

 REVIEW  
ARTICLE

# Comparative summary of the ethnomedicinal use, phytochemical constituents, and pharmacological properties of *Syzygium aromaticum* and *Ocimum sanctum*



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## ABSTRACT

Medicinal plants are the primary sources of easily accessible remedies frequently used by the traditional people in developing regions. It is a common practice for sick people to combine conventional medicine with traditional medicine. Clove and Tulsi are among the most widely used herbs prescribed for their therapeutic benefits in a wide range of ailments. The purpose of this review was to accumulate and compare the benefits of both plants by focusing on their phytochemical and nutraceutical components and biological responses. Ethnomedicinal data were obtained through extracting information from journals, books, and websites belonging to the therapy. The study categorized the pharmacological properties possessed by these two plants according to their bioactive compounds, among which eugenol was found most potent and commonly present in both offering antioxidant, and anesthetic activities. Other common phytochemical components of essential oils include  $\alpha$ -Pinene,  $\beta$ -Pinene, Limonene, and Camphene, 1.8-Cineole,  $\alpha$ -Terpineol,  $\beta$ -Caryophyllene, Germacrene D,  $\delta$ -Cadinene,  $\alpha$ -Selinene,  $\alpha$ -Cadinol, etc. In literature, both these plants have been reported to have a wide variety of pharmacological potentials including antimicrobial, anticancer, anti-inflammatory, chemopreventive, radioprotective, cardioprotective, hepatoprotective, anthelmintic, anticoagulant activities. The study also identified some key areas as opportunities for further scientific investigations such as assessment of safety profile of co-administration, alternative use, nutraceutical values, and disease-specific dose determination, etc. The study compiled comparative information to aid scientists for additional research and the tribal communities for specifying targeted use against particular diseases.

## Keywords

Clove,  
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## INTRODUCTION

Natural plants have long been used as medicinal agents due to their biological and pharmacological activities since ancient times. Different parts of plants and their crude extracts have been employed for centuries in herbal medicine to prevent diseases, both therapeutically and prophylactically. Clove and Tulsi are known for their ethnomedicinal values and are considered abundant sources of bioactive compounds. Different compounds and plant parts of these herbs have been found to ameliorate various clinical conditions.

Clove (*Syzygium aromaticum*) is an aromatic plant, belonging to Myrtaceae family (Table 1). It is indigenous to the Maluku Islands, off the coast of east Indonesia. However, it is currently grown in Sri Lanka, India, Madagascar, Malaysia, Tanzania (Zanzibar Island) and in the northeast regions of Brazil [1]. The whole and ground cloves are used to enhance the flavor of dishes. They are utilized as a carminative to promote peristalsis and enhance gastric hydrochloric acid [2]. It has been proven to be a good anesthetic for sedating fish in a variety of invasive and noninvasive fisheries management and research techniques [3]. Furthermore, clove essential oil possesses a wide range of biological activities, including antibacterial, antioxidant, antifungal, antiseptic, and insecticidal effects [4-6]. The abundance of eugenol, a highly potent pharmacologically active compound, in

clove essential oil is responsible for most of the biological activities however, other compounds are still in research.

Tulsi (*Ocimum sanctum* L.) is an aromatic shrub belonging to the Lamiaceae family of basil (tribe ocimeae). It originated in north-central India and is now cultivated as a native species in the eastern tropics of the world [7]. Tulsi is one of the most well-known examples of Ayurveda's holistic approach to healthcare. Tulsi has been included in spiritual and lifestyle practices in India, which is due to its wide range of health benefits. Several types of research have been conducted based on traditional Ayurvedic wisdom to investigate the medicinal benefits of tulsi and have suggested that this herb is a tonic for the body, mind, and spirit that can treat a variety of modern-day health issues. Tulsi is said to improve the appearance of the skin, the sweetness of the voice, and the development of intelligence, and stamina [8,9]. Leaves, fruits, essential oils of tulsi exert anti-tussive, antioxidant, antimicrobial, radioprotective, antihypertensive, and immunomodulatory effects [10-14].

This review mainly focused on the comparative study of *Syzygium aromaticum* (Clove) and *Ocimum sanctum* (Tulsi) depending on their nutraceutical values, compositions, essential oils, traditional applications, biological and toxic effects in order to have a clear concept of the similarities and dissimilarities between the two medicinal plants.

**Table 1:** Taxonomical classification of *S. aromaticum* and *O. sanctum* [15,16]

<b>Classification</b>	<b><i>S. aromaticum</i></b>	<b><i>O. sanctum</i></b>
Kingdom	Plantae	Plantae
Order	Myrtales	Lamiales
Family	Myrtaceae	Lamiaceae
Genus	<i>Syzygium</i>	<i>Ocimum</i>
Species	<i>S. aromaticum</i>	<i>O. tenuiflorum</i>
Binomial Name	<i>Syzygium aromaticum</i> (L.) Merr. & L.M. Perry	<i>Ocimum sanctum</i> L.
General Name	Clove	Holy Basil

## Ethnomedicinal Use

*Syzygium aromaticum* (clove) and *Ocimum sanctum* (tulsi) have been documented as the most prominent sources of traditional medicine for centuries. Approximately 80% of the world's population currently depends on traditional medicines as a primary source of health treatment [17]. Different parts of these plants are traditionally used in Ayurveda and Siddha medicine to prevent and treat a variety of illnesses and everyday ailments which have been shown in Table 2. Within Ayurveda practice, tulsi is renowned as "The Queen of Herbs," "Mother Medicine of Nature" and is

revered as an "elixir of life". It is said that daily consumption of tulsi prevents disease, promotes general health, wellbeing, and further helps to manage the stresses of daily life. Chewing leaves helps to treat cold and sore throat [18]. In ancient times, the leaves are used to treat a variety of fevers such as boiled leaves are taken with tea as a treatment to prevent dengue and malaria fever whereas dried powder of leaf is used to cure teeth disorder [19]. On the other hand, cloves have traditionally been used as a remedy for indigestion, nausea, and vomiting. Cloves have been used to cure a variety of illnesses including malaria, cholera, and tuberculosis in tropical Asia. In America, it's used to treat different types

of worms and viruses, candida, and a number of protozoan and bacterial infections. In addition to their recreational purposes, cloves are said to be a natural anthelmintic [20].

**Table 2:** Comparison of ethnomedicinal uses between *S. aromaticum* and *O. sanctum* plant parts

<i>Ethnomedicinal Use</i>	<i>S. aromaticum</i>	<i>O. sanctum</i>
Diabetes	Flower [21], Essential Oil [22,23]	Leaves [24]
Emetic Syndrome	Flower [25]	Leaves [26]
Common Colds, Headaches, Flu, Earache, Migraine, Chronic Fever	Flower [27], Essential Oil [27]	Leaves [28], Essential oil [29]
Cholic Pain, Arthritic Pain, Inflammation	Essential Oil [30]	Leaves [31], Seeds [32], Whole Plant [33]
Burn, Wound, Snakebite, Insect bite	Essential Oil [34]	Leaves [35], Whole Plant [36]
Ulcers, Diarrhea, Dysentery, Digestive Disorders	Flower [37]	Leaves [38,39]
Skin Diseases	Essential Oil [40]	Leaves [41]
Bronchial Asthma, Cough, Sore Throat,	Essential Oil [42]	Leaves [43]
Heart Disease	Flower [44]	Leaves [45], Seeds [46]
Night Blindness, Eye Infection, Eye Health	Essential Oil [47]	Leaves [26]
Scabies, Cholera, Malaria, and Tuberculosis	Flower, Whole plant [48]	Leaves [49], Root [50]
Bacterial, Fungal and Protozoal Infections	Flower [51], Essential Oil [52- 55]	Essential Oil [56]
Carcinoma	Flower [57]	Leaves [58], Seeds [59]
Muscular Cramp	Essential Oil [60]	Flower [61]
Fatigue	Not reported	Leaves [62]
Memory Improvement	Flower [63]	Whole Plant [64]
Worm Remedy	Essential Oil [65]	Flower [66], Leaves [67]
Immune Booster	Essential Oil [68,69]	Leaves [70]
Mosquito Repellent	Essential Oil [71]	Root, Stem [50]
Parasites	Essential Oil [72]	Not reported
Tooth Infections and Toothaches	Flower [73]	Not reported
Tonic, Stimulant	Essential Oil [36]	Leaves [27]
Convulsions	Not reported	Leaves [74]
Insomnia	Not reported	Leaves [75]
Mouth and Urinary Tract Infection	Not reported	Leaves [76]
Anxiolytic, Antidepressant	Not reported	Leaves [77], Root [78]

Alongside, these two are popular as condiments and flavoring agents in preparing traditional dishes as well as common ingredients in formulating toothpaste commercially [79,80].

### Nutraceutical Compounds

The composition of a clove varies slightly as it is produced, processed, and stored in the agro-climatic conditions. A typical evaluation determines the following approximate chemical composition of clove: volatile oil (13.2%), non-volatile ether (15.5%), carbohydrate (57.7%), protein (6.3%), crude fibre (11.1%), mineral matter (5.0%), calcium (0.7%), phosphorus (0.11%), iron (0.01%), sodium (0.25%), potassium (1.2%), ash insoluble in HCl (0.24%), vitamins (mg/100g): Vit A: 175 I. U., Vit B1: 0.11, Vit B2: 0.04, niacin:1.55, Vit C:80.9 and calorific value (food energy): 430 calories/100g [20]. The

nutritional analysis of *Ocimum sanctum* exhibits a high level of protein (30 Kcal, 4.2 g), carbohydrate (2.3 g), and fat (0.5 g) contents. It also contains vitamin A and C (25 mg per 100 g), and minerals such as calcium (25 mg), iron (15.1 mg), and phosphorus (287 mg) [9].

### Phytochemical Constitutes

The nature of compounds present in medicinal herbs can be identified through phytochemical analysis. It is also performed to evaluate the effects of available bioactive components. Phytochemical constituents such as eugenol, polyphenols, flavonoids have been considered to be a valuable source for the development of innovative pharmaceutical compounds that have been utilized to treat serious ailments [81]. Clove and tulsi possess a wide range of phytocompounds that have been compared in Table 3. Among them, the content of eugenol is found to

be the most common in both these plants apart from other mutual compounds such as gallic acid, oleanolic acid, stigmasterol, campesterol, etc. Besides, these medicinal plants also contain bicyclic sesquiterpenes, phenolic

compounds, phenolic acids, triterpenes, C-glucosides, flavonoids, tannins, triterpenoid saponins, and steroids which have been demonstrated to have pharmacological actions.

**Table 3:** Comparison of phytochemical compounds of whole plants of *S. aromaticum* and *O. sanctum*.

Group	<i>S. aromaticum</i>	<i>O. sanctum</i>
Essential Oil	Eugenol [27]	Eugenol [82]
Bicyclic sesquiterpene	$\beta$ -caryophyllene [83]	Caryophyllene oxide [84]
Phenolic compounds	Vanillin, Eugenitin, Eugenin	Rosmarinic acid [85]
Triterpenes	Crategolic acid (Maslinic acid) [86]	Betulinic acid
Flavonoid	Kaempferol, Rhamnetin, Myricetin [87]	Apigenin, cirsimaritin, isothymusin, isothymonin, Orientin [88], Vicenin [89]
Phenolic acid	Gallic acid [90]	Gallic acid, p-Hydroxy-benzoic acid, Chlorogenic acid, Sinapic acid, Vanillic acid [91]
Fatty acid	Omega-3 [92]	Propanoic acid [9]
Tannin	Bicornin, gallotannic acid, methyl salicylate [93]	Not reported
Triterpenoid saponin	Oleanolic acid [93]	Ursolic acid, oleanolic acid [82]
Steroid	Stigmasterol, and campesterol [93]	$\beta$ -sitosterol, stigmasterol, campesterol, ergosterol [94]
C-glycoside	Biflorin, Isobiflorin [95]	Not reported

**Table 4:** Comparison of phytochemical constituents of essential oils of *S. aromaticum* and *O. sanctum*.

Terpenes	<i>S. aromaticum</i> [96]	<i>O. sanctum</i> [91]
Monoterpene Hydrocarbons	$\alpha$ -Pinene, $\beta$ -Pinene, Limonene, $\Delta^3$ -Carene, Cis- $\beta$ -Ocimene, Trans- $\beta$ -Ocimene, Terpinene-4-o, Pulegone	$\alpha$ -Pinene, Camphene, Sabinene, $\beta$ -Pinene, Limonene
Oxygenated Monoterpenes	1,8-Cineole, Linalol, $\alpha$ -Terpineol, $\alpha$ -Terpinyl Acetate, Carvone	1,8-cineol, cis-Sabinenehydrate, Linalool, Camphor, Borneol, $\alpha$ -terpinenol, D-carvone, Anethole, Eugenol
Sesquiterpene Hydrocarbons	$\alpha$ -Cubebene, $\alpha$ -Copaene, $\beta$ -Bourbonene, $\epsilon$ -Cadinene, $\beta$ -Caryophyllene, Zonarene, $\alpha$ -Caryophyllene, $\gamma$ -Muurolene, Germacrene D, $\alpha$ -Muurolene, $\alpha$ -Selinene, $\alpha$ -Farnesene, $\delta$ -Cadinene, $\gamma$ -Cadinene, Cadina-1.4-diene, $\alpha$ -Amorphene, Calamenene, Jasmine, Isocaryophyllene oxide	$\gamma$ -Elenene, $\beta$ -Elemene, $\alpha$ -Gurjunene, $\beta$ -Caryophyllene, $\beta$ -cubebene, $\beta$ -gurjunene, Alloaromadendrene, Germacrene D, $\beta$ -Selinene, $\alpha$ -Selinene, $\beta$ -Bisabolene, $\delta$ -Cadinene, 1-4, Cadinadiene, $\alpha$ -Calacorene
Oxygenated Sesquiterpenes	Epoxy-6.7-humulene, Caryophyllenol, Cubenol, Sesquiterpenol, $\alpha$ -Cadinol,	Nerolidol, Spathulenol, Caryophyllene oxide, $\alpha$ -Cadinol, Aromadendrene oxide
Others Compounds	2-Heptanone, Heptyl acetate, 2-Methyl-6-methylene-1.7-octadien-3-one, Sulcatone, 2-Nonanone, 2-Undecanone, Methyl benzoate, Acetophenone, Ethyl benzoate, Dihydrocarvyl acetate, Benzyl acetate, Methyl salicylate, Methyleugenol, Acetyeugenol, Chavicol, Isoeugenol, Caryophylla-3.7-dien-6-ol, 2. 3. 4-trimethoxyacetophenone, Benzyl Benzoate	Eicosane, Tricosane

### Phytochemical Constitutes of Essential Oil

Terpenes, or terpenoids, are the most abundant and diversified class of naturally occurring chemicals in natural plants. They are categorized as mono, di, tri, tetra, as well as sesquiterpenes depending on the number of isoprene units they contain. Table 4 categorizes monoterpene, oxygenated monoterpenes, sesquiterpene hydrocarbons, oxygenated sesquiterpenes and other compounds present in clove and tulsi. Among monoterpene hydrocarbons, both plants are enriched with  $\alpha$ -Pinene,  $\beta$ -Pinene, Limonene, and Camphene. Besides, some compounds such as 1,8-Cineole,  $\alpha$ -Terpineol,  $\beta$ -Caryophyllene, Germacrene D,  $\delta$ -Cadinene,  $\alpha$ -Selinene,  $\alpha$ -Cadinol contained by sesquiterpenes are the most common in these two natural herbs [91,96].

### Toxicological Studies

Many studies have reported several therapeutic actions of *S. aromaticum* and *O. sanctum*. The World Health Organization (WHO) found that the daily amount of clove that is acceptable in humans is 2.5 mg/kg of weight whereas the daily consumption of tulsi is 30 ml/kg (Table 5). It can cause possible side effects such as liver damage, seizures, and fluid imbalances. There have not been found noteworthy evidences about clove's safety in medicinal doses [97]. However, it has been recommended to avoid its use for pregnant or breastfeeding women [97]. In respect of tulsi, studies revealed favorable therapeutic results with low or no side effects for formulations, irrespective of dose, or for any participant's age or gender [28].

**Table 5:** Toxic Dose and Safety profile of *S. aromaticum* and *O. sanctum*.

Findings	<i>S. aromaticum</i>	<i>O. sanctum</i>
Toxic Dose	Equal or greater than 1500 mg/kg [98]	55 ml/kg [99]
Maximum Daily Intake	2.5 mg/kg[35]	30 ml/kg [99]
LD50	18.2 $\pm$ 5.52 mg/ml in <i>Danio rerio</i> and 21.7 $\pm$ 0.8 mg/ml in <i>Poecilia reticulata</i> at 96h[100]	42.5 ml/kg 99]
Adverse Reaction	Spermicidal activity in males, allergic action when used in dentistry, increased endogenous redox enzyme levels and Reduced lipid peroxidation in humans resulted in disseminated intravascular coagulopathy, generalized seizures, and hepatotoxicity, detoxification, and cardiac health effects, allergic contact dermatitis in guinea pigs[98] [101]	Clinical trial reporting transient moderate nausea [102]

The absence of any adverse effects does not rule out the possibility of long-term side effects. However, the long traditional history of daily usage of tulsi indicating any major long-term health risks are rare and daily intake of tulsi has been reported safe [28].

### Biological Responses

Clove and Tulsi are essential therapeutic plants because of the extensive spectrum of pharmacological properties accumulated over centuries of traditional use and documented in literatures. These plants are abundant with many phytoconstitutes that leads many researchers to identify specific compounds in response to particular disease. Eugenol, the major compound of clove is reported to participate in photochemical reactions [103]and photocytotoxic properties [104]. In 1995, the radioprotective effect of *Ocimum sanctum* was first documented [105]. Besides, clove and tulsi both plants have showed antibacterial, antifungal, anticarcinogenic,

analgesic, cardioprotective, anti- inflammatory, anti-fertility activities depending on their phytoconstituents. Table 6 represents biological responses of both plants according to their phytochemicals.

### RECOMMENDATIONS

The review recommends a wide range of pharmaceutical activities categorized based on their bioactive compounds. However, it also identified opportunities for further investigations in vital areas. As such, no studies were found on the co-administration (intake) of these two plants in laboratory or human model to identify their safety profile, adverse reactions or contraindications whereas, in vice versa, no report suggested their use in ailments alternatively. Moreover, very few studies documented the nutrients presents in isolated parts of these herbs. In addition, no studies were found on determining the daily intake or safe doses individually for particular diseases or disorder. Thus, current comparison

**Table 6:** Comparative summary of pharmacological properties of *S. aromaticum* and *O. sanctum* by representing the biological response

Pharmacological Activity	<i>S. aromaticum</i>		
	Biological Response	Bioactive Compounds	Biological Response
Antimicrobial activity	<ol style="list-style-type: none"> <li>1. Acts against non-toxigenic strains of <i>E. coli</i> O157:H7 [106]</li> <li>2. Active against foodborne gram-positive bacteria (<i>S. aureus</i>, <i>B. cereus</i>, <i>E. faecalis</i>, <i>L. monocytogenes</i>) and gram-negative bacteria (<i>E. coli</i>, <i>Y. enterocolitica</i>, <i>S. choleraesuis</i>, <i>P. aeruginosa</i>) [51]</li> <li>3. Suppress growth of methicillin-resistant clinical isolates at 1000 and 500mg/ml concentration[51]</li> <li>4. Inhibits growth of 31 strains of <i>H. pylori</i> [51]</li> <li>5. Active against yeasts and filamentous fungi [107]</li> </ol>	<p>Eugenol, eugenyl acetate, <math>\beta</math>-Caryophyllene, 2-heptanone, [108] acetyl-eugenol, <math>\alpha</math>-humulene, methyl salicylate, iso-eugenol, methyl-eugenol, [109] phenyl propanoides, dehydrodieugenol, trans-coniferyl aldehyde, biflorin, kaempferol, rhamnetin, myricetin, gallic acid, ellagic acid and oleanolic acid [110]</p>	<ol style="list-style-type: none"> <li>1. Inhibits cell growth of <i>E. coli</i>, <i>S. aureus</i> and <i>proteus</i> by aqueous extract [106]</li> <li>2. Inhibits multidrug-resistant strains of <i>cholera</i> by alcoholic extract [107]</li> <li>3. Potential effect against <i>N. gonorrhoeae</i> [113]</li> <li>4. Inhibits <i>P. aeruginosa</i>, <i>S. aureus</i> and <i>O. sanctum</i> fixed oil [114]</li> </ol>
Antioxidant activity	<ol style="list-style-type: none"> <li>1. Strong antioxidant efficiency compared to BHA and pyrogallol [115]</li> <li>2. Suppresses linoleic acids lipid peroxidation by clove oil at 15ug/ml. Scavenging potential by lower concentration of essential oil compared to eugenol, BHA, BHI [98]</li> <li>3. Improves kidney and liver functions as well as antioxidant status [116]</li> <li>4. Provides potential protection against cell damages induced by H<sub>2</sub>O<sub>2</sub> [87].</li> <li>5. Protective effect against CCL<sub>4</sub> induced fibrosis [117]</li> </ol>	<p>Eugenol, <math>\beta</math>-caryophyllene, Vanillin, Kaempferol, Rhamnetin, Gallic acid, Biflorin, Myricetin [98,116]</p>	<ol style="list-style-type: none"> <li>1. Protects membrane by flavonoid compounds [118]</li> <li>2. Reduces radiation-induced lipid peroxidation significantly in the mouse liver [119]</li> <li>3. Processes high scavenging activity against free radicals [34]</li> <li>4. Decreases lipid peroxidation significantly after mercury (HgCl<sub>2</sub>) poisoning [120]</li> </ol>
Anticancer activity	<ol style="list-style-type: none"> <li>1. Exhibits anticarcinogenic and antimutagenic potential [121,122]</li> </ol>	<p>Oleanolic acid, Eugenol [123,91]</p>	<ol style="list-style-type: none"> <li>1. Modulates carcinogen metabolism by inducing cytochrome P450, aryl hydrocarbon receptor [124]</li> </ol>

<b>Pharmacological Activity</b>	<b><i>S. aromaticum</i></b>		
	<b>Biological Response</b>	<b>Bioactive Compounds</b>	<b>Biological Response</b>
Anticancer activity (cont.)	<ol style="list-style-type: none"> <li>2. Plays chemopreventive role for lung, skin and digestive cancers [87]</li> <li>3. Prevents tumor growth and encourages cell cycle arrest and apoptosis [123]</li> <li>4. Interferes with NF-κB and other cells signaling pathways [87]</li> <li>5. Inhibits malignant melanoma, of both anchorage-dependent and anchorage-independent growth, reduce tumors size and blocks melanoma invasion and metastasis [124]</li> <li>6. Prevents cervical carcinoma and gemcitabine at low concentrations [ 91]</li> <li>7. Decreases the possibility of apoptosis of Bcl-2, COX-2 and IL-1β, lessens inflammation, and facilitates the efficacy of gemcitabine [87]</li> <li>8. Displays better remedial effects in skin malignancy and melanoma [87]</li> </ol>	(cont.)	<ol style="list-style-type: none"> <li>cytochrome b5, and glutathion</li> <li>alcoholic extract of tulsi leaves</li> <li>2. Inhibits human fibrosarcoma</li> <li>cytoplasm, condensed nuclei,</li> <li>[126]</li> <li>3. Reduces benzo(a)pyrine induc</li> <li>neoplasia in mice as well as 3'</li> <li>dimethylaminoazobenzene indu</li> <li>[127]</li> <li>4. Inhibits chemically induced sk</li> <li>[128]</li> <li>5. Induces papillomagenesis sign</li> <li>tumour incidence, average nu</li> <li>or/and cumulative number of</li> <li>6. Elevates reduced GSH content</li> <li>7. Prevents early events of DMB</li> <li>carcinogenesis by oral treatm</li> <li>8. Blocks or suppresses the even</li> <li>chemical carcinogenesis by in</li> <li>activation of the carcinogen [1</li> <li>9. Protects Swiss Albino mice ag</li> <li>carcinoma (EAC) and S 180 tu</li> </ol>
Anti-inflammatory activity	<ol style="list-style-type: none"> <li>1. Inhibits respiratory inflammation by essential oil [133]</li> <li>2. Lessens musculoskeletal pain and nasal congestion by COX-2 inhibition [134]</li> <li>3. Alleviates cold, cough, asthma, bronchitis and sinusitis through inhalation of aromatic oil [135]</li> <li>4. Mimics endolac at 0.025 and 0.1 ml/kg and Indomethacin at 0.05 and 0.2ml/kg doses.</li> <li>5. Decreases the volume of pleural exudates keeping the total blood leukocyte count unchanged at 200 and 400 mg/kg [136]</li> </ol>	Flavonoids including kaempferol, rhamnetin and β-Caryophyllene [135] and eugenol [136]	<ol style="list-style-type: none"> <li>1. Shows analgesic, antipyretic, a</li> <li>in acute and chronic inflamma</li> <li>2. Restores the stress alteration</li> <li>(leucopenia, elevated corticos</li> <li>neutrophil functions) values t</li> <li>a stress-relieving action [138]</li> </ol>

<b>Pharmacological Activity</b>	<b><i>S. aromaticum</i></b>		
	<b>Biological Response</b>	<b>Bioactive Compounds</b>	<b>Biological Response</b>
Chemo-preventive activity	<ol style="list-style-type: none"> <li>1. Inhibits cell multiplication during carcinogenesis.</li> <li>2. Lowers COX-2 levels 13.49 % and 55.93%, by clove infusion on 17th and 26th weeks of carcinogenesis [59]</li> </ol>	Eugenol [140]	<ol style="list-style-type: none"> <li>1. Promotes antiproliferative and anti-inflammatory activities in mice [141]</li> <li>2. Elevates levels of reduced GSH in stomach tissues [141]</li> </ol>
Radio-protective activity	<ol style="list-style-type: none"> <li>1. Promotes radioprotective activity by inhibiting lipid peroxidation, showing strong reducing power, and superoxide radical scavenging activity [143]</li> </ol>	Polyphenol, trace element [144]	<ol style="list-style-type: none"> <li>1. Protects human lymphocytes from damage by radiation at low and non-toxic doses of radiation [145]</li> <li>2. Potentiates radioprotective activity by increasing protection of bone marrow from the toxicity of WR-2721 [145]</li> </ol>
Anti-hypertensive and cardio-protective activities	<ol style="list-style-type: none"> <li>1. Minimizes the risk of cardiovascular disease, arterial sclerosis, and many other conditions linked to oxidative stress. [35]</li> <li>2. Responsible for reversible and negative inotropic effects in the heart muscle.[35]</li> <li>3. Acts as smooth muscle relaxant and hypotensive agent [35]</li> </ol>	Eugenol [35]	<ol style="list-style-type: none"> <li>1. Prevents temporary and long-term hypotension and hypoperfusion [34]</li> <li>2. Shows hypotensive effect in an experimental animal peripheral vasodilatory activity [34]</li> <li>3. Protects Wister rats from isoproterenol-induced myocardial necrosis by increasing the levels of antioxidant [146]</li> <li>4. Inhibits the transcriptional expression of genes modulating atherogenesis by decreasing cytokine production and cellular adhesion molecules in the arterial wall [147]</li> <li>5. Lowers serum cholesterol, LDL-cholesterol and triacylglycerol levels, showing a hypocholesterolemic effect [9]</li> <li>6. Decreases blood total cholesterol, triglycerides, phospholipids, and LDL-cholesterol levels, and a significant increase in HDL-cholesterol levels [148]</li> </ol>
Hepato-protective activity	<ol style="list-style-type: none"> <li>1. Lowers alkaline phosphatase activity indicating hepatoprotective effect of clove oil [150]</li> </ol>	Flavonoids and polyphenolic [150]	<ol style="list-style-type: none"> <li>1. Protects liver injury induced by carbon tetrachloride administration [151]</li> <li>2. Prevents carbon tetrachloride (CCl<sub>4</sub> subcutaneously)-induced liver damage [89]</li> </ol>

<b>Pharmacological Activity</b>	<b><i>S. aromaticum</i></b>		
	<b>Biological Response</b>	<b>Bioactive Compounds</b>	<b>Biological Res</b>
Anthelmintic activity	<ol style="list-style-type: none"> <li>1. Reveals anthelmintic property against <i>H. contortus</i> worms.</li> <li>2. Effectively kills worms at high concentrations where 100% mortality was attained within minutes of exposure [153]</li> </ol>	Phenolics, Tannins and Alkaloids[154]	<ol style="list-style-type: none"> <li>1. Shows putative anthelmintic a elegance model [155]</li> <li>2. Impacts in non-hatching of egg larvae, and paralysis and death of gastrointestinal nematodes [156]</li> </ol>
Analgesic activity	<ol style="list-style-type: none"> <li>1. Helps to inhibit inflammatory mediators such as prostaglandins, leukotrienes [87]</li> <li>2. Inhibits pain perception by suppressing sensory receptor [157]</li> <li>3. Lowers the action potential conduction [158]</li> <li>4. Inhibits NMDA - GABA receptor stimulation which are involved in pain sensitivity [159]</li> </ol>	Eugenol [157]	<ol style="list-style-type: none"> <li>1. Effective against acetic acid induced pain in mice in a dose dependent manner [160]</li> <li>2. Processes combined inhibitory effects on prostaglandins, histamine and serotonin [161]</li> </ol>
Central Nervous System (CNS) depressant activity	<ol style="list-style-type: none"> <li>1. Prevents convulsions through inhibitory activity via strychnine and picrotoxin effects at glycine and GABAA receptor sites, respectively by clove essential oil [87]</li> <li>2. Promotes hypnotic and anxiolytic effects by increasing the concentration of GABA in the brain[99]</li> </ol>	Eugenol, B-Caryophyllene, Humulene [99]	<ol style="list-style-type: none"> <li>1. Extends the period of lost reflex recovery and severity of electrical pentylenetetrazole-induced convulsions [162]</li> <li>2. Reduces apomorphine-induced hyperlocomotion [161]</li> <li>3. Increases swimming time in antidepressant mimicking doses [163]</li> <li>4. Increases sleeping time in rats pretreated with pentobarbitone [46]</li> <li>5. Enhances the levels of dopamine (DA), 5-HT, and 5-HT turnover in nucleus accumbens areas during sub-chronic noise stress [164]</li> <li>6. Prevents the noise-induced increase in neurotransmitters without affecting their release, indicating probable herbal treatment of noise-induced biogenic amine alterations [165]</li> </ol>
Antipyretic activity	<ol style="list-style-type: none"> <li>1. Mimics acetaminophen intragastrically and intravenously to treat fever [165]</li> </ol>	Eugenol [165]	<ol style="list-style-type: none"> <li>1. Reduces the febrile response in mice and activity against typhoid-paratyphoid fever induced pyrexia in rats [166], exhibiting antipyretic effect at a dose of 300 mg/kg [167]</li> </ol>

Pharmacological Activity	<i>S. aromaticum</i>		
	Biological Response	Bioactive Compounds	Biological Res
Antidiabetic activity	<ol style="list-style-type: none"> <li>1. Contributes hypoglycemic effect via molecular dynamics, molecular mechanic and molecular Docking [167]</li> </ol>	Acetyeugenol, Eugenol, alpha-Humulen [167]	<ol style="list-style-type: none"> <li>1. Potentiates the action of exogenous insulin on fasting blood glucose and glucose tolerance in a randomized trial [169]</li> <li>2. Reduces fasting and postprandial glucose levels in a randomized trial [169]</li> <li>3. Processes aldose reductase activity and prevents complications of diabetes such as neuropathy, etc [170]</li> </ol>
Antiulcer activity	<ol style="list-style-type: none"> <li>1. Prevents ethanol- and indomethacin-induced stomach ulcers in rat model [172]</li> <li>2. Improves gastrointestinal health, particularly in chronic alcohol users [171]</li> <li>3. Provides gastroprotective effect via synthesis of mucus [172]</li> </ol>	Eugenol, Clovinal [171,172]	<ol style="list-style-type: none"> <li>1. Elicits notable antiulcer activity against indomethacin, reserpine, histamine (50%), serotonin or stress-induced ulcers [171]</li> <li>2. Possesses antiulcer activity due to its inhibitory effects, histamine and antisecretory activities [173]</li> </ol>
Antiarthritic activity	<ol style="list-style-type: none"> <li>1. Promotes bone-preserving efficacy by the hydroalcoholic extract of dried clove buds in ovariectomised rat model of osteoporosis [174]</li> </ol>	Eugenol [30]	<ol style="list-style-type: none"> <li>1. Improves in formaldehyde induced arthritis comparable to aspirin [166]</li> <li>2. Inhibits inflammatory mediators such as histamine, bradykinin and PGE<sub>2</sub> induced arthritis and joint edema [166]</li> </ol>
Adaptogenic activity/anti-stress activity	<ol style="list-style-type: none"> <li>1. Shows significant antidepressant like activity against monoamine oxidase in CD-1(ICR) mice [176]</li> </ol>	Eugenol [176]	<ol style="list-style-type: none"> <li>1. Shows adaptogenic activity via its capacity [177]</li> <li>2. Increases resistance to a variety of biological changes [89]</li> </ol>
Anesthetic Activity	<ol style="list-style-type: none"> <li>1. Exhibits slight anesthetic activity in humans and fish by <i>S. aromaticum</i> oil [178, 179]</li> <li>2. Blocks prostaglandin H (PHS) production [180]</li> <li>3. Able to anesthetize rabbit fish (<i>Saiganus lineatus</i>), rainbow trout (<i>Oncorhynchus mykiss</i>), and coral reef fish (<i>Pomacentrus amboinensis</i>), crabs [181]</li> <li>4. Generates fast anesthesia in Zebra fish with a short recovery time [87]</li> </ol>	Eugenol [180]	<ol style="list-style-type: none"> <li>1. Exhibits the shortest induction time and highest anesthetic activity to fish [87]</li> </ol>

<b>Pharmacological Activity</b>	<b><i>S. aromaticum</i></b>		
	<b>Biological Response</b>	<b>Bioactive Compounds</b>	<b>Biological Res</b>
Anticoagulant activity	<ol style="list-style-type: none"> <li>1. Inhibits human platelet aggregation on stimulated platelet activating factor, arachidonic acid (AA) or collagen [87]</li> <li>2. Protects PAF against AA at induced thrombosis [87]</li> <li>3. Reduces the production of thromboxane A2 and 12-HETE by human platelets treated with [C [14]] AA. [182]</li> <li>4. Suppresses in vitro prostaglandin biosynthesis, formation of thromboxane B2, and arachidonic acid-induced platelet aggregation in vitro [83][183]</li> <li>5. Supersedes aspirin in preventing platelet aggregation induced by arachidonate, adrenaline and collagen.</li> <li>6. Exerts equivalent efficacy to indomethacin in arachidonate induced aggregation [184]</li> </ol>	Eugenol and acetyl eugenol [184]	<ol style="list-style-type: none"> <li>1. Prolongs blood clotting time in antiaggregatory action of oil o to aspirin [149]</li> <li>2. Increases blood clotting time a and could be due to inhibition</li> </ol>
Immuno-modulatory activity	<ol style="list-style-type: none"> <li>1. Increases humoral and cell-mediated immune responses via immunomodulatory action[185]</li> </ol>	Not reported	<ol style="list-style-type: none"> <li>1. Modifies humoral immune res formation [82]</li> <li>2. Influences both humoral and o responses, and GABAergic pat</li> </ol>
Antifertility activity	<ol style="list-style-type: none"> <li>1. Decreases and distorts pattern of spermatozoa, thickening of the membrane, vacuolization within seminiferous</li> <li>2. Decreases length and weight of testis considerably [187]</li> <li>3. Inhibits testicular activity administering high and mid dose points a biphasic effect of clove flower bud [188]</li> </ol>	Not reported	<ol style="list-style-type: none"> <li>1. Decreases total sperm count, s of testis [189]</li> <li>2. Reduces sperm count, sperm r reproductive organ weight for</li> <li>3. Reduces the sexual behavioral Wistar rats [190]</li> </ol>
Memory enhancer activity	<ol style="list-style-type: none"> <li>1. Improves learning and memory subsequently through reduction in lipid peroxides [63]</li> <li>2. Improves scopolamine-induced memory deficit at a relatively higher dose (0.1 ml/kg).</li> </ol>	Not reported	<ol style="list-style-type: none"> <li>1. Ameliorates the amnesic impa mg/kg) as well as aging-induc [192]</li> <li>2. Improves step-down latency ( acetylcholinesterase inhibition diseases including dementia a [192]</li> </ol>

recommends further phytochemical and pharmacological analysis to establish clove and tulsi as prescribed natural agents.

## CONCLUSION

The role of natural plants in medicine have always been well-documented in literatures. This review was focused on the comparison of traditional uses, biological responses, chemical compositions, toxicity and safety profiles of clove and tulsi herbs. Alongside the comparative analysis, the study also revealed common constituents and common pharmacological activities among these two plants; which have indicated the role of different bioactive compounds for same biological responses. The review concludes that both clove and tulsi are highly potent pharmacological agents and can be used for different ailments prior assessing their safe dose profile against the particular disease or disorder.

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## Authors' Contributions

Authors MNI structured and organized the project. Author JS collected the findings and prepared the manuscript.

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