

# Neuroprotection and Beyond: The Therapeutic Potential of *Ocimum sanctum*

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**Abstract:** Neurodegenerative diseases are severe disorders characterized by the gradual deterioration of the normal structure and function of the central nervous system. Multiple factors, including protein depletion, oxidative and inflammatory stress, and environmental influences, contribute to the development of these disorders, with aging being the most significant risk factor. Neurodegenerative diseases are among the most debilitating, persistent, and often irreversible brain conditions, which have led to widespread research interest. Conventional treatments are often insufficient for managing certain neurodegenerative conditions, prompting researchers to explore herbal alternatives. Phytochemicals exert neuroprotective effects through several mechanisms, including antioxidant, anti-inflammatory, antithrombotic, antiapoptotic, acetylcholinesterase, and monoamine oxidase inhibition, and neurotrophic activities. In recent years, herbal plants with strong neuroprotective and antioxidant properties have been utilized to improve the quality of life of individuals suffering from neurodegenerative diseases. According to Ayurveda, the traditional Indian system of medicine, *Ocimum sanctum* (holy basil) is believed to have therapeutic effects on hriddaurbalya (mental weakness), aakshhepayukta vikara (nervous disorders), and shiroroga (head-related ailments). This plant has been selected for study due to its potent anti-inflammatory and antioxidant properties, as well as a substantial body of preclinical and clinical research supporting its efficacy. This chapter focuses on *Ocimum sanctum* and its potential role in managing neurodegenerative disorders. The objective is to explore the therapeutic effects of holy basil in various neurodegenerative conditions and to identify possible targets for reducing neurotoxicity and promoting neurological health.

**Keywords:** Neurodegenerative diseases, Oxidative stress, Phytochemicals, *Ocimum sanctum*, Neurotoxicity reduction.

## 1. Introduction

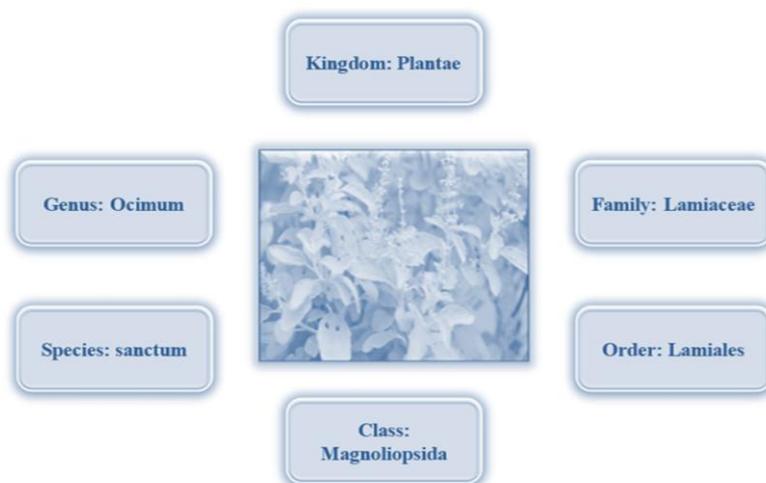
Tulsi, or *Ocimum sanctum* L., is a valued herb widely used in both culinary and medicinal applications, belonging to the Lamiaceae family. It is also commonly referred to as holy basil or Tulasi. For over three millennia, Tulsi has been employed in Ayurvedic medicine. It has been honored with titles such as "Nature's Mother Medicine" and "Queen of Plants" [1]. The term Tulsi signifies the "incomparable one" or "matchless one" [2]. Historically, Tulsi has been recognized as a divine and therapeutic herb [3-4]. Holy basil holds significant importance in traditional medical systems, including Ayurveda, Siddha, and Traditional Chinese Medicine, due to its diverse therapeutic properties and health benefits [5]. Ancient scriptures, such as the Padma Purana and Tulsi Kava Cham, describe Tulsi as a protector of life. The sages, or rishis, integrated it into religious rituals, facilitating its incorporation into daily life [6]. Holy basil is often referred to as the "Elixir of Life" and has historically been used to manage a wide range of diseases [7]. In Sanskrit, Tulsi is also known as Vishnu Priya, Divya, Tulsi, and Thulasi, while in Tamil, it is called Thulasi. In English, it is commonly referred to as holy basil, and in Hindi, as Kala Tulsi or Tulasi [8]. Additional synonyms of the plant are listed in **Table 1**.

**Table 1:** Synonyms of the plant *Ocimum sanctum*.

Language	Commonly called Name
Assamese	Tulasii
English	Holy Basil
Bengali	Tulasai
Kannada	Tulaseii, Shri Tulsi, Vishanu Tulsi
Gujrati	Tulasei, Tulsi
Malayalam	Tulsii, Tulasae
Hindi	Tulasii
Marathi	Tulase
Tamil	Tulaesi, Thulasii, Theiru Theezaei
Punjabi	Tulsi
Sanskrit	Surasa, Krishna tulasi, Bana Tulasi
Telugu	Tulasii
Urdu	Tulss, Raihana

### 1.1 Taxonomical Classification of *Ocimum sanctum* L

The taxonomical classification of *Ocimum sanctum* L. is depicted in **Figure 1**.



**Figure 1:** Taxonomical Classification of *Ocimum sanctum* L.

### 1.2 Traditional Knowledge and Historical Use

Tulsi (*Ocimum sanctum* L.) has been used therapeutically since 400–500 BC. The earliest references to Tulsi are found in the Rigveda, dating back to 3500–1600 BC. Tulsi extract, often called “The Extract of Life,” is believed to promote longevity [9].

### 1.3 History Behind Tulsi Formation

In Hinduism, holy basil is considered a manifestation of the goddess Tulasi. According to popular belief, the demon Jalandhara, created by Shiva’s fire, was ultimately defeated due to his wife Vrinda’s virtue and Vishnu’s intervention. After her death, Vrinda transformed into the holy basil plant, symbolizing love, immortality, purity, and protection. Basil also holds significance in burial rituals across various cultures [10]. Furthermore, it is regarded as a manifestation of the goddess Lakshmi and is highly revered as a symbol of protection and purity [11]. Tulsi is believed to possess spiritual and cleansing properties, and its leaves are widely used in religious rituals, offerings, and ceremonies.

## 2. Historical Use of Tulsi

Various parts of *Ocimum sanctum*—including leaves, flowers, stems, roots, and seeds—demonstrate potential pharmacological activities such as anticancer, hypolipidemic, expectorant, hypotensive, analgesic, hepatoprotective, and antistress effects. It has been traditionally employed to treat fevers, arthritis, convulsions, and bronchitis [12-14]. Historically, Tulsi has been consumed in multiple forms, including herbal teas, powders, and mixed with honey or ghee. Classical Ayurvedic texts such as *Susrut Samhita*, *Charak Samhita*, and the *Rigveda* (3500–1600 BCE) describe Tulsi as a Rasayana therapy for conditions like impotence, arthritis, coughs, poisoning, and respiratory ailments [15]. Tulsi is considered an adaptogen and nervine tonic, enhancing health during cancer treatment and mitigating stress [16-17]. In Ayurveda, Tulsi is a “medhya rasayana,” known to improve cognitive function, memory, and mental clarity [18]. It is considered “sattvic,” promoting purity and clarity of thought [11]. Tulsi leaves exhibit refrigerant, febrifuge, expectorant, carminative, and laxative properties, and their infusion is used as a stomachic for gastrointestinal issues in infants. Fresh leaf juice serves as a first-aid remedy for earaches [19]. Therapeutic properties of Tulsi according to Ayurveda [20] include:

- Anti-inflammatory effects that balance vata, reducing swelling and pain.
- Treatment of skin disorders, including rashes, insect bites, itching, ringworm, and leukoderma.
- Reduction of acne, pimples, and scars through leaf extracts.
- Use in Nasya karma with fresh leaf juice to relieve headaches and ailments of the head and neck, acting as a nervous tonic.
- Remedies for indigestion, constipation, and intestinal parasites.
- Management of respiratory conditions such as fever, bronchitis, and cough using crushed leaves.
- Support for cardiac health and blood purification.
- Seeds possess aphrodisiac properties and may prevent premature ejaculation.

Other traditional uses of *Ocimum sanctum* are illustrated in **Figure 2**.

Leaves(juice)	• Cough, cold, bronchitis, ringworm, gastric disorders, and catarrh • Diarrhoea and dysentery
Plant paste	• Fever
Flowers juice with honey, ginger and onion juice	• Bronchitis
Dried leaves with ghee	• Dysentery, colic and piles
Leaves, flower top and roots (juice)	• Antidote in snake poisoning
Leaves paste	• Antidote for scorpion bite
Leaves	• Cough, cold, leg swelling and fever
Dried leaves	• Blood purification
Fresh leaf with water	• Enhancing mental power
Whole plant	• Cough, cold, headache, nausea, fever and skin diseases
Leaves (crushed and filtered extract)	• Stomach ache and head ache
Leaf decoction with flower heads of <i>Leucas cephalotes</i> and with <i>Piper nigrum</i> and <i>palmgur</i>	• Fever

**Figure 2:** Some of the Traditional Uses of the Plant *Ocimum Sanctum*.

## 3. Phytochemistry

The chemical composition of Tulsi (*Ocimum sanctum* L.) is complex and can vary significantly depending on environmental conditions, species, and even individual plants within the same region [21-23]. The plant contains numerous nutrients and biologically active compounds, many of which contribute to its therapeutic potential. Eugenol is recognized as a major active component of Tulsi, with multiple health benefits. It belongs to the allylbenzene class of volatile compounds and is a prominent constituent of the essential oil, valued for

its use in food flavoring and industrial applications [21]. Tulsi leaves contain approximately 0.7% volatile oil, of which 71% is eugenol and 20% is methyl eugenol. The oil also contains sesquiterpenes, caryophyllene, hydrocarbons, and carvacrol [10, 20, 24-27]. The pungent taste of holy basil is primarily attributed to beta-caryophyllene, a sesquiterpenoid, and eugenol, a phenylpropanoid found in hydro-distilled leaf oil, which is traditionally used to treat joint pain, inflammation, and skin disorders [28]. Other essential oils extracted from Tulsi leaves include camphor,  $\alpha$ -camphene, benzaldehyde, borneol, bornyl acetate,  $\alpha$ -myrcene,  $\alpha$ -pinene,  $\beta$ -pinene, furaldehyde, caryophyllene oxide, heptanol, cis- $\alpha$ -terpineol, cubenol, oleic acid, cardinene, germacrene, eucalyptol, humulene, limonene, n-butyl benzoate, ocimene, eicosane, sabinene, methyl chavicol, D-limonene, farnesene, farnesol, selinene, phytol,  $\beta$ -guaiene, veridifloro,  $\alpha$ -thujene,  $\beta$ -gurjunene, and linalool. Several flavonoids have been isolated from the aqueous leaf extract, including orientin and vicenin [24, 29-31]. Other compounds identified from the leaf extract include molludistin, luteolin, apigenin, and lutein-7-O-glucuronide [32]. Phenolic compounds with antioxidant properties, such as circimaritin, cirsilineol, rosmarinic acid, isothymusin, and apigenin, have also been reported from fresh stems and leaves, along with significant amounts of eugenol [33]. The plant is a source of essential minerals, including calcium, phosphorus, iron, zinc, copper, and chromium, as well as vitamins C and A [34]. Seed oils are rich in oleic acid, linoleic acid, stearic acid, linolenic acid, and palmitic acid [20]. The alcoholic extracts of leaves and aerial parts contain a wide array of bioactive compounds, including caffeic acid, luteolin, aesculectin, molludistin, aesculin, orientin, stigmasterol, gallic acid, circineol, apigenin, galuteolin, protocatechuic acid, vitexin, isoorientin, ursolic acid, vallinin, isovitexin, and vallinic acid [26]. The distribution of phytochemicals across different parts of *Ocimum sanctum* is summarized in **Figure 3** and **Table 2**.



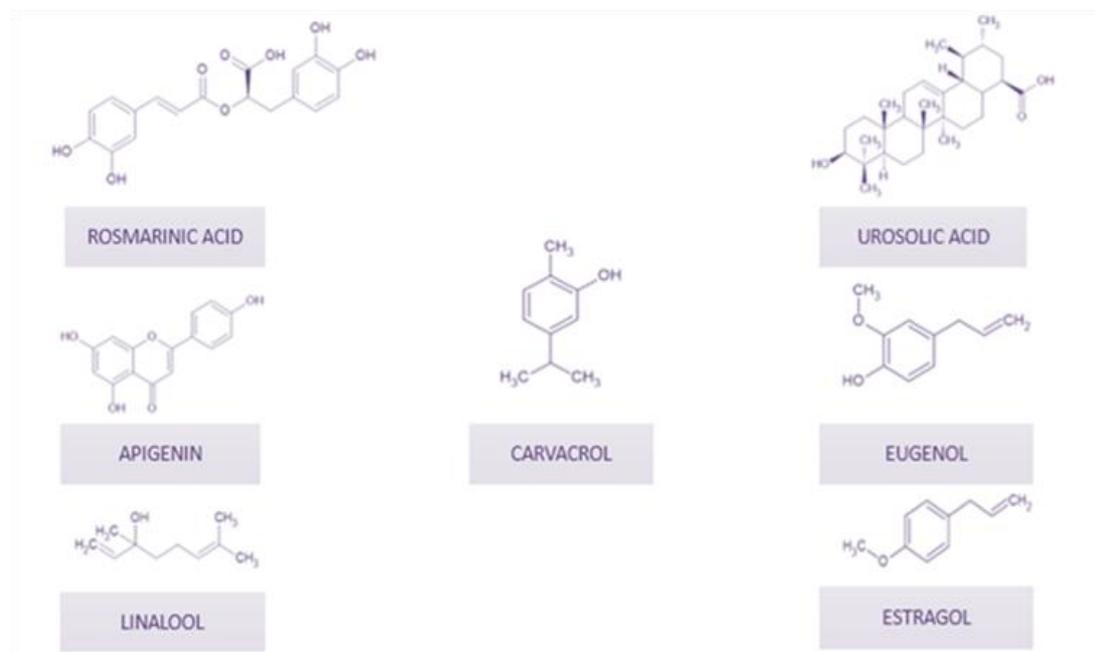
**Figure 3:** Phytochemicals Present in Different Parts of *Ocimum Sanctum*.

**Table 2:** The chemical constituents of *Ocimum sanctum*.

Sr. No.	Chemical constituents class	Chemical components	References
1	Aliphatic aldehyde	Citronellal	[35]
2	Fatty acid	Ethyl isovalerate, Ethyl 13-methyl-tetradecanoate, Ocimumnaphthanoic acid, Ethyl palmitate, Methyl 9-methyltetradecanoate, Methyl 7-Z-hexadecanoate	[36-38]
3	Phenolic compounds	rosmarinic acid, orientin, p-coumeric acid, vicenin, p-hydroxybenzoic acid, apigenin, cirsimaritin, Vanillin, Sinapic acid, Methylisoeugenol, Vanillic acid, Ferulic acid, Eugenol, Bieugenol	[11, 39-41]

4	Flavanoids	apigenin, luteolin, Galuteolin, Isovitexin, Chrysoeriol, Cirsilineol, Isothymunin, Vitexin, Isothymusin, Orientin, Cirsimaritin, Molludistin, kaempferol, and quercetin, Isoorientin, Vicenin, Luteolin-5-glucoside, Esculin, Esculectin	[18, 35-36, 40]
5	Alkaloids	vascobasine, vasicine, and vasicinone	[40]
6	Carboxylic acids	(Z)-3-Hexenil acetate	[42]
7	Sterols	$\beta$ -sitosterol, stigmasterol, and campesterol	[40]
8	Essential oils	methyl ether, eugenol, eugenol methyl ether, methyl eugenol, 1,8-cineole, and linalool	[20]
9	Terpenoids	beta-caryophyllene, germacrene-D, $\alpha$ -Terpinyl acetate, beta-elemene, Monoterpenoids: Bornyl acetate, Estragole, Carvacrol, Linalool, Terpinolene, $\alpha$ -Bergomatene Sesquiterpenoids: Spathulenol, Methylene-4,8,8-trimethyl-4-vinyl bicyclo[5.2.0]nonane, $\alpha$ -Humulene, $\alpha$ -Guaiol Triterpenoids: betulinic acid, Oleanolic acid, lupeol and Ursolic acid	[11, 35-40, 43-44]
10	Glycosides	ocimarin	[18]
11	Phenylpropanoids	Rosmarinic acid	[39, 43]
12	Benzenoids	Protocatechuic acid, Di-n-2-propyl pentyl phthalate	[35, 37]
13	Vitamins and Minerals	vitamins A, K, and C, calcium, zinc, and iron,	[11]
14	Unsaturated hydrocarbons	1,2,4- Trimethylcyclohexane	[35]
15	Polyphenols	rosmarinic acid, catechins, and ellagic acid	[18, 40]
16	Volatile compounds	limonene, eugenol, myrcene, and beta-pinene	[40]

The chemical structure of some of the therapeutic phytochemicals of *Ocimum sanctum* is depicted in **Figure 4**.



**Figure 4:** Some of the therapeutic phytochemicals of *Ocimum sanctum*.

## **4. Pharmacological Activities**

Extensive pharmacological research has demonstrated that *Ocimum sanctum* L. (Tulsi) possesses a wide range of therapeutic activities. Tulsi extracts and essential oils exhibit diverse pharmacological properties, contributing to their health benefits.

### **4.1 Antioxidant Activity**

Tulsi is rich in phenolic compounds and flavonoids, which confer strong antioxidant properties [18]. Rosmarinic acid, a polyphenol present in Tulsi, protects cells against oxidative damage by scavenging free radicals [45]. Studies report that aqueous extracts of Tulsi significantly enhance catalase and superoxide dismutase activity compared to controls [46].

### **4.2 Anti-inflammatory Activity**

Phytochemicals such as eugenol, rosmarinic acid, and flavonoids contribute to Tulsi's anti-inflammatory effects [47]. Compounds including isothymonin, cirsilineol, rosavinic acid, civsimavatine, apigenin, and eugenol exhibit COX inhibitory and anti-inflammatory activity [48]. Methanolic and aqueous extracts of Tulsi reduce inflammation, edema, and pain in various experimental models [8, 49].

### **4.3 Antinociceptive (Analgesic) Activity**

Alcoholic leaf extracts of Tulsi reduce pain perception in mice, as evidenced in the acetic acid-induced writhing and tail withdrawal tests [50]. The fixed oil demonstrates prostaglandin inhibitory activity, contributing to antipyretic effects [51].

### **4.4 Adaptogenic Activity/Antistress Activity**

Tulsi exhibits adaptogenic properties, helping regulate stress hormones such as cortisol and supporting adrenal function [10-11]. Eugenol and caryophyllene are key bioactive compounds contributing to its Rasayana effects. Aqueous extracts enhance survival time and reduce stress in animal models [52].

### **4.5 Anticancer Potential**

Alcoholic and aqueous extracts of Tulsi inhibit tumor growth in mice with Sarcoma-180 and show chemopreventive activity [29, 53]. Leaf extracts suppress chemical carcinogenesis by inhibiting procarcinogen activation and promoting cell cycle arrest and apoptosis in cancer cells [18, 54-55].

### **4.6 Antibacterial Activity**

Tulsi exhibits broad-spectrum antibacterial activity against both Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*, *Escherichia coli*, *Shigella*, and *Enterobacter* species [56-58]. The high linolenic acid content of its fixed oil contributes to this activity.

### **4.7 Immunomodulatory Effect**

Tulsi enhances both humoral and cellular immune responses, stimulating antibody production, lymphocytosis, and WBC synthesis, thereby strengthening the body's defense mechanisms [18, 51, 59].

### **4.8 Antidiabetic Potential**

Ethanollic extracts and various fractions of Tulsi stimulate insulin secretion in the rat pancreas [60]. Tulsi also exhibits aldose reductase inhibitory activity, potentially mitigating diabetic complications such as cataracts and retinopathy [61].

### **4.9 Anti-Fungal Activity**

Methanolic and aqueous extracts, as well as hexane, n-butanol, and chloroform fractions of Tulsi, show antifungal activity against dermatophytes, primarily due to compounds such as methyl chavicol and linalool [20, 62].

#### 4.10 Hepatoprotective Activity

Tulsi extracts protect against hepatotoxicity induced by paracetamol and CCl<sub>4</sub> in rats. Co-administration with silymarin enhances hepatoprotective effects [63].

#### 4.11 Antifertility Effect

Tulsi leaves contain ursolic acid, which exhibits antifertility effects in female rats. Petroleum ether and benzene extracts reduce sperm count and motility in male rats [15, 64].

#### 4.12 Miscellaneous Activity

Tulsi (*Ocimum sanctum* L.) exhibits extensive health-promoting properties beyond its primary pharmacological activities. It supports respiratory health by alleviating symptoms of cough, cold, and asthma, while extracts from its stem, leaves, flowers, and roots show potent antiplasmodial activity [65-66]. The plant stabilizes mast cells, suppresses IgE production, and demonstrates analgesic, wound-healing, and antiplatelet effects, contributing to overall immune and tissue health [15, 24, 62, 67]. Additionally, Tulsi enhances cardiovascular function by lowering cholesterol, regulating blood pressure, and preventing thrombosis [11, 18]. Its flavonoids, such as vicenin and orientin, protect lymphocytes from radiation-induced damage and improve bone marrow recovery, while traditional applications include treatment of ulcers, infections, liver disorders, constipation, tachycardia, and various other ailments in humans and animals [68-70].

### 5. Experimental and Clinical Evidence of *Ocimum sanctum* for Neuroprotective Effects

Extensive literature, including in vitro, in vivo, and in silico studies, as well as clinical trials, demonstrates the neuroprotective potential of *Ocimum sanctum*. Both preclinical animal models and clinical investigations have shown promising effects of Tulsi against neurodegenerative disorders. Key preclinical and clinical findings are summarized below:

#### 5.1 Preclinical Data

Studies have shown that ethanolic extracts of *Ocimum sanctum* (OSEE) positively influence central nervous system functions, particularly memory and learning. Tulsi administration modulates neurotransmitter levels, which are critical for neuronal activity. In vitro experiments demonstrated that OSEE protects SH-SY5Y neuronal cells against H<sub>2</sub>O<sub>2</sub>-induced cell death [71-74]. OSEE also enhances the survival of HEK293 cells by preserving choline acetyltransferase (ChAT) expression and preventing neurodegenerative symptoms. Neuroprotection is mediated through inhibition of caspase-3 and -9, while active constituents of OSEE may bind to amyloid- $\beta$  (A $\beta$ ) sites, preventing oligomerization [75]. In vivo, foot shock-induced neuronal damage in the substantia nigra of rats was significantly reduced by treatment with fresh Tulsi leaf extract, which prevented behavioral deficits and neuronal impairment [76]. These findings highlight Tulsi's potential as a neuroprotective agent in preclinical models of neurodegeneration.

#### 5.2 Clinical Data

An 8-week, randomized, double-blind, placebo-controlled trial investigated the effects of *Ocimum sanctum* extract on mood, stress, and sleep in adults experiencing stress. Tulsi supplementation reduced subjective stress, decreased cortisol levels, and improved sleep quality by 3.4% according to wrist-worn sleep trackers. However, no significant changes in sleep efficiency, total sleep time, or self-reported mood indices were observed. The study emphasized the need for further trials with varied treatment durations, gold-standard sleep monitoring, and diverse populations [77]. In another placebo-controlled study, ethanolic Tulsi leaf extract improved cognitive function in healthy adults. Compared to placebo, the extract group demonstrated enhanced performance in Stroop and Sternberg tests, with significant reductions in error rates and reaction times. Improvements were also observed in salivary cortisol, P300 latency, and the State-Trait Anxiety Inventory,

suggesting enhanced cognition and stress modulation [78]. **Table 3** summarizes the therapeutic effects of *Ocimum sanctum* in human clinical trials related to neurodegenerative disorders.

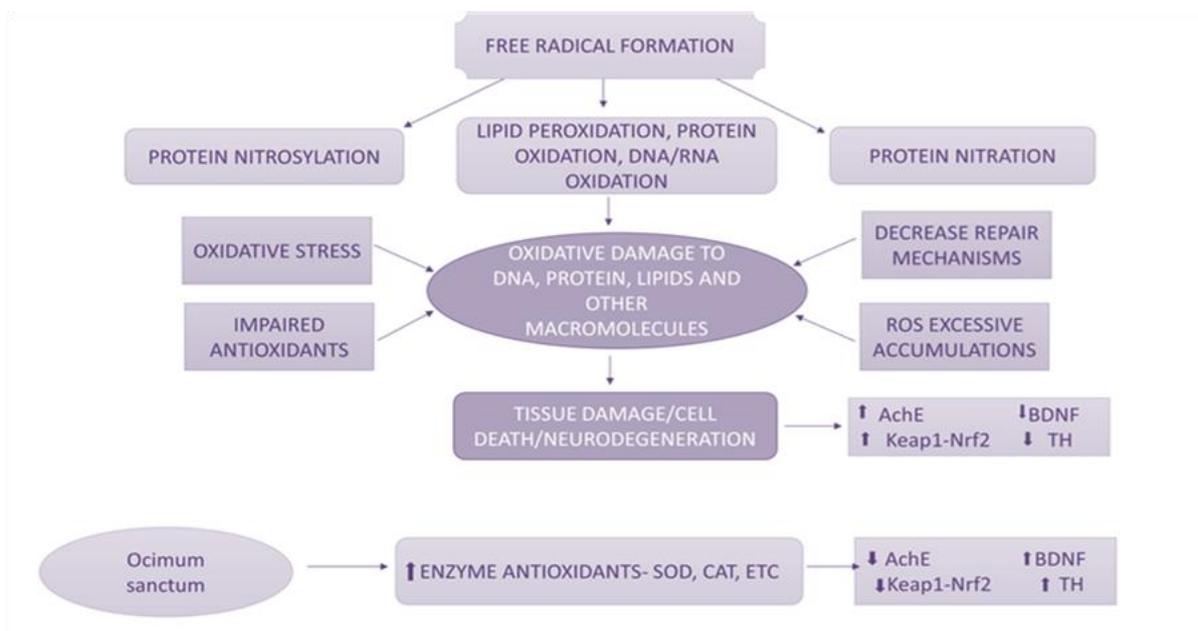
**Table 3:** Therapeutic effects of *Ocimum sanctum* on neurodegenerative disorders in human clinical trials.

S.N.	Study design	Participants	Holy basil extract	Duration	Outcome	Reference
1	placebo-controlled clinical trial, Double-blind, Randomized	40 adults (disease-free) (age between 18–30 years)	Eth. Extract of holy basil leaves (capsule before meals) 300 mg/day	4 weeks	Improved working memory, Cognitive flexibility, and Attention only after day 15	[78]
2	placebo-controlled 8-trial, double-blind, Randomized	100 volunteers (18–65 years)	<i>Ocimum sanctum</i> (Holixer™) 125 mg twice daily	8 weeks	reduced perceived stress and improved sleep quality.	[77]
3	placebo-controlled, Randomized, double-blind	150 volunteers (adults), stress volunteers (between age 18 and 65 years)	whole plant capsules after meals 400 mg 3 times/day	42 days	Reduction in sleep, fatigue, sexual problems, and other stress-related symptoms	[79]
4	Clinical trial	35 volunteers with GAD (ages between 18 and 60 yrs)	Eth. Holy basil leaves capsules 500 mg 2x daily after meals	8 weeks	↓ anxiety, stress, Self-reported questionnaire, & depression	[80]
5	Clinical trial	24 volunteers, psychosomatic (aged between 60 and 80 years)	whole plant tulsi powder	84 days	significantly lowered biological age score	[81]

## 6. Mechanism of Action in Neurodegenerative Disorders

Neurodegenerative diseases are characterized by progressive neuronal loss and impaired function in various regions of the central nervous system (CNS). For instance, Huntington’s disease (HD) leads to diffuse cerebral atrophy and the loss of medium-sized striatal spiny neurons; Parkinson’s disease (PD) is marked by dopaminergic nigrostriatal neuron degeneration; and Alzheimer’s disease (AD) results in widespread cerebral atrophy [82]. Due to the limitations and side effects of conventional drugs, research has increasingly focused on herbal remedies as alternative therapies. Medicinal plants exhibit numerous therapeutic effects in neurodegenerative disorders, including antioxidant, anti-apoptotic, and anti-inflammatory activities, and modulation of neuronal function [83]. Despite existing evidence, several herbal species remain underexplored for their neuroprotective potential. *Ocimum sanctum* L. is among the promising candidates due to its well-documented neuroprotective properties. Its diverse effects on cognition are summarized in **Figure 5**, emphasizing its multifactorial role in enhancing neurological function.

Belonging to the Lamiaceae family, *Ocimum* species have been traditionally used to treat various ailments [84]. These plants are rich in bioactive compounds such as alkaloids, vitamin C, phenolic compounds, and terpenoids, which contribute to their medicinal benefits [11]. Numerous cellular and molecular pathways in neurodegenerative disorders have demonstrated the neuroprotective activity of *Ocimum sanctum*, highlighting its potential in drug discovery and development.



**Figure 5:** Main resources and mechanisms for oxidant production in NDs.

*O. sanctum* is widely used in Asia for its antioxidant and anti-inflammatory properties [85]. Its chemical constituents, including rosmarinic acid, cirsilineol, oleanolic acid, quercetin, isoflavones, and sulforaphane, exhibit strong antioxidant activity, while apigenin and diosgenin provide both antioxidant and anti-inflammatory effects, suggesting potential neuroprotection [86-87]. Oxidative stress has been implicated in AD pathology, and the antioxidant-rich profile of *O. sanctum* helps restore redox homeostasis and regulate stress-related signaling pathways [88-89]. Mechanistic studies indicate that *O. sanctum* and its bioactive components restore neuronal marker gene expression, including brain-derived neurotrophic factor (BDNF) and tyrosine hydroxylase (TH), reduce acetylcholinesterase (AChE) activity, and inhibit Keap1-Nrf2 binding. These multifaceted actions—antioxidant, lipid-lowering, anti-inflammatory, and neuroprotective—highlight the potential of *O. sanctum* as a therapeutic agent for dementia and other neurodegenerative disorders.

### 6.1 Antioxidant Activity

Numerous studies have highlighted the potent antioxidant properties of *Ocimum sanctum*, which play a key role in neuroprotection. In one investigation, *O. sanctum* extract significantly protected Wistar albino mice from cadmium-induced toxicity by enhancing the activity of various antioxidant enzymes. In vivo studies also demonstrated that Tulsi reduced radiation-induced lipid peroxidation in the mouse liver, emphasizing its protective role against oxidative stress [48, 90-91]

### 6.2 Anti-inflammatory Activity

The fixed oil of *O. sanctum* has been shown to inhibit both lipoxygenase (LOX) and cyclooxygenase (COX) pathways of arachidonic acid metabolism, contributing to its anti-inflammatory effects [69].

### 6.3 Cholinesterase Inhibitory Activity

Eugenol, a key component of Tulsi essential oil, has been reported to inhibit acetylcholinesterase (AChE) activity, supporting its potential in neurodegenerative disorders such as Alzheimer's disease [92].

### 6.4 Antistress Activity

The adaptogenic properties of *O. sanctum* are believed to result from its immunostimulatory effects, helping mitigate both physical and psychological stress [93-94].

### 6.5 Immunomodulatory Activity

In sensitized rats, *O. sanctum* oil significantly increased anti-sheep RBC antibody levels, reduced histamine release from peritoneal mast cells, enhanced footpad thickness, and inhibited leukocyte migration, indicating strong immunomodulatory activity [95].

## 6.6 Lipid-Lowering Activity

Oral administration of *O. sanctum* oil significantly decreased serum triacylglycerol, total cholesterol, and LDL+VLDL cholesterol levels in cholesterol-fed rats. The treatment also reduced the atherogenic index, highlighting cardiovascular benefits [46].

## 6.7 Some Notable Neuroprotective Potential of *Ocimum sanctum*

*Ocimum sanctum* exhibits significant neuroprotective potential in various experimental models. In rotenone-induced Parkinson's disease in rats, Tulsi treatment ameliorated neuronal damage [96]. Hydroalcoholic extracts, rich in polyphenols and flavonoids, demonstrated strong antioxidant activity against DPPH, ABTS, and hydroxyl radicals, protecting neuronal cells from oxidative stress-induced damage by preventing lipid peroxidation, DNA fragmentation, ROS generation, and mitochondrial membrane depolarization. The extracts also enhanced catalase and superoxide dismutase activities, reduced HSP-70 overexpression, and maintained cellular integrity [73]. Furthermore, ethanolic extracts stimulated choline acetyltransferase expression in human cerebral microvascular endothelial cells, supporting cognitive function and neuronal protection [97]. These studies collectively suggest that Tulsi's crude extracts and bioactive components may provide a multifaceted approach to neurodegenerative disease management, primarily through antioxidant and anti-apoptotic mechanisms [98].

## 7. Conclusion

Tulsi (*Ocimum sanctum*) is a historically revered herb with a wide range of pharmacological activities. Although preclinical and limited clinical studies indicate its neuroprotective potential, further human clinical trials are necessary to fully elucidate its benefits and mechanisms. Neuroprotective antioxidants, such as those in Tulsi, represent promising interventions for slowing neurodegeneration and limiting neuronal loss. *O. sanctum* demonstrates diverse pharmacological actions, including antioxidant, anti-inflammatory, lipid-lowering, anticholinesterase, and immunostimulatory effects, supporting its potential in dementia and other neurodegenerative disorders. Future studies, including double-blind clinical trials and mechanistic investigations in animal and cell culture models, are essential to comprehensively understand Tulsi's therapeutic potential. This chapter provides a detailed overview of *O. sanctum*, encompassing its traditional usage, phytochemistry, pharmacological activities, and neuroprotective properties, while highlighting research gaps and future opportunities for drug development. Overall, *O. sanctum* emerges as a promising candidate for neuroprotection and as a source of bioactive compounds for therapeutic exploration in neurodegenerative diseases.

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