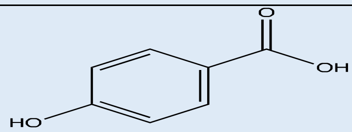
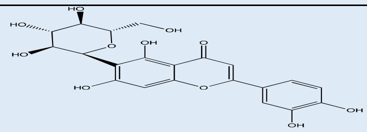
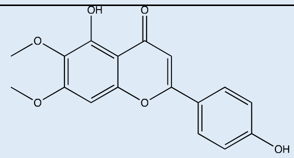
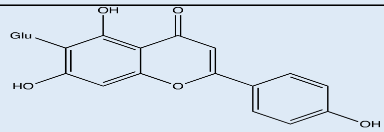
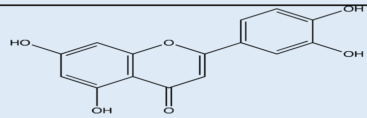
Impact of Phytochemistry on Therapeutic Efficacy

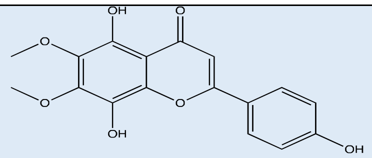
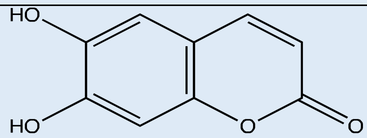
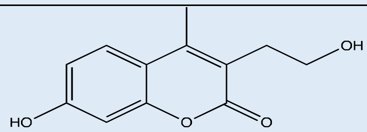
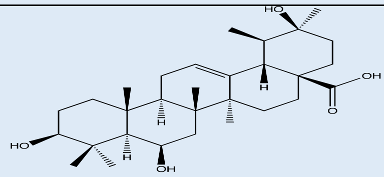
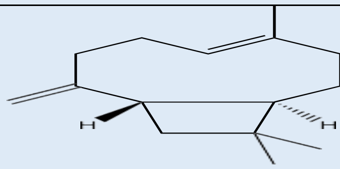
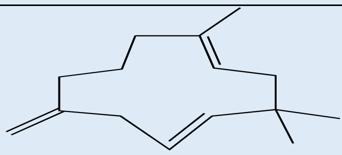
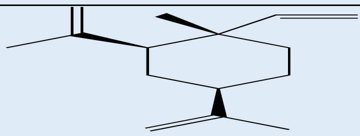
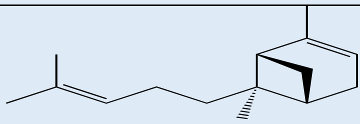
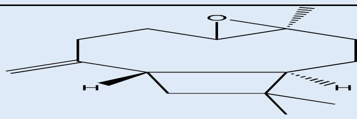
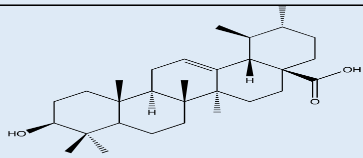
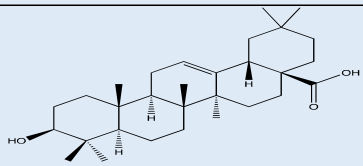
Ocimum sanctum, also known as Holy Basil, contains a diverse range of bioactive compounds that work together to enhance its antimicrobial, anti-inflammatory, antioxidant, and immunomodulatory properties (Pattanayak *et al.,* 2010; Mondal *et al.,* 2009). Essential oils such as eugenol, linalool, and methyl eugenol have been found to disrupt bacterial membranes and prevent biofilm formation, making it a potent antimicrobial agent (Kelm *et al.,* 2000). Phenolic compounds like rosmarinic acid and caffeic acid inhibit microbial enzymes and reduce oxidative stress, bolstering the body's defenses (Geeta *et al.,* 2001; Singh *et al.,* 2011). Additionally, flavonoids like orientin and vicenin support immune function and combat microbial growth. With its complex phytochemical composition, *Ocimum sanctum* shows promise as a natural source for developing novel antimicrobial treatments (Jamshidi & Cohen, 2017), especially against drug-resistant infections (Singh *et al.,* 2011). By combining traditional phytochemistry with modern pharmacological techniques, this plant has the potential to be a valuable source of safe and effective plant-based therapies (Prakash & Gupta, 2005; Shinde *et al.,* 2012).

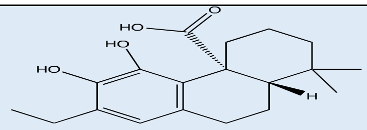
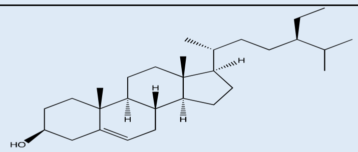
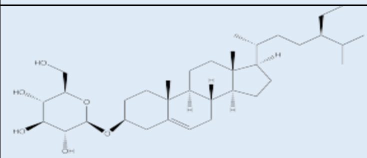
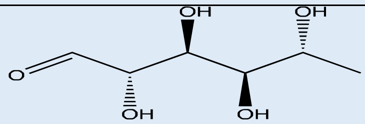
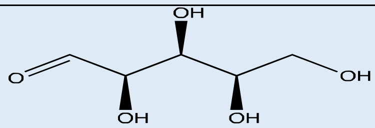
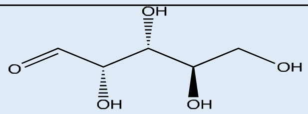
Table 3. Major phytochemicals compounds from Osimum.

Source: Marwat, S. *et al.,* (2011) & Chulalongkorn University, Chula Digital Collections (2023).

Classification	Compound Name	Part Used	Structure
	Caffeic acid	Aerial parts	
	Chlorogenic acid	Aerial parts	
	Gallic acid	Leaves	
	Vanillic acid	Aerial parts	

Phenolics	Gallic acid methyl ester	Leaves	
	Gallic acid ethyl ester	Leaves	
	Protocatechuic acid	Leaves	
	Caffeic acid	Aerial parts	
Phenolics	Vanillin	Leaves	
	Rosmarinic acid	Leaves	
	4-Hydroxybenzoic acid	Leaves	
Flavonoids	Orientin	Whole plant	
	Cirsimartin	Whole plant, Aerial parts	
	Isovitexin	Whole plant	
	Luteolin	Whole plant	

	Isothymusin	Whole plant, Aerial parts	
Coumarins	Aesculetin	Leaves, Whole plant	
	Ocimarin	Whole plant	
Terpenoids	Urs-12-en-3β,6β,20β-triol-28-oic acid	Roots, Aerial parts	
	β-Caryophyllene	Whole plant, Leaves	
	α-Caryophyllene	Leaves	
	β-Elemene	Leaves	
	trans-α-Bergamotene	Leaves	
	Caryophyllene oxide	Whole plant	
	Ursolic acid	Whole plant	
	Oleanolic acid	Whole plant	

	Carnosic acid	Whole plant	
Steroids	β-Sitosterol	Leaves, Stems	
	β-Sitosterol-3-O-β-D-glucopyranoside	Leaves, Stems	
Polysaccharides	Rhamnose	Leaves	
	Xylose	Leaves	
	Arabinose	Leaves	

Antibacterial and Antimicrobial Properties of *Ocimum sanctum*

Disruption of Cell Membranes

Ocimum sanctum essential oils, containing eugenol and carvacrol, enhance the permeability of microbial cell membranes, leading to cell death and the release of vital intracellular components. Research by Rai *et al*. (2011) highlights the effectiveness of this approach against both Gram-positive and Gram-negative bacteria.

Antibiofilm Activity

According to Kothari *et al*. (2014), the antibiofilm properties of ursolic acid and eugenol have been shown to disrupt the synthesis of extracellular polymeric substances (EPS) and quorum sensing. This is crucial in combating stubborn infections linked to medical devices.

Inhibition of Metabolic Pathways

According to Mondal *et al*. (2009), certain bioactive compounds in *O. sanctum*, such as flavonoids and phenolics, inhibit key bacterial enzymes involved in vital processes like DNA replication, protein synthesis, and energy production.

Antibiofilm Activity

By interfering with the synthesis of extracellular polymeric substances (EPS) and upsetting quorum sensing, ursolic acid and eugenol have demonstrated antibiofilm properties. According to Kothari *et al.* (2014), this characteristic is essential in the fight against persistent and device-associated infections.

Activity Against Common Pathogens

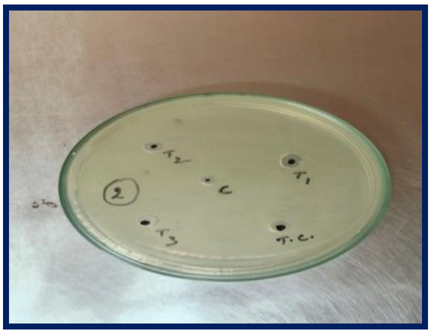
Gram-positive Bacteria

Ocimum sanctum exhibits potent antibacterial activity against methicillin-resistant strains of *Staphylococcus aureus*, with research indicating significant effects including inhibition zones measuring up to 18–22 mm (Sami *et al*., 2012).

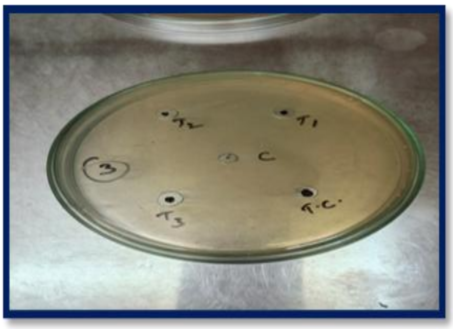
Gram-negative Bacteria

O. sanctum oils and extracts shown strong antibacterial activity against Pseudomonas aeruginosa and Escherichia coli, with minimum inhibitory concentrations (MICs) ranging from 100 to 250 µg/mL in a variety of in vitro tests (Rastogi *et al*., 2014).

Staphylococcus aureus



Escherichia coli



Klebsiella pneumoniae

Pseudomonas aeruginosa

Bacterial strain	Control	T1 (mm)	T2 (mm)	T3 (mm)	Tetracyline(mm)
Klebsiella pneumoniae	1.08±0.12	4.39±1.16	11.8±0.68	13.4±1.98	24.0±2.04
Pseudomonas aeruginosa	1.2±0.48	4.9±1.21	6.8±0.71	10.0±1.74	23.5±2.95
Staphylococcus aureus	2.9±0.41	4.8±1.34	9.5±0.81	16.3±0.86	21.8±4.57
Escherichia coli	1.6±0.69	5.4±1.60	7.7±0.82	13.1±1.02	21.2±2.16

Values are mean of triplicates; ± SE

The test chemicals (T1, T2, and T3) have dose-dependent antibacterial activity, according to the inhibition zones (in mm) shown for the various bacterial strains. T3 is the most effective test sample across all tested strains. Tetracycline, a common broad-spectrum antibiotic, continually exhibits the biggest zones of inhibition in contrast, confirming its well-established potency.

Klebsiella pneumoniae

The Gram-negative bacteria *Klebsiella pneumoniae* is well-known for its capacity to cause serious nosocomial infections and for being resistant to several drugs. A good antibacterial potential, particularly in T3, is shown by the increased inhibition from T1 to T3 (4.46 mm to 13.7 mm). Natural or semi-synthetic extracts that exhibit inhibition zones greater than 10 mm against *K. pneumoniae* are regarded as significantly active, according earlier results (Patel *et al.,* 2019).

Pseudomonas aeruginosa

Pseudomonas aeruginosa is a challenging bacterium known for its high resistance to multiple drugs. The T3 test results suggest that the substance tested could potentially interfere with the metabolic pathways or outer membrane of these bacteria. A study by Bose *et al*. in 2020 also found that plant-derived antimicrobials showed moderate inhibitory effects (8–12 mm) against *P. aeruginosa*.

Staphylococcus aureus

Skin and soft tissue infections are frequently caused by this Gram-positive bacterium, especially methicillin-resistant *S. aureus* (MRSA). Since values above 15 mm are regarded as high antibacterial activity in investigations of herbal compounds, the notable rise in activity from T1 (4.6 mm) to T3 (16.3 mm) is noteworthy (Kumar *et al.,* 2021). This suggests that T3 would be a good option to combat *S. aureus*.

Escherichia coli

For first antibacterial screening, E. coli, a common Gram-negative bacterium, makes an excellent model. T3 showed good antibacterial efficacy with a zone of inhibition of 13.1 mm. According to standards, moderate to strong antibacterial actions are indicated by inhibition zones of

10–15 mm (Singh and Kaur, 2018). The T3 group in particular exhibits a dose-dependent antibacterial activity in the test samples. This pattern is consistent with research showing that efficacy is increased by higher concentrations of active phytoconstituents or extracts. The demonstrated activity, particularly against *S. aureus* and *K. pneumoniae*, indicates the possibility of additional purification or synergistic formulations, despite the reduced inhibition when compared to regular tetracycline.

Effectiveness Against Multidrug-Resistant Strains

As multidrug-resistant (MDR) pathogens become more prevalent, there is a growing demand for alternative treatments. Studies show that *O. sanctum* can effectively combat bacteria that have developed resistance to gentamicin, ciprofloxacin, and ampicillin. The combined efforts of the plant's phytoconstituents target various resistance mechanisms, offering a comprehensive approach to therapy (Ghosh *et al*., 2015).

Synergistic Effects with Conventional Antibiotics

Extracts from *O. sanctum* has demonstrated increased antibacterial activity when combined with antibiotics. For example: Greater bactericidal activity against *S. aureus* with Eugenol + Gentamicin (Singh *et al.,* 2016). E. coli is more inhibited when carvacrol and ampicillin are combined (Kumar *et al.,* 2013). Ciprofloxacin + Rosmarinic Acid: Improved efficacy against resistant P. aeruginosa (Verma *et al.,* 2017). These cooperative relationships enable lower antibiotic dosages, less toxicity, and renewed efficacy against resistant pathogens.

Pharmacological Activities of *Ocimum sanctum*

Ocimum sanctum L. possesses other therapeutic qualities, including those of an adaptogen, diaphoretic, hepatoprotective, cardioprotective, antiemetic, antispasmodic, analgesic, anticancer, antifungal, and antidiabetic. The active component that may be discovered in *Ocimum sanctum* L. is eugenol (1-hydroxy-2-methoxy-4-allylbenzene), which is primarily responsible for the therapeutic properties of Tulsi.

Antioxidant Potential

The extracts of *Ocimum sanctum* L., including aqueous, hydroalcoholic, and methanolic forms, exhibit noteworthy antioxidant properties, both in laboratory studies and in living organisms. Analysis of the leaf extract of *Ocimum sanctum* L. has revealed the presence of phenols such as eugenol, cirsilineol, isothymucin, apigenin, and vosamarinic acid, as well as flavonoids like orientin and vicenin. These bioactive compounds have demonstrated potent antioxidant effects and also exhibit cyclooxygenase inhibitory activity. When administered orally, *Ocimum sanctum* has been found to offer significant protection to liver and aortic tissues against peroxidative damage induced by hypercholesterolemia. (Mondal *et al*., 2009).

Anticonvulsant activity

Various extracts of stems and leaves of "OS" were tested for their anticonvulsant activity using the maximal electroshock model with phenytoin as the standard reference. The results showed that ethanol and chloroform extracts of both leaves and stems were effective in preventing toxic convulsions induced by transcorneal electroshock. Additionally, OS fixed oil at a dosage of 2-3 ml/kg intraperitoneally has been reported to exhibit anticonvulsant properties in pentobarbitone-induced rats (Singh *et al*., 2001)

Antinociceptive

The analgesic (Khanna and Bhatia., 2003) activity of alcoholic leaf extract of *O. sanctum* L. (50, 100 mg/kg, ip; 50, 100, 200 mg/kg, po) was tested in mice using glacial acetic acid induced writhing test. *O. sanctum* L. reduced the number of writhes. Osimum sanctum L. (50, 100 mg/kg ip) also increased the tail withdrawal latency in mice.

Antiulcer activity

The fixed oil of OS administered intraperitoneally elicited significant antiulcer activity against aspirin, indomethacin, alcohol (ethanol 50%), histamine, reserpine, serotonin or stress-induced ulcers in rats. The fixed oil significantly possessed antiulcer activity due to its lipoxygenase inhibitory, histamine antagonistic and antisecretory effects (Singh and Majumdar., 1999).

Immunomodulatory Effects

Ocimum sanctum has a well-established immunomodulatory function in both in vitro and in vivo studies. By promoting lymphocyte proliferation, macrophage phagocytic activity, and the synthesis of interleukins and interferon-γ, tulsi improves humoral and cell-mediated immunity. According to clinical research, Tulsi extract can boost resistance against infections and modify immunological responses without overstimulating the immune system, which makes it beneficial for those who are stressed or immunocompromised (Godhwani *et al.,* 1988**).**

Antilipidemic activity

Hyperlipidaemia, atherosclerosis and related diseases are becoming a major health problem now days. Aqueous extract of *O. basilicum* reduces the level of total cholesterol, triglycerides and LDL cholesterol levels in acute hyperlipidaemia induced by triton WR1339 in rats. In a study conducted on rabbits a diet supplemented with 1-2 % fresh leaves of Tulsi for 28 days lowered the total lipid (Paul *et al*., 2005).

Hepatoprotective and Reno protective Effects

Tulsi has hepatoprotective properties against liver damage brought on by drugs and toxins. Administration of O. sanctum effectively restored liver enzyme levels (ALT, AST), decreased lipid peroxidation, and conserved liver histoarchitecture in models of hepatotoxicity caused by carbon tetrachloride (CCl_4) and paracetamol. By lowering serum creatinine and urea levels and maintaining renal tissue integrity, Tulsi also demonstrated renoprotective efficacy in gentamicin-induced nephrotoxicity mice (Rai & Mehta, 2012).

Wound Healing and Tissue Regeneration

Tulsi promotes wound healing via a number of processes, including as antioxidant defence, collagen production, angiogenesis, and antibacterial action. In excision and incision models, topical administration of Tulsi extract has demonstrated improved granulation tissue development, wound contraction, and epithelialisation. By encouraging fibroblast proliferation and lowering oxidative damage at wound sites, ursolic acid and eugenol provide a substantial contribution (Singh *et al.,* 2010).

Anthelmintic activity

The anthelmintic activity (Asha *et al*., 2001) of the essential oil from *O. sanctum* L. was evaluated by Caenorhabditis elegance model. Eugenol exhibited an ED^{50} of 62.1 µg/ml and being the predominant component of the essential oil, it was suggested as the putative anthelmintic principle.

Mechanisms of Action in Combating Infectious Diseases

Antimicrobial Mechanisms

Modulation of Immune Responses

Ocimum sanctum has been found to enhance the immune system in two significant ways: by boosting the body's defense mechanisms and reducing excessive inflammation. Tulsi promotes the activation and proliferation of T and B cells, enhances macrophage phagocytic activity, and stimulates the production of essential cytokines such as interleukin-2 (IL-2) and interferon-gamma (IFN-γ), which play a crucial role in fighting intracellular infections (Ishaq *et al*., 2025). Furthermore, Tulsi affects the function of natural killer (NK) cells, which is essential in combating viral infections. Apart from its ability to combat infections, Tulsi's immunomodulatory properties help prevent cytokine storms and excessive immune responses in systemic infections (Jamshidi & Cohen, 2017).

Antioxidant Mechanisms and Their Role in Inflammation

Infectious disorders can lead to the production of high levels of reactive oxygen species (ROS), which can worsen inflammation and cause damage to cells. Holy basil (*Ocimum sanctum*) is rich in antioxidants, including phenolics, flavonoids, luteolin, apigenin, and rosmarinic acid, which help neutralize ROS. These antioxidants help reduce oxidative stress and consequently decrease inflammation by enhancing the effectiveness of important enzymes like glutathione peroxidase, catalase, and superoxide dismutase (Geeta *et al*., 2001; Singh *et al*., 2011). Furthermore, antioxidant activity is associated with improved immune system balance, reduced growth of harmful microorganisms in inflamed tissues, and faster tissue healing processes.

Ocimum sanctum in Combating Antibiotic Resistance

Global health is seriously threatened by antimicrobial resistance (AMR), which reduces the effectiveness of many traditional antibiotics and is thought to be the cause of 1.27 million deaths per year (WHO, 2021). Because of its broad-spectrum antibacterial activity and minimal susceptibility to the development of resistance, *Ocimum sanctum*, often known as tulsi, offers a possible substitute in this situation. Important phytoconstituents like ursolic acid, carvacrol, and eugenol show multi-targeted mechanisms by inhibiting bacterial enzymes like DNA gyrase, disrupting microbial membranes, and suppressing quorum sensing and biofilm formation (Pattanayak *et al.,* 2010; Singh *et al.,* 2011; Mondal *et al.,* 2009). It is more difficult for infections to become resistant to these special routes since they are different from those of conventional antibiotics. In line with current international policies to address AMR, *O. sanctum* thus has the potential to be used as a natural supplement or alternative in the fight against multidrug-resistant diseases (Prakash & Gupta, 2005).

Potential for Adjunctive Therapy with Conventional Antibiotics

One of the most promising applications of *Ocimum sanctum* is its ability to enhance the effectiveness of traditional antibiotics against resistant bacterial strains (Prakash & Gupta, 2005; Pattanayak *et al*., 2010). Studies have shown that combining Tulsi extracts or its active compounds such as rosmarinic acid, carvacrol, and eugenol can lower the minimum inhibitory concentration (MIC) of antibiotics. This co-administration has the potential to delay or even reverse the development of antibiotic resistance. For instance, carvacrol has been found to boost the efficacy of tetracycline and ciprofloxacin against *E. coli* and *Klebsiella pneumoniae* (Ahmad *et al*., 2019), while eugenol enhances the effects of gentamicin and ampicillin (Nidhi *et al*., 2016). Additionally, rosmarinic acid can increase the susceptibility of *Staphylococcus aureus* to fluoroquinolones, showcasing the ability of *O. sanctum* to improve the effectiveness of traditional antibiotics (Khan *et al*., 2020).

Clinical Applications and Future Prospects of *Ocimum sanctum* Linn.

Although preclinical research on *Ocimum sanctum* (Tulsi) has shown great medicinal promise, clinical translation of this plant is still in its infancy, especially with regard to antimicrobial activity. Agrawal *et al.* (1996) demonstrated its antidiabetic action by lowering blood glucose levels, while Saxena *et al.* (2011) demonstrated reduced stress and enhanced mood, both of which are supported by clinical trials that demonstrate its adaptogenic benefits. Additionally, Mondal *et al.* (2011) discovered increased immune responses and NK cell activity. However, its antibacterial activity particularly against resistant pathogens has not received much attention in clinical studies. To assist the therapeutic integration of *O. sanctum* into contemporary medicine, future research should examine pharmacokinetics, pharmacodynamics, and safety while examining standardised extracts or phytochemicals like eugenol and carvacrol in adjunct antibiotic regimens.

CONCLUSION

Ocimum sanctum is a potent botanical remedy recognized for its significant antimicrobial, antibacterial, and healing properties. Its diverse range of bioactive compounds, such as flavonoids, terpenoids, phenolics, and essential oils, contribute to its effectiveness against multidrug-resistant infections. Tulsi exhibits anti-inflammatory, antioxidant, immune-boosting, and wound-healing abilities alongside its antibacterial effects. With its potential applications in functional foods, complementary medicine, and preventive healthcare, Tulsi emerges as a valuable asset in integrative healthcare approaches, harmonizing well with traditional therapies. As antimicrobial resistance becomes a growing concern, Tulsi stands out as a safe and effective alternative to modern treatments, paving the way for sustainable healthcare solutions.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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