A Comprehensive Review on Phytoconstituents and Pharmacological Activity of Holy Basil *Ocimum sanctum* (Tulsi)

Anil K. Yadav*, Yash K. Singh, Pranay Wal, Ashish Srivastava, Ankita Wal, Parul Srivastava, Priyanka Verma, Navdeep Kumar and Shivam Sachan

Pranveer Singh Institute of Technology (Pharmacy), Kanpur, 209305, Uttar Pradesh India

Abstract:

Ocimum sanctum Linn., also referred to as Holy Basil or Tulsi, is a Southeast Asian Ayurvedic plant with a long history of conventional use. The significance of this plant for use in food, medicine, and industry prompted researchers to examine its chemistry and pharmacology. Over 60 chemical substances, including phenolics, flavonoids, phenyl propanoids, terpenoids, fatty acid derivatives, essential oil, fixed oil, & steroids have been identified in O. sanctum. According to the study, tulsi leaf extract contains a number of secondary metabolites, including glucose, tannin, flavonoids, saponins, glycosides, terpenoids, fatty acids, and phenol. Its anti-inflammatory, analgesic, antipyretic, antidiabetic, hepatoprotective, hypolipidemic, antistress, & immunomodulatory properties have been demonstrated by scientific investigations. Preclinical research has also demonstrated that tulsi and some of its phytochemicals, including eugenol, rosmarinic acid, apigenin, myretenal, luteolin, -sitosterol, and carnosic acid, prevented cancers of the skin, liver, mouth, and lung caused by chemicals. These effects were mediated by a rise in antioxidant activity, changes in gene expression, induction of apoptosis, and inhibition of angio. It has been demonstrated that Tulsi's aqueous extract and the flavonoids orientin and vicenin in it shield mice from radiation-induced disease and mortality while protecting normal tissues just from the tumor-crushing effects of radiation.

The pharmacological effects of O. sanctum substances demonstrate their value as drugs and in the standardisation of pharmaceuticals. The creation of new active ingredients and nutraceuticals in the fight against medication resistance and the spread of chronic disease vectors will be aided by this compilation. This review highlights elements that call for further investigation to confirm the activity of the numerous phytoconstituents found in Tulsi as well as their pertinent pharmacological actions.

Keywords: Tulsi, Phenolics, Flavonoids, Anti-inflammatory, Antioxidant and Antidiabetic

Corresponding Author: Anil K. Yadav
Orchid I'd: 0000-0002-6111-2407
Email: anu7364@gmail.com

Introduction:

A well-known "Emporium of medicinal plants" is India. It is one of the 12 major biodiversity centres and has roughly 8% of the world's estimated biodiversity, with about 12600 species. There are two hotspots for biodiversity throughout the Western Ghats as well as the North-Eastern region. (Gordon MC, David JN et al., 2001).

Since the dawn of time, plants have been essential to phytomedicine and are strong biochemists. Today, man may extract an amazing range of industrial chemicals from plants.

Ancient scholarly works like the Atharvaveda (an Indian religious text), Ayurveda (Indian traditional system of medicine), and others have a rich heritage of information on preventive and therapeutic remedies. According to an estimate, over 13000 plant species have been exploited to make medications globally.

Any portion of the plant, such as the bark, leaves, flowers, roots, fruits, seeds, and so on, may include active components when producing plant-based natural constituents. The mixtures of secondary products found in plants are often what give plant materials their positive therapeutic properties, (Gordon MC, David JN et al., 2001)

This idea, according to which the combination of secondary products in a given plant is taxonomically distinct, is consistent with the notion that the medical effects of specific plant species or groupings. (Wink M. 2000) In many laboratories, normal tasks include the systematic screening of plant species with the goal of finding new bioactive chemicals. The identification of the active ingredients in the plants should be a part of further research into medicinal plants. A scientific analysis of the treatments could result in product standardisation and quality control to guarantee their safety. They may be approved for use in primary healthcare after such examination. As in the past, these research initiatives may result in the creation of novel medications. Lead made from analogues of the naturally occurring furanochromone khelline includes conventional antiasthmatic substances such sodium cromolyn and sodium cromoglycate. (Cor JS, et al.,19970) (Visammin). We will therefore have the foundation for creating novel, life-saving medications thanks to pharmacological screening and exploration of the chemical components of the plants.

For its numerous therapeutic benefits, Ocimum sanctum L. (also known as Ocimum tenuiflorum, or Tulsi) has been utilised in Ayurveda for thousands of years. One of the holiest and most revered of the numerous healing and health-giving plants of the orient is tulsi, the Queen of Herbs and the fabled "Incomparable One" of India. Tulsi, the sacred basil, is well-known for its spiritual and religious holiness as well as its significant place in the Eastern systems of holistic medicine and health care known as Ayurveda and Unani. In the Ayurvedic classic known as the Charaka Samhita, Charaka makes reference to it. Tulsi is regarded as an adaptogen since it balances many bodily functions and aids in stress adaptation. Due to its potent perfume and astringent flavour, it is known in Ayurveda as an "elixir of life" and is thought to lengthen life. Tulsi extracts are utilised in Ayurvedic treatments for malaria, different poisonings, headaches, stomach problems, inflammation, and colds. O. sanctum L. is traditionally consumed as fresh leaf, dried powder, or herbal tea. Insect-repelling grains have been used with dried Tulsi leaves for ages. (Biswas NP, et al.,2005)

Ayurveda and lifestyle medicine

The world's oldest medical system and a science of life, Ayurveda takes a holistic approach to health and disease, emphasising the preservation and promotion of good health and the prevention of disease through adopting a healthy lifestyle. Consumption of fresh, minimally processed foods, the use of Rasayanas (formulas) that prevent disease and ageing, sophisticated detoxification techniques, and routine use of apoptogenic herbs are some of these practises. These practises also improve the body's ability to maintain balance in the face of various stressors. When it comes to variety, Ayurveda's use of medicinal and culinary herbs is unmatched by any other medical system. However, none of the herbs employed can compare to the prominence of tulsi or holy basil. (*Ocimum sanctum*).

Divine tulsi

Every component of the tulsi plant is venerated and regarded as sacred in Hinduism, including the leaves, stem, flower, root, seeds, and oil. Even the local soil, which has recently been discovered to contain helpful endophytic fungi, is regarded as a part of the divine. Tulsi serves both utilitarian and ceremonial uses, and as a result, Hindi families are not considered complete without one. Tulsi is often grown in an elaborate earthen pot in the courtyard of a home. For instance, tulsi's distinctive clove-like perfume, which results from its high eugenol content, links the homeowner to the divine while simultaneously warding off mosquitoes, flies, and other dangerous insects. Evening and morning rituals, as well as other spiritual and cleansing practises that may involve sipping tulsi tea or its leaves, further integrate tulsi into daily life.

Tulsi is used ceremonially throughout Hinduism as well as some Greek Orthodox Churches to make "holy water" in addition to sanctifying the home. Tulsi malas, which are bead strings used to aid in mind concentration during meditation, chanting, and devotional activities and so ceremonially unite the mind, body, and spirit, are also made from tulsi wood or seeds.

Thousands of tulsi plants have been planted all around the Taj Mahal in Agra to help shield the famous marble structure from environmental pollution damage. Tulsi has also been utilised in towns to battle air pollution. (Mishra M.2008; Maller C, et al.,2009)

Ocimum sanctum (morphology):

When fully grown, it will stand upright and reach a height of 30 to 60 cm. Simple, aromatic, opposite, obtuse, elliptical, and with dentate margins are the characteristics of its leaves. They can be as long as 5 cm. Purple, elongate racemes with tight whorls make up the flowers. Fruits are tiny and have radish-yellow seeds. After the rainy season, it is planted, and a few months later, it is harvested.

Scientific classification:

Kingdom	**Plantae**
Division	Mangoliophyta
Class	Mangoliopsida
Order	Lamiates
Family	Labiatae
Genus	Ocimum
Species	*O. santum* linn

Tulsi: A potent adaptogen

Tulsi is an aromatic shrub native to the tropics of the eastern continent that belongs to the Lamiaceae (tribe ocimeae) family of basil. (Bast F, et al.,2014) It is believed to have originated in north central India. Tulsi is recognised as an "elixir of life" that is unparalleled for both its therapeutic and spiritual virtues in Ayurveda and is known as "The Incomparable One," "Mother Medicine of Nature," and "The Queen of Herbs." (Singh N, et al.,2010)

Tulsi has been included into spiritual ceremonies and way of life in India, where it offers a wide range of health advantages that modern science is only now beginning to prove. New research on tulsi reveals that it is a tonic for the body, mind, and spirit that provides remedies to a number of contemporary health issues, supporting the traditional Ayurvedic understanding. One of the best representations of Ayurveda's holistic lifestyle approach to health is arguably tulsi. Tulsi is claimed to enter deep tissues, dry tissue secretions, and balance kapha and vata. It has a spicy, bitter taste. The regular ingestion of tulsi is thought to help people cope with daily stress, avoid disease, and increase overall health, happiness, and longevity.

Tulsi is also credited with giving luster to the complexion, sweetness to the voice and fostering beauty, intelligence, stamina and a calm emotional disposition. (Singh N, et al.,2010; Mahajan N, et al.,2013; Mohan L, et al.,2011; Pattanayak P, et al.,2010) Tulsi is also advised as a treatment for a number of ailments, such as anxiety, cough, asthma, diarrhoea, fever, dysentery, arthritis, eye diseases, otalgia, indigestion, hiccups, vomiting, gastric, cardiac, and genitourinary disorders, back pain, skin conditions, ringworm, insect, snake, and scorpion bites, and malaria, in addition to these health-promoting qualities. (Pattanayak P, et al.,2010; Mondal S, et al.,2009) Considered as a potent adaptogen, Tulsi contains a special mix of pharmacological effects that foster resilience and well-being. Although the term "adaptogen," or a herb that aids in stress adaption and the promotion of homeostasis, is not frequently used in Western medicine, Western science has discovered that tulsi does, in fact, possess numerous pharmacological effects that serve this function.

Numerous scientific investigations have examined the therapeutic effects of tulsi, including in vitro, animal, and human trials. These studies reveal that tulsi has a unique combination of actions that include: Antimicrobial (including antibacterial, antiviral, antifungal, antiprotozoal, antimalarial, anthelmintic), mosquito repellent, anti‐ diarrheal, anti‐ oxidant, anti‐ cataract, anti‐ inflammatory, chemopreventive, radioprotective, hepato‐ protective, neuro‐ protective, cardio‐ protective, anti‐ diabetic, anti‐ hypercholesterolemia, anti‐ hypertensive, anti‐ carcinogenic, analgesic, anti‐ pyretic, anti‐ allergic, immunomodulatory, central nervous system depressant, memory enhancement, anti‐ asthmatic, anti‐ tussive, diaphoretic, anti‐ thyroid, anti‐ fertility, anti‐ ulcer, anti‐ emetic,anti‐ spasmodic, anti‐ arthritic, apoptogenic, anti‐ stress, anti‐ cataract, anti‐ leukodermal and anti‐ coagulant activities. (Mondal S, et al.,2009) These pharmaceutical effects restore physiological and psychological function while assisting the body and mind in overcoming a variety of chemical, physical, viral, and emotional stresses.

Toxicant stress: Chemicals, heavy metals and radiation

Numerous experimental research has proven that tulsi can defend against the harmful effects of certain toxins. These studies demonstrate to tulsi's capacity to prevent liver, kidney, and brain damage by guarding against the genetic, immunological, and cellular damages brought on by medications, industrial pollutants, and pesticides. Tulsi has therefore been demonstrated to guard against the harmful effects of industrial pollutants like butylparaben and carbon tetrachloride, (Bawankule DU, et al., 2008) copper sulphate and ethanol, and common pesticides such as rogor, chlorpyrifos, (Khanna A, et al., 2011) endosulfan and lindane. Tulsi has also been shown to protect against the toxic effects of many pharmaceuticals' drugs including acetaminophen, meloxicam, paracetamol, haloperidol and anti- tubercular drugs. (Khare, C.P., et al., 2016) Tulsi has been found to protect against the harmful effects of heavy metals like lead, arsenic, cadmium, chromium, and mercury as well as the toxic effects of radiation in addition to guarding against toxic compounds. (M.M. Rahman et al., 2013) By scavenging free radicals and lowering the oxidative cellular and chromosomal damage brought on by radiation, tulsi reduces organ damage and improves post-radiation survival in laboratory animals.

Physical stress

The measures taken to combat the toxicity of many physical stressors also assist in addressing the toxicity of chemicals and radiation. By causing physiological and metabolic stress, prolonged physical effort, physical restraint, exposure to the cold, and excessive noise upset homeostasis. When a person's ability to adjust to various stressors is surpassed, maladaptation takes place, which harms organ function, biochemical pathways, and overall health. Apoptogenic plants like tulsi can prevent this harm by improving a variety of cellular and physiological adaptation processes. Tulsi been found to improve aerobic metabolism, improve swimming time, minimise oxidative tissue damage, and regulate a wide range of physiological and biochemical markers induced by physical stressors in studies involving forced swimming, restraint, and cold exposure stress in laboratory animals. The measures taken to combat the toxic effects of radiation and chemicals also aid in addressing the toxic consequences of numerous physical stressors. Physical stress brought on by prolonged physical effort, physical restriction, exposure to cold, and loud noises disturbs homeostasis. When the ability to deal with these challenges isn't there Similar to human studies, animal studies have shown that tulsi helps mitigate the effects of acute and chronic noise-induced stress. This is demonstrated by increased levels of neurotransmitters and oxidative stress in specific brain regions, as well as enhanced immune, ECG, and corticosteroid responses. (Shivanna, M.B., et al., 2011; Chakravarty, S et al., 2012)

Metabolic stress

Modern lifestyles are characterised by metabolic stress brought on by poor food, insufficient exercise, and psychological stress. It is believed that up to one-third of modern populations are affected by the "metabolic syndrome." The "deadly quartet" of centripetal obesity, hypertension, high cholesterol, and improper glucose regulation make up the metabolic syndrome, also known as "prediabetes" or "Syndrome X," which is linked to chronic inflammation and a higher risk of diabetes, heart disease, and stroke. There is evidence to suggest that tulsi can help in coping with several characteristics of metabolic syndrome and their effects, even though the actual origins of metabolic syndrome are still under question. Numerous in vitro, animal, and human clinical investigations have demonstrated the anti-diabetic properties of tulsi. Tulasi has been demonstrated in studies to lower blood glucose and rectify aberrant lipid profiles in diabetic laboratory animals. (Singh, D., et al.,2014; Nagaprashantha, L.D., et al 2011) and protect the liver and kidneys from the metabolic damage caused by high glucose levels.[48] Tulsi has also been shown to improve lipid profiles, (Kelm, M.A., et al.,2000; Uma Devi, et al.,2004) prevent weight gain, hyperglycemia, hyperinsulinemia, hypertriglyceridemia and insulin resistance, (Vrinda, B., et al.,2001; Patil, R.,et al.,2011) and protect the organs and blood vessels from atherosclerosis (Ali, H.,et al.,2012) in laboratory animals fed high- fat diets. Similarly, in human clinical trials, tulsi has shown to decrease glucose levels, improve blood pressure and lipid profiles (Naji-Tabasi, et, et al.2017; Koroch, A.R., et al.,2010) and reduce many diabetic symptoms in patients with type 2 diabetes.

Infection protection

According to recent studies, tulsi has antibacterial, antiviral, and antifungal properties, including activity against many microorganisms that cause infections in humans (Brophy, J.J., et al., 1993). By increasing immunological responses in both non-stressed and stressed animals and healthy humans, tulsi has also been proven to strengthen defences against infectious threats (Asha, M.K., et al., 2001; Zheliazkov, V.D., et al., 2008; Suanarunsawat, T., et al. 2016) Despite the lack of published human trials, there is experimental evidence that suggests tulsi may be effective in treating a number of bacterial infections in people, including gonorrhoea, herpes, typhoid fever, skin and wound infections, cholera, tuberculosis, and typhoid fever (Nagaprashantha, L. et al., 2011).

Mental stress

Modern living is linked to higher levels of psychological stress due to the various demands and quick pace of modern life, in addition to physical, poisonous, and infectious stress. This tension intensifies the toxic effects of chemical pollutants, and the ongoing worry about dangerous chemicals being all around us can cause stress and anxiety that may even be more toxic than the chemicals themselves. While the reality of daily chemical exposure cannot be denied, regular tulsi use not only safeguards and detoxifies the body's cells and organs but also offers numerous psychological advantages, such as anti-depressant activity and favourable effects on memory and cognitive function, helping to reduce toxic stress.

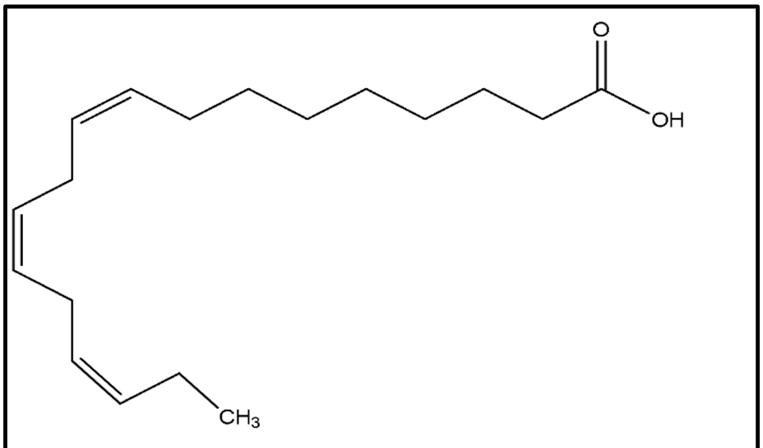
Animal studies on the psychotherapeutic effects of tulsi have revealed that it possesses anti-anxiety and anti-depressant characteristics with effects similar to those of diazepam and antidepressant medications. Further research on animals shows that tulsi improves memory and cognitive function and guards against age-related memory losses. A 6 week, randomised, double-blind, placebo-controlled trial found that tulsi dramatically reduced general stress ratings, sexual and sleep issues, and symptoms including forgetfulness and weariness. In human studies, tulsi has also been found to alleviate stress, anxiety, and depression.

Nutraceutical value (minerals, pigments and mucilage)

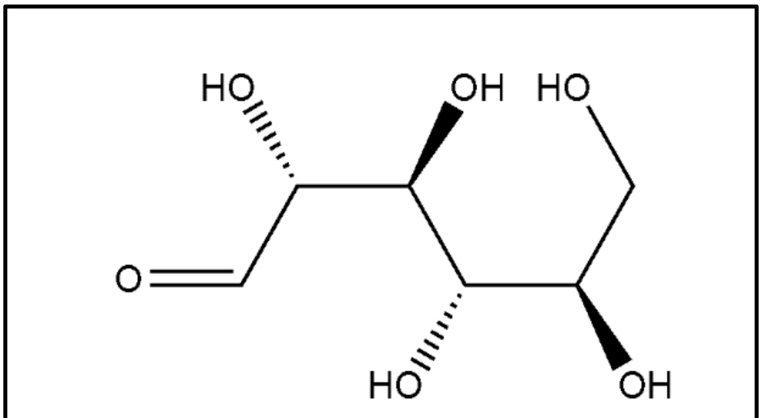
Minerals that are regularly consumed through diet play a significant role in the food and nutraceutical industries. Herb Os has been used as a home treatment for a number of ailments as well as to give meals a particular flavour. Os is a rich source of vitamins, minerals, fat, protein, polysaccharide, fibre, pigments, and mucilage, according to the growing interest in its nutraceutical benefits (Pattanayak, P., et al.,2010; Vidhani, S.I., et al.,2016). In this section, the macro and micro contents of OS are explained. Inductively Coupled Argon Plasma Atomic Spectroscopy (ICAP-AES) and Laser Induced Breakdown Spectroscopy (LIBS) techniques were used to conduct an elemental analysis on the macro and micro contents of Os leaves, which showed that almost all nutritionally significant elements were present. An intriguingly high potassium concentration was also found. (10521.477 ± 391.7 mg/kg leaves) (Tripathi, D.K., et al.,2015). High potassium concentrations and lighter elements like C, H, O, and N point to the use of Os as an organic compound source and for maintaining electrolytic balance, respectively. Vitamins A and C, beta-carotene, chlorophyll, insoluble oxalates, protein (30 Kcal), fat (0.5 g), carbohydrate (2.3 g), minerals, and other phytonutrients are all present in os. Carotene (2.5 g), Ca (3.15%), P (0.34%), Cr (2.9 g), Cu (0.4 g), Zn (0.15 g), V (0.54 g), Fe (2.32 g), and Ni (0.73 g) are all present in each 100 g of leaf. the total carotenoid content (19.77 0.01 g/100 g), total phenolic content (2.09 0.10 g/100 g), and total flavonoid content (1.87 0.02 g/100 g) of dry weights after analysing the antioxidant levels in Os leaves. Os leaves can be consumed as a dietary supplement, an alternative affordable source of vitamins, and a natural antioxidant due to the presence of ascorbic acid (8.21 mg/100 g), riboflavin (0.06 mg/100 g), and thiamine (0.3 mg/100 g) contents.

Two main components of basil seed gum or mucilage are (i) an acid-stable core gluco mannan and (ii) -linked xylan with acidic side chains at C-2 and C-3 of xylosyl residues in acid-soluble part (Khare, C.P., 2016.). Hexouronic acid (27.25%), pentoses (38.9%), and ash

(0.2%) are all naturally occurring polymers that may be found in the seed mucilage of Os (yield: 30%). (Naji-Tabasi, S., Razavi, S.M.A., 2017). On a phytochemical level, Os seed mucilage revealed protein and amino acids, and it had a swelling index of 20 ml (water) and a low ash value. These physicochemical characteristics of mucilage point to its potential as a medicinal excipient.



Alpha-Linolenic Acid



Galactose

Phytoconstituents of Os

Tulsi has a very complex chemical makeup that includes a wide range of nutrients and other biologically active substances, the amounts of which can vary greatly between strains and even between plants in the same area. Furthermore, a variety of growing, harvesting, processing, and storage circumstances that are still poorly understood have a major impact on the quantity of several of these elements.

The entire herb's nutritive and pharmacological characteristics, as it has been traditionally utilised, come from the synergistic combination of numerous active phytochemicals. As a result, single substances or extracts cannot completely mimic the entire effects of Tulsi. Tulsi standardisation has so far escaped modern science due to its inborn botanical and biochemical complexity.

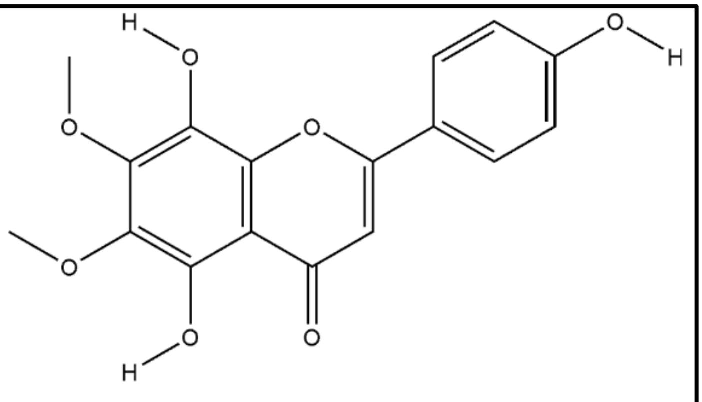
Volatile oil (0.7%), phenolics, flavonoids, neolignans, terpenoids, and fatty acid derivatives are all abundant in os leaves. The unsaponifiable content of os seeds contains fixed oil (18–22%), mucilage, polysaccharides, and beta-sitosterol. Os seed oil is abundant in triglycerides (94–98%), with linolenic acid (43.8%) constituting the majority of them (Naji-Tabasi, S., et al.,2017). The list of chemical components reported from Os and their associated biological activities are compiled in the structure of the principal secondary metabolites of Os.

Phenolics

Os leaves have a total phenolic content of 4.07 0.11 g gallic acid equivalent/100 g dry weight (Koroch, A.R., et al.,2010). From the aerial portions of Os, caffeic acid, chlorogenic acid, vanillic acid, ocimum naphthanoic acid, and menthyl salicylic glucoside were identified (Skaltsa, H., et al.,1999; Ali, M., et al.,2012). Authentic samples were used in the HPLC analysis to demonstrate the presence of the naturally occurring phenolic chemicals protocatechuic acid, 4-hydroxybenzoic acid, vanillin, and 4-hydroxybezaldehyde. Using APCI mass spectrometry, rosmarinic acid, an ester of caffeic acid, is measured at 0.27% w/w in Os leaves. (Sundaram, R.S., et al.,2012).

Flavonoids

The primary class of bioactive compounds are flavonoids, which include methoxy flavonoids and their glycosides (luteolin, isothymusin, and cirsimartin), as well as C-glycoside flavonoids (orientin, isoorientin, isovitexin, and vicenin) from oysters (Norr, H., Wagner, H., 1992). Using atmospheric pressure chemical ionisation mass spectrometry (APCI-MS), Grayer et al., 2001 investigated the distribution of 8-oxygenated flavones on Os leaf surface and identified apigenin, cirsimaritin, salvigenin, crisilineol, eupatorin, isothymusin, and gardenin. According to the investigation, Os is characterised by flavone-7-O-glycosides, but all nine species of Ocimum, including Os, are thought to include luteolin-5-O-glucoside as a marker chemical (Grayer, R., et al.,2002) From the aerial portions of Os, the flavones apigenin, isothymusin, cirsimaritin, and crisilineol were extracted. (Suzuki, A., et al.,2009).



Isothymusin

Phenyl propanoids

The most prevalent phenyl propanoid in the essential oil of Os leaves is eugenol. Citrusin C, ferulaldehyde, bieugenol, and dehydrodieugenol, as well as other phenyl propane derivatives, were extracted from the leaves of Os (Kelm, M.A., Nair, M.G., 1998).

Neolignans

Seven unique neolignans with the names Tulsinol A through Tulsinol G were discovered in the methanol extract of Os leaves. Eugenol is polymerized to create these neolignans.

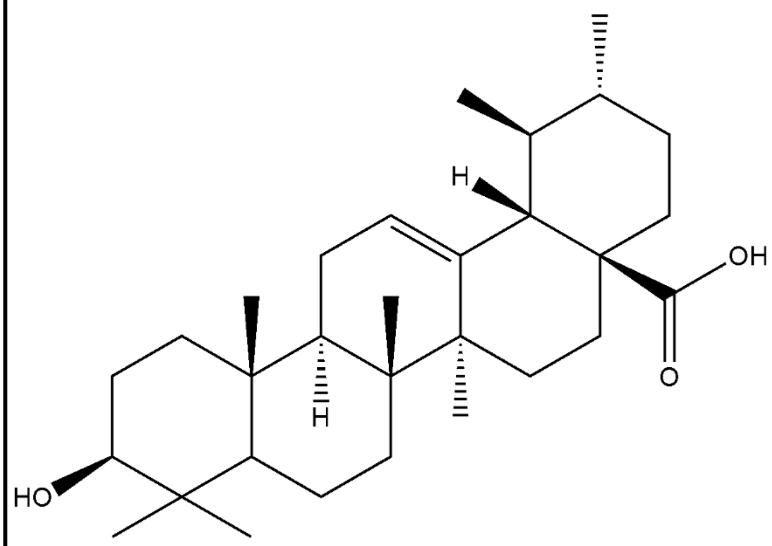
Coumarins

Three coumarins named ocimarin, aeculetin and aesculin were reported from Os (Gupta, P., et al.,2007).

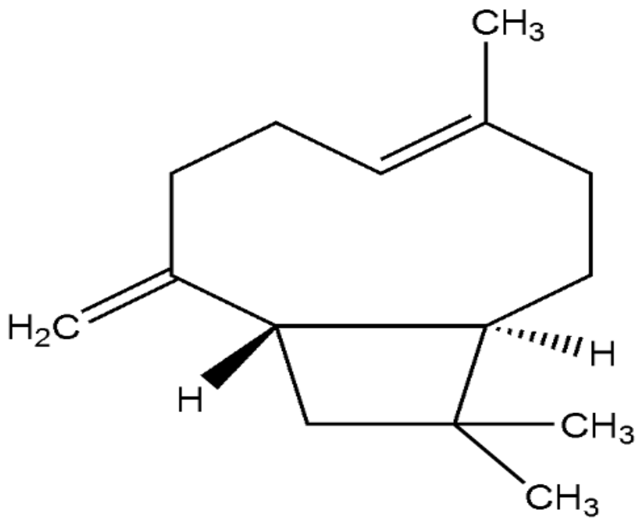
Terpenoids

Many terpenoids, including sesquiterpenoids (4,5-epoxy-caryophyllene and -caryophyllene), abietane diterpenoids (carnosic acid), oleane triterpenoids (oleanolic acid, -Amyrin glucopyranoside), and ursane triterpenoids (ursolic acid, urs-12-en-3,6-triol-28-o (Baliga, M.S., et al.,2013; Patil, R., et al.,2011). The quantification tests using HPTLC and UPLC-ESI-MS/MS, respectively, identified ursolic acid as the most prevalent ingredient in Os with 0.252%-0.478% w/w and 0.62-19.10 mg/g. (Anandjiwala, S., et al.,2006). Urs-12-en-3,6,20-triol-28oic acid and 16-hydroxy-4,4,10,13- tetramethyl-17-(4-methyl-pentyl)-hexadecahydrocyclopenta phenanthren-3-one, respectively, were produced by two independent antidiabetic activity-guided isolations on Os roots and aerial parts (Patil, R., et al.,2011) In addition, a novel tricyclic sesquiterpenoid, 2-(hydroxymethyl)-5,5,9-trimethyl cyclo [7.2.0.03,6] undecan-2-ol, was isolated from Os leaves together with -caryophyllene, elemene, -humulene, -caryophyllene, germacrene-A, trans-bergamotene, and 5-

hydroxycaryophyl Biosynthetically, the new tricyclic sesquiterpenoid was produced from β-caryophyllene.



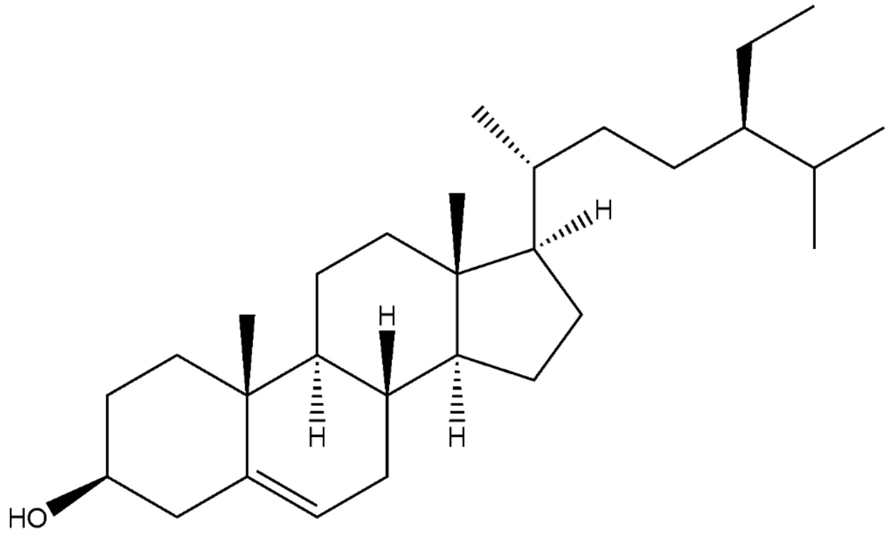
Ursolic Acid



Beta-Caryophyllene

Steroids

From the leaves and stems of Os sp., four commonly occurring phytosterols—sitosterol, sitosterol-3-O-D-glucopyranoside, stigmasterol, and campesterol—were identified. (Joshi, S., Karna, A.K., 2013.).

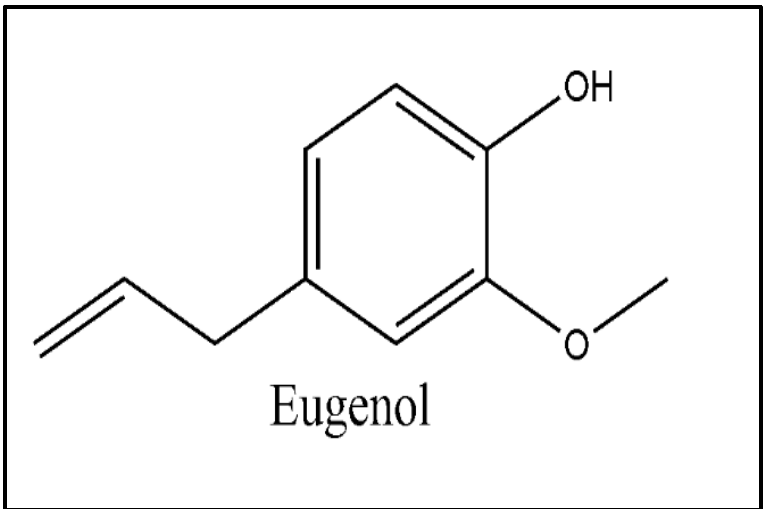


Beta-Sitosterol

Essential oil

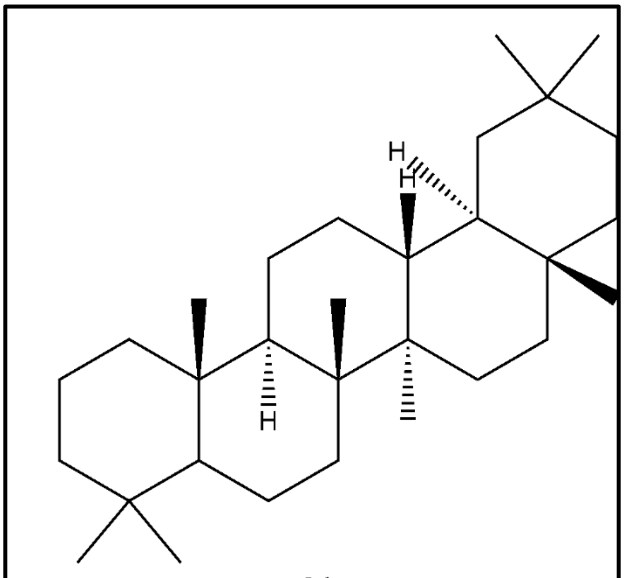
Os essential oil (yield 0.3–4.1%) is primarily made up of terpenoids, such as sesquiterpenoids, aliphatic aldehydes, phenolic acids, and monocyclic, bicyclic, and acyclic terpenoids. Os essential oil's composition and yield vary according on the location, cultivar (green and purple), collection season, stage of harvesting, and climatic circumstances where it is harvested. (Saharkhiz, M.J., et al.,2015; Padalia, R.C., Verma, R.S., 2011.). By taking into account the various harvesting stages and cultivars, the main components of Os essential oil were discovered to be eugenol and/or methyl chavicol. Ocimum species were most diversely found in Africa, next in South America (Brazil), and then in Asia (India) (Verma, R.S., et al.,2015). The primary ingredient in oils from the USA, India, Germany, Thailand, Cuba, and Brazil was discovered to be eugenol (27-83%), whereas methyl chavicol predominates in oils from plants cultivated in Australia. More intriguingly, the polymerization and synthesis of neolignans and/or further oxidation of phenolic compounds, catalysed by the increase in polyphenoxidase and peroxidase activity, may be the causes of the decreasing concentration of eugenol and methyl eugenol contents in Os essential oil in mature leaves (Brophy, J.J., rt al.,1993). By using solid phase microextraction (SPME), GC-

MS, flame ionisation detection (FID), and olfactory evaluations, the aroma components of Os essential oil (methyl eugenol chemotype, 56.18%) were found. (Dey, B.B.,1983). Methyl eugenol, -caryophyllene, -caryophyllene oxide, and germacrene D are responsible for the spicy-green notes and spicy-peppery notes of Os essential oil, respectively (Asha, M.K., et al.,2001). The primary pharmacological properties of Os essential oil, including its antibacterial, anthelmintic, and mosquitocidal properties, have also been identified. The mammalian kidney fibroblast (VERO) and kidney epithelial cells tested negative for toxicity to Os essential oil (40 g/ml). (LLC-PK11) using Neutral Red assay (Zheliazkov, V.D., et al.,2008).



Fixed oil (non-volatile oil)

Linoleic acid (66.1%), -linolenic acid (15.7%), oleic acid (9.0%), palmitic acid (6.94%), and stearic acid (2.1%) make up the majority of the fixed oil contained in Os seeds, which ranges from 18 to 22%. (Mondal, S., et al.,2009). Fixed oil's main ingredients, linoleic acid and linolenic acid, were thought to be responsible for its anti-inflammatory, anticoagulant, hypotensive, chemopreventive, anti-hypercholesterolaemic, and immunomodulatory properties. (Singh et al., 2007) Anti-inflammatory, anti-arthritic, antibacterial, and antiulcer effects of fixed oil of Os have been documented. Fixed oil's ability to reduce inflammation is a result of its combined suppression of arachidonate metabolism and antihistaminic properties (Singh, S., et al.,2007). On the isolation of fixed oil (yield 1.046%) from Os leaves and its anti-diabetic and antioxidant properties, just one report is published. Fixed oil made from Os leaves has high concentrations of linoleic acid (17.86%), palmitic acid (60.60%), and -linolenic acid (15.65%) (Suanarunsawat, T., et al.,2016).



Olean

Fatty acid derivatives

The leaves and roots of Os were used to isolate fatty acid derivatives, including four cerebrosides. While cerebrosides shown antistress effect, fatty acid derivatives with mosquitocidal properties were palmityl glucoside and sanctumoic acid. (Gupta, P., et al.,2007).

Polysaccharide

The monosaccharide components rhamnose (23.3%), xylose (19.2%), arabinose (42.2%), glucose (10.3%), and galactose (5.0%) are found in a polysaccharide (106 Da) isolated from Os leaves. (Subramanian, M., et al.,2005).

Other secondary metabolites

From the aerial portions of Os, an acetone oligomer known as (E)-6-hydroxy-4,6-dimethyl-3-heptene-2 was extracted as a colourless oil.

Therapeutic Properties/Pharmacological activities of Os secondary metabolites:

The therapeutic potential of Os' chemical components, such as its anticancer, antioxidant, anti-inflammatory, leishmanicidal, radiation-protective, mosquitocidal, antibacterial, and antistress action, is the main focus of these studies. The pharmacological effects of Os secondary metabolites are covered in this article and are compiled in the Table.

Anticancer activity

Using doxorubicin as a reference (IC50 9.7 g/ml), a tricyclic sesquiterpenoids 2-(hydroxymethyl)-5,5,9-trimethylcyclo [7.2.0.03,6] undecan-2-ol derived from the oil of Os leaves demonstrated antiproliferative action against MCF-7 cell line (IC50 30 0.5 M) (Singh, D., Chaudhuri, P.K., 2013). Sesquiterpenes -caryophyllene, 4,5-epoxycaryophyllene, and 5-hydroxycaryophyllene displayed IC50 values of 73.0, 7.0, and 4.8 g/ml against the MCF-7 cell line in further antiproliferative screening. The anticancer potential of the substances rosmarinic acid, apigenin, luteolin, orientin, vicenin-2, ursolic acid, and oleanolic acid has been extensively researched (Nagaprashantha, L.D., et al.,2011). The primary class of chemicals responsible for the anticancer activity of Os are terpenoids and flavonoids.

Antioxidant activity

The free radical scavenging potential of a tricyclic sesquiterpenoids 2-(hydroxymethyl)-5,5,9-trimethylcyclo [7.2.0.03,6] undecaprenols/flavonoids of Os was studied. Six flavonoids, including apigenin, rosmarinic acid, isothymusin, isothymonin, cirsimaritin, and cirsilineol along with eugenol, were obtained from Os leaves and stems that were isolated based on their antioxidant activity in a liposome oxidation model. Comparing the antioxidant activity of isothymusin, isothymonin, and eugenol to industry standards TBHQ (terbutyl hydroquinone) and BHT (butylated hydroxyl toluene), it was discovered that rosmarinic acid was the primary component responsible for the antioxidant activity of Os due to its quick scavenging effect on free radicals. n Separated 2-ol from Os leaf oil shown (Koroch, A.R., et al.,2010). A polysaccharide extracted from Os leaves showed antioxidant activity in DPPH free radical scavenging, anti-lipid peroxidation, hydrogen peroxide scavenging, and superoxide radical scavenging assays. It is composed of 23.3% rhamnose, 19.2% xylose, 42.2% arabinose, 10.3% glucose, and 5% galactose (Subramanian et al., 2005). With an IC0.2 value of 5.61 0.17 g/ml, the polysaccharide demonstrated strong DPPH free radical scavenging activity when compared to -tocopherol (IC0.2=11.9 0.2 mM) and BHA (IC0.2=14.5 2.5 mM). Additionally, at concentrations of 10 and 50 g/ml, Os polysaccharide scavenged 54% and 79% of superoxide free radicals, respectively. (Kelm, M.A., et al.,2000). According to the antioxidant studies, Os polysaccharide has the ability to chelate iron and scavenge reactive oxygen species. Pre-treatment with Os polysaccharide at a concentration of 100 g/ml shields 30 3.2% of mouse splenocytes against irradiation with beta rays. Os polysaccharide's antioxidant ability to prevent oxidative damage to lipid, DNA, and splenocytes justifies its use in radiation protection.

Anti-inflammatory activity

Os seeds and leaves are said to lower uric acid levels, which are the root cause of arthritis and joint inflammation. The cyclooxygenase-1 (COX-1) and COX-2 inhibitory actions of chemicals isolated from Os aerial parts, including rosmarinic acid, apigenin, isothymusin, isothymonin, cirsimaritin, cirsineol, and eugenol, have been studied for their anti-inflammatory potential (hPGHS-1). Ibuprofen, naproxen, and aspirin only showed 33%, 58%, and 46% COX-1 inhibition at 10, 10, and 1000 M, respectively. The most effective drug, eugenol, inhibited COX-1 by 97% at 1000 M. Additionally, the COX-1 enzyme was inhibited by cirsineol, cirsimaritin, isothymonin, and apigenin to varying degrees (37%, 50%, 37%, and 65%, respectively) (Singh, S., Majumdar, D.K., 1997). The cyclooxygenase inhibition and lipo-oxygenase pathways in arachidonic acid metabolism were discovered to be the mechanisms by which Os volatile oil suppresses arachidonic and leukotriene caused inflammation. Os fixed oil, however, had an anti-inflammatory effect since it had both antihistaminic and dual suppression of arachidonate metabolism. (Sarkar, A., et al.,1990).

Radiation protective activity

Uma Devi and Ganasoundari were the ones who initially looked into the radioprotective properties of Os in the aqueous extract of leaves (1995). With an LD50 of 6.0 g/kg body weight, it was determined that 50 mg/kg b.w. (i.p.) was the ideal dose of extract for radiation protection. Two water-soluble flavonoids, orientin (8-C-D-glucopyranosyl-luteolin) and vicenin (8-C-D-xylopyranosyl-8-C-D-glucopyranosyl-apigenin), were also discovered through chemical analysis of Os aqueous extract. Due to their abilities to scavenge free radicals and chelate metals, both flavonoids showed protective benefits in mice against radiation-induced chromosomal damage. (Uma Devi, et al.,1995). As a result of flavonoids' iron chelating properties, the production of thiobarbituric acid reactive substances (TBRAS), which prevent lipid peroxidation brought on by iron ions attached to the lipid membrane, was prevented. The optimal dose of the flavonoids orientin and vicenin, or 50 g/kg body (in vivo), for radiation protection against bone marrow damage has since been studied (Nayak, V., et al., 2005). At doses of 50 g/kg, both flavonoids had comparable protective effects, although vicenin at a higher dose (150 mg/kg) exhibited superior bone marrow protection. Additionally, vicenin demonstrated longer-lasting protective benefits at 30 days and demonstrated superior survival effects than orientin. Additionally, vicenin (LD50=1.37) and orienti (LD50=1.30), which both had similar protective effects against -ray-induced lipid peroxidation in mouse liver, were shown to have larger dosage modification factors. The considerable radiation protection that orientin and vicenin provided to human peripheral cells (in vitro) suggests their potential use as normal tissues protectors in cancer radiotherapy. (Vrinda, B., et al.,2001).

Antihyperlipidemic and antidiabetic activity

Os leaves have been investigated for their ability to decrease serum cholesterol levels in both normal albino rabbits and diabetic rats. Their essential oil content is primarily responsible for their antihyperlipidemic effects (Suanarunsawat et al., 2016). In hypercholesterolemic rats, serum total cholesterol (93.62 3.29) mg/dl and triglycerides (36.29 3.33 mg/dl) were reported to be suppressed by os essential oil rich in eugenol (18.25%), methyl eugenol (47.06%), and -caryophyllene (23.68%), compared to the negative control group, which included rats treated with high cholesterol (Os essential oil also shown antihyperlipidemic effects equal to those of simvastatin, a commonly prescribed medication (total cholesterol, 90.35 5.70 mg/dl; triglyceride, 48.50 4.35 mg/dl). Due to the inhibition of hepatic lipid synthesis and the presence of phenylpropanoid components, Os essential oil has antihyperlipidemic properties. Os essential oil may be helpful in the prevention and treatment of diseases including atherosclerosis and cardiovascular problems, according to these antihyperlipidemic studies. (Suanarunsawat, T., et al.,2009).

In streptozotocin-induced type 1 diabetes mellitus mice, the fixed oil made from fresh Os leaves contains mostly -linolenic acid (60.60%), which considerably lowers blood glucose levels and the lipid profile with an increase in serum insulin levels within three weeks (Suanarunsawat, T et al.,2016). In comparison to the untreated group (serum insulin, 3.22 0.18 U/ml; total cholesterol, 93.0 7 mg/dl; and triglyceride, 92.0 7), fixed oil considerably increases serum insulin (4.50 0.24 U/ml) and lowers the serum lipid profile (total cholesterol, 70.0 4 mg/dl; and triglyceride, 45.0 8).

Fixed oil lowers blood urea nitrogen and creatinine levels by (p 0.001) 1.27 0.18 mg/dl and 20.2 0.7 mg/dl, respectively. The high TBRAS level is also reduced by fixed oil, and the liver and heart tissues' antioxidative enzyme activity are increased. Additionally, it is advised to investigate the fixed oil potential in type 2 diabetes. 16-hydroxy-4,4,10,13-tetramethyl-17-(4-methyl-pentyl)-hexadecahydro-cyclopenta [a] is a tetracyclic triterpene. -phenanthren-3-one was discovered in the hydro alcoholic extract of Os aerial parts' antidiabetic activity-guided fraction (Patil et al., 2011). In alloxan-induced diabetic rats, the bioactive fraction (20 mg/kg) significantly (p 0.001) reduced serum glucose, triglycerides, LDL cholesterol, and total cholesterol levels.

Antistress activity

Since ancient times, Os has been known for its immunomodulatory and adaptogenic qualities, which are attributed to its antistress action. Ociglycoside-I (> 0.1%w/w), rosmarinic acid (> 0.2%w/w), oleanolic acid, and ursolic acid (> 2.5%), the required level of active constituents, were combined to create the designed extract known as OciBest, which was discovered to be effective against chronic variable stress (Richard et al., 2016). Using a cell-based experiment, the antistress effects were examined in relation to cortisol release and CHHR1 receptor activity, whereas cell-free studies focused on catechol-O-methyltransferase (COMT) and 11-hydroxysteroid dehydrogenase type 1 (11-HSD1). Additionally, OciBest demonstrated inhibitory effect on COMT (IC50=11.65 g/ml) and 11-HSD1 (99.96% at 200 g/ml), in contrast to the industry-standard 3,5-dinitrocatechol (IC50=24.91 nM) and carbenoxolone (61.44% at 200 g/ml). Additionally, ursolic acid (625 M to 10 M) may be responsible for Os's (6.25-100 g/ml) ability to block cortisol release in forskolin-induced human adreno-carcinoma cells (NCI-H295R) [91]. Thus, it is discovered that the antistress activity of Os is caused by the reduction of cortisol release, blockage of the CRHR1 receptor, inhibition of 11-HSD1, and COMT effects (Richard et al., 2016). The prolonged study on the antistress potential of ocimumoside A and B on chronic unpredictable stress (CUS) normalises the stress-induced responses, such as changes in antioxidant systems, plasma corticosterone levels, and monoaminergic (nor-adrenalin, dopamine, serotonin, and their metabolites, such as dihydroxyphenyl acetic acid, homovanillic acid, and 5-hydroxyindole acetic acid) systems (Ahmad et al.,2012b).

Ocimumoside A and B (40 mg/kg body weight p.o.) pre-treatment considerably lowers plasma corticosterone levels in CUS-induced mice, which are 211.50 13.67 and 225.13 13.28, respectively. These findings held true when using melatonin as a standard antioxidant (20 mg/kg i.p.) and CUS-induced animals as the control (308.11 24.59). Ocimumoside A and B also normalises the CUS-induced changes in enzymatic processes including glutathione level and lipid peroxidation in seven days. It's interesting to note that when provided alone, these substances do not alter the baseline values of stress-related indicators. The researchers also support determining the pathway via which these chemicals can modify the amounts of neurotransmitters. These results point to the historic use of Os as an adaptogen in conjunction with contemporary pharmaceutical activity. The antistress potential of Os compounds suggests further research in the treatment of neurological illnesses brought on by stress.

Lieshmanicidal activity

Leishmania donovani was resistant to the leishmanicidal effects of the essential oil from Os (Zheliazkov et al., 2008). Using pentamidine (IC50=1.46 0.51 g/ml and IC90=4.98 1.1 g/ml) and amphotericin B (IC50=0.09 0.01 g/ml and IC90=0.35 0.12 g/ml) as positive controls, the essential oil showed leishmanicidal action with IC50=37.3 4.6 g/ml The leishmanicidal activity of (+)—cadinene, a minor element of essential oil with yields of 0.168 0.0194% and IC50 values of 4.0 g/ml and 7.0 g/ml, respectively, was strikingly different from that of the major components of essential oil, eugenol and methyl chavicol. In comparison to pentamidine, which inhibits promastigotes of L. amazonensis by 96.9 0.2% and 99.2 0.3% at

50 and 100 g/ml, the hydroalcoholic extract of Os leaves inhibits growth by 8.8 1.2% and 10.3 1.3% at 50 g/ml, respectively (Garcia, M., et al.,2010). Ferulaldehyde and ursolic acid with IC50 values of 0.9 g/ml and 2.2 g/ml, respectively, against promastigotes of Leishmania major were produced by the leishmanicidal activity-guided isolation of Os ethyl acetate fraction in comparison to the positive control amphotericin B (IC50=0.04 g/ml). (Suzuki et al., 2009). Eugenol and caryophyllene oxide had IC50 values more than 25 g/ ml against L. major, although bieugenol and dehydrodieugenol were shown to be more effective leishmanicidal substances. Furthermore, the significant leishmanicidal activity of the new neolignan tulsinol C (5-Allyl- 3-(4-allyl-2-methoxyphenoxymethyl)-2-(4-hydroxy-3-methoxyphenyl)-7-methoxy-2,3-dihydrobenzofuran) was demonstrated with an IC50 value of 9.1 g/ml against L. major. (Zheliazkov, V.D., et al., 2008).

Antimicrobial activity

Using the disc diffusion method, the Os flavonoids orientin and vicenin were tested for their ability to inhibit bacterial strains that cause urinary tract infections in humans, such as Staphylococcus aureus, Staphylococcus cohni (gramme positive), and Escherichia coli, Proteus, and Klebsiella pneumonia (gramme negative). With maximum zone of inhibitions (ZOI) of 18.04, 17.13, and 16.11 mm, respectively, orientin (400 mg/ml) demonstrated antibacterial efficacy against S. aureus, S. cohni, and K. pneumonia.

While vicenin at 400 mg/ml was discovered to be effective against Proteus and E. coli (ZOI, 18.84 mm) (ZOI, 17.16 mm). Additionally, the synergistic effect of orientin and vicenin (in a ratio of 1:1) on antibacterial activity produced better outcomes in all strains than individual flavonoids, with maximum ZOI values of 20, 12, 20, 75, 20, 95, and 20, 31 mm at 400 mg/ml concentrations against E. coli, Proteus, S. aureus, S. cohni, and K. pneumonia, respectively. The antibacterial activity results showed that flavonoids orientin and vicenin have a strong synergistic impact that can be employed as a novel option for the treatment of UTI infections caused by bacteria (Ali, H., Dixit, S., 2012). It is also advised to utilise a positive control during antimicrobial screening to confirm these findings.

Mosquitocidal activity

Eugenol and (E)-6-hydroxy-4,6- dimethyl-3-heptene-2-one were produced by the mosquitocidal activity of Os against Aedes aegyptii larvae (Kelm, M.A., et al.,2000). With LD100 values of 200 g/ml for eugenol and 6.25 g/ml for (E)-6-hydroxy-4,6-dimethyl-3-heptene-2-one, respectively, in 24 hours, there was no mortality for control larvae. The researchers also advise looking at several Os extracts in an effort to find brand-new chemicals with mosquito-killing properties.

Tulsi as a vehicle of consciousness

Tulsi's global distribution, which is based on its production employing ethical, fair trade, organic, and ecological agricultural practises, is probably one of its biggest advantages in the modern world. There is a growing understanding that a move in agriculture from a "green revolution" to an "ecological intensification revolution" is necessary to address challenges with food security, rural poverty, hunger, environmental degradation, and climate change. The world community is urged to support and promote local solutions to toxicity, food insecurity, and poverty, such as the use of organic and small-scale farming over the use of genetically modified organisms and monocultures, according to a recent United Nations report titled "Wake Up Before It's Too Late." Despite not being unique to tulsi, ecological farming techniques have been successfully used in tulsi growing.

authored by Organic India Pvt. Ltd. This business, which was founded as a "vehicle of consciousness," collaborates with thousands of organic tulsi growers in India to create a business ecosystem that gives rural Indian farmers their dignity and a healthy and sustainable livelihood while helping to care for the land they live on. They also produce a variety of teas that allow people all over the world to access the benefits of tulsi.

Discussion:

This is the first thorough literature review of published human research on the consumption of tulsi as a single herbal intervention. Despite a long history of traditional use and widespread availability, relatively few human intervention studies have been conducted on the effectiveness of tulsi for clinical conditions.

Tulsi may in fact be a potent adaptogen that can play a part in assisting with the management of the psychological, physiological, immunological, and metabolic stresses of contemporary living, as evidenced by the finding that the reviewed studies reported favourable clinical effects across these domains. Regardless of dosage, formulation, participant age or gender, all examined trials indicated favourable clinical outcomes with few to no side effects, and just one clinical trial reported brief, moderate nausea.

This paper contends that tulsi is a prime example of the Ayurvedic holistic lifestyle approach to health and that it offers a wide range of health advantages that address numerous contemporary health issues, there is inadequate proof that any one tulsi formulation can help with a particular ailment. Before specific recommendations for the therapy of any particular condition can be made, more thorough research with larger sample sizes, longer durations, and uniform formulations are required. This review also emphasises the need to investigate and identify distinctive signature compounds unique to each of the three tulsi varieties in

Plant parts (preparation used)	Ethnomedicinal uses	Region/Country	References

order to shed light on the underlying mechanism of action on metabolic and inflammatory pathways and to identify the bioactive metabolites that may interact synergistically.

Table: Traditional uses of O. sanctum

Fresh leaf with water	Enhancing mental power	Himachal Pradesh (India)	(Vidyarthi, S, et al.,2013)
Leaves with Bruguiera gymnorrhiza and coconut oil (pounded and rubbed on body)	Renovating from tiredness	Nicobar Island (India)	(Muthu, C., et al., 2006)
Leaves pounded with onion bulbs (juice taken orally)	Cough, cold and headache	Tamil Nadu (India)	(Chowdhury, M.S.H. et al.,2010)
Leaves (juice)	Cough, cold, leg swelling and fever	Bangladesh	(Sharkar, P., et al.,2013)
Whole plant	Cough, cold, headache, nausea, fever and skin diseases	Chuadanga, (Bangladesh)	(Rahman, M.M., et al.,2013)
Leaves pounded with garlic, leaves of Achyranthes aspera and pepper	Typhoid fever	Andhra Pradesh, India	(Reddy, M.B., et al., 1988)
Leaves pounded with fruits of Tricosanthes diocia, flowers of Leucas indica and leaves of Aristolochia bracteata	Typhoid fever	Andhra Pradesh (India)	(Reddy, M.B., et al., 1988)
Leaf decoction with flower heads of Leucas cephalotes	Fever	Makawanpur (Nepal)	(Bhattarai, N.K., et al., 1991)
Leaf decoction with Piper nigrum and palmgur	Fever	India	(Nazar, S., et al., 2008)
Leaves paste with black pepper	Diarrhea and fever	Central Himalaya (India)	(Kandari, L.S., et al.,2012)
Leaves paste with black pepper	Diarrhoea and dysentery	Tripura (India)	(Sen, S., et al.,2011)
Leaves (juice)	Diarrhoea and dysentery	Central Himalaya	(Sen, S., et al.,2011)
Dried leaves with ghee	Dysentery, colic and piles	Central Himalaya (India)	(Sen, S., et al.,2011)
Leaves (paste and decoction)	Stomach disorder, inflammations and wound cuts	Arunachal Pradesh (India)	(Namsa, N.D., et al.,2011)
Leaves (crushed and filtered extract)	Stomach ache and head ache	Assam (India)	(Sajem, A.L., et al., 2006)
Flowers juice with honey, ginger and onion juice	Bronchitis	India	(Watt, G., 1972.)
Leaves (juice)	Bronchitis and catarrh	India	(Watt, G., 1972.)
Dried leaves (vegetable)	Blood purification	Central Himalaya (India)	(Siddiqui, M.B., et al.,1989)

Leaves (juice)	To treat ringworm	Uttar Pradesh (India)	(Shivanna, M.B., et al.,2011)
Leaves crushed in goat's urine and mixed with coconut oil	Skin allergy	Karnataka (India)	(Sharkar, P., et al.,2013)
Plant (paste)	Skin infection	Tripura (India)	(Sharkar, P., et al.,2013)
Leaves pounded with Catharanthus roseus leaves and mild heated	Ear boils	Karnataka (India)	(Shivanna, M.B., et al., 2011)
Leaves powder with honey	Diabetes	Assam (India)	(Chakravarty, S., et al.,2012)
Leave, flower top and roots (juice)	Antidote in snake poisoning	India	(Shivanna, M.B., et al.,2011)
Leaves paste	Antidote for scorpion bite	Andhra Pradesh (India)	(Communities in Hosanagara 2011)

Table: Pharmacological activities of secondary metabolites from O. sanctum.

Pharmacological activities	Compounds/plant part	Class of compound	Results	Reference
Anticancer	2-(Hydroxymethyl)-5,5,9-trimethylcyclo [7.2.0.03,6]	Sesquiterpenoid	IC50 30 ± 0.5 µM against MCF-7 cell line	(Singh, D., et al.,2014)
	Luteolin (Lf and Ap)	Flavonoid	IC50 (78 ± 6 µM) for androgen-independent carcinoma of prostate (LNCaP) and IC50 (53 ± 4 µM) for androgen-dependent carcinoma of prostate (PC-3 and DU-145) cells at 72 h.	(Nagaprashantha, L.D., etal.,2011)
	Orientin (Lf and Ap)	Flavonoid	IC50 (124 ± 7 µM) for androgen independent carcinoma of prostate (LNCaP) and IC50 (104 ± 7 µM) for androgen dependent carcinoma of prostate	(Nagaprashantha, L.D., etal.,2011)

			(PC-3 and DU-145) cells at 72 h.	
	Vicenin-2 (Apigenin 6,8-diglucoside (Lf and Ap)	Flavonoid	IC50 (44 ± 3 μM) for androgen-independent carcinoma of prostate (LNCaP) and IC50 (25 ± 3 μM) for androgen-dependent (PC-3, DU-145) cells at 72 h.	**(**Nair, A.G.R., et al.,1982**)**
Antioxidant	Rosmarinic acid (Lf and St)	Phenolic acid	Better antioxidant than vitamin E in liposome oxidation model.	**(**Kelm, M.A., et al.,2000**)**
	Isothymusin (Lf and St)	Flavonoid	Strong antioxidant activity (50% more active than positive control TBHQ and BHT) in liposome oxidation model.	**(**Kelm, M.A., et al.,2000**)**
	Eugenol (Lf)	Phenyl propanoid	Better antioxidant activity than positive controls TBHQ and BHT using liposome oxidation model.	**(**Kelm, M.A., et al.,2000**)**
Anti-inflammatory	Apigenin (Lf, Ap and St)	Flavonoid	Showed 65% COX-1 enzyme inhibition activity, compared to ibuprofen, naproxen and aspirin with 33%, 58% and 46% at 10, 10 and 1000 μM concentration, respectively	**(**Kelm, M.A., et al.,2000**)**
	Rosmarinic acid (Lf and St)	Phenolic acid	Showed 58% COX-1 enzyme inhibition activity, compared to ibuprofen, naproxen and aspirin with 33%, 58% and 46% at 10, 10 and 1000 μM concentration, respectively.	**(**Kelm, M.A., et al.,2000**)**
	Eugenol (Lf)	Phenyl propanoid	Showed 97% COX-1 enzyme inhibition compared to ibuprofen, naproxen	**(**Kelm, M.A., et al.,2000**)**

			and aspirin with 33%, 58% and 46% at 10, 10 and 1000 µM, respectively	
Radiation protection	Orientin (Lf and Ap)	Flavonoid	Pre-treatment of vicenin protected foetal against irradiation induced genomic damage, and reduced the delayed chromosomal abnormalities and tumorigenesis in pregnant Swiss albino mice.	(Uma Devi, P et al.,2004)
	Vicenin (Lf)	Flavonoid	Pre-treatment of vicenin protected foetal against irradiation induced genomic damage, and reduced the delayed chromosomal abnormalities and tumorigenesis in pregnant Swiss albino mice.	(Vrinda, B., et al.,2001)
Antidiabetic	16-Hydroxy-4,4,10,13-tetramethyl-17-(4-methylpentyl)-hexadecahydrocyclopenta [a]-phenanthren-3-one (Ap)	Triterpenoid	Isolated from antidiabetic activity-guided fraction	(Patil, R., et al.,2011)
Antimicrobial	Orientin (Lf and Ap)	Flavonoid	Active against S. aureus, S. cohni and K. pneumonia with maximum zone inhibition (18.04, 17.13 and 16.11 mm).	(Ali, H., Dixit, S., 2012)
	Vicenin (Lf)	Flavonoid	Effective against E. coli and Proteus with maximum ZOI (18.84 and 17.16 mm).	(Ali, H., Dixit, S., 2012)

Conclusion

In conclusion, the current study found that there are various phytoconstituent are present in ocimum sanctum which very useful for the prevention and treatment of diseases.

Authors contribution

All the authors play equal role for completing this work.

Funding: None

Acknowledgement

We thank to Director PSIT, Pharmacy Dr. Awani K. Rai for their constant support and encouragement for writing this review article.

Conflict of Interest

The authors declared that there is no conflict of interest

References:

Ali, H., Dixit, S., (2012). In vitro antimicrobial activity of flavonoids of Ocimum sanctum with synergistic effect of their combined form. Asian Pac. J. Trop. Dis. S396–S398.

Ali, H., Dixit, S., 2012. In vitro antimicrobial activity of flavonoids of Ocimum sanctum with synergistic effect of their combined form. Asian Pac. J. Trop. Dis. S396–S398.

Ali, M., Ali, M., 2012. New fatty acid derivatives from Ocimum sanctum L. leaves. Indian Drugs 49, 13–18.

Amuthavalluvan V. (2011) Ethno medicinal practices and traditional healing system of Kattunayakan in Tamilnadu: An anthropological study, Int Mult Res J, 1[7], 47-51.

Anandjiwala, S., Kalola, J., Rajani, M., 2006. Quantification of eugenol, luteolin, ursolic acid, and oleanolic acid in black (Krishna Tulasi) and green (Sri Tulasi) varieties of Ocimum sanctum Linn. Using high-performance thin-layer chromatography. JOAC Int. 89, 1467–1474.

Asha, M.K., Prashanth, D., Murli, B., Padmaja, R., Amit, A., (2001). Anthelmintic activity of essential oil of Ocimum sanctum and eugenol. Fitoterapia 72, 669–670.

Baliga, M.S., Jimmy, R., Thilakchand, K.R., Sunitha, V., Bhat, N.R., (2013). Ocimum sanctum L (Holy Basil or Tulsi) and its phytochemicals in the prevention and treatment of cancer. Nutr. Cancer 65 (S1), 26–35.

Bast F, Rani P, Meena D. (2014) Chloroplast DNA phylogeography of holy basil (Ocimum tenuiflorum) in Indian subcontinent. Scientific World Journal 2014:847‐ 482.

Bawankule DU, Pal A, Gupta S, Yadav S, Misra A, Rastogi S, *et al.* (2008) Protective effect of *Ocimum sanctum* on ethanol‑ induced oxidative stress in Swiss Albino Mice brain. Toxicol Int 2008; 5:121‑ 5.

Bharath BK, Anjaneyulu Y, Srilatha C. (2011) Imuuno‑ modulatory effect of *Ocimum sanctum* against endosulfan induced immunotoxicity. Vet World 4:25‑ 7.

Bhattacharya, A., Aggarwal, A., Sharma, N., Cheema, J., (2014). Evaluation of some antioxidative constituents of three species of Ocimum. Int. J. Life Sci. 8, 14–17.

Bhattarai, N.K., (1991). Folk herbal medicines of Makawanpur district Nepal. Int. J. Pharmcogn. 29, 284–295.

Biswas NP, Biswas AK. (2005) Evaluation of some leaf dusts as grain protectant against rice weevil Sitophilus oryzae (Linn.). Environ Ecol 23:485-8.

Brophy, J.J., Galdsack, R.J., Clarkson, J.R., (1993). The essential oil of Ocimum tenuiflorum L. (Lamiaceae) growing in Northern Australia. J. Essent. Oil Res. 5, 459–461.

Chakravarty, S., Kalita, J.C., (2012). An investigation on antidiabetic medicinal plants used by villagers in Nalabari district Assam, India. IJPSR 3, 1693–1697.

Chowdhury, M.S.H., Koike, M., (2010). Towards exploration of plant-based ethno-medicinal knowledge of rural community: basis for biodiversity conservation in Bangladesh. New For. 40, 243–260.

communities in Hosanagara Taluk of Shimoga district in Karnataka, India. J. Herbs Spices Med. Plants 17, 291–317.

Cor JS, Beach JF, Blair A, Clark AJ, King J, Lee TB, *et al*. (1970) Disodium chromoglycate. Adv Drug Res 5:190-6.

Dagar, H.S., (1989). Plant folk medicine among nicobarese tribals of car nicobar island India. Econ. Bot. 43 (2), 215–224.

Dey, B.B., Choudhuri, M.A., (1983). Effect of leaf development stage on changes in essential oil of Ocimum sanctum. Biochem. Physiol. Pflanz 13, 331–335.

Garcia, M., Monzote, L., Montalvo, A.M., Scull, R., (2010). Screening of medicinal plants against Leishmania amazonensis. Pharm. Biol. 48, 1053–1058.

Gordon MC, David JN. (2001) Natural product drug discovery in the next millennium. Pharm Boil 39:8-17.

Gowrishankar, R., Kumar, M., Menon, V., Divi, S.M., Saravanan, M., Magudapathy, P., Panigrahi, B.K., Nair, K.G.M., Venkataramaniah, K., (2010). Trace element studies on Tinospora cordifolia (Menispermaceae), Ocimum sanctum (Lamiaceae), Moringa oleifera

(Moringaceae), and Phyllanthus niruri (Euphorbiaceae) using PIXE. Biol. Trace Elem. Res. 133, 357–363.

Grayer, R., Kite, G.C., Veitch, N.C., Eckert, M.R., Marin, P.D., Senanayake, P., Paton, A.J., (2002). Leaf flavonoids glycosides as chemosystematic characters in Ocimum. Biochem. Syst. Ecol. 30, 327–342.

Gupta, P., Yadav, D.K., Siripurapu, K.B., Palit, G., Maurya, R., (2007). Constituents of Ocimum sanctum with antistress activity. J. Nat. Prod. 70, 1410–1416.

Joshi, S., Karna, A.K., (2013). Analysis of phytoconstituents and cytotoxic activities of different parts of Ocimum sanctum. Int. J. Appl. Sci. Biotechnol. 1, 137–144.

Kadam, P.V., Yadav, K.N., Jagdale, S.K., Shivatare, R.S., Bhilwade, S.K., Patil, M.J., (2012). Evaluation of Ocimum sanctum and Ocimum basilicum mucilage-as a pharmaceutical excipient. J. Chem. Phar. Res. 4, 1950–1955.

Kandari, L.S., Phondani, P.C., Pyal, K.C., Rao, K.S., Maikhuri, R.K., (2012). Ethnobotanical study towards conservation of medicinal and aromatic plants in upper catchments of Dhauli Ganga in the central Himalaya. J. Mt. Sci. 9, 286–296.

Kelm, M.A., Nair, M.G., (1998). Mosquitocidal compounds and a triglyceride, 1,3-dilinoleneoyl-2-palmitin, from Ocimum sanctum. J. Agric Food Chem. 46 (3092-3092).

Kelm, M.A., Nair, M.G., Strasburg, G.M., DeWitt, D.L., (2000). Antioxidant and cyclooxygenase inhibitory phenolic compounds from Ocimum sanctum Linn. Phytomedicine 7, 7–13.

Khanna A, Shukla P, Tabassum S. (2011) Role of Ocimum sanctum as a Geno protective agent on chlorpyrifos‑ induced genotoxicity. Toxicol Int 18:9‑ 13.

Khare, C.P., (2016). Ayurvedic Pharmacopoeial Plant Drug: Expanded Therapeutics. CRC Press, London, New York, pp. p–396.

Koroch, A.R., Juliani, H.R., Sims, C., Simon, J.E., (2010). Antioxidant activity, total phenolics, and rosmarinic acid content in different basils (Ocimum spp.). Isr. J. Plant Sci. 58, 191–195.

Mahajan N, Rawal S, Verma M, Poddar M, Alok S. (2013) A phytopharmacological overview on *Ocimum* species with special emphasis on *Ocimum sanctum*. Biomed Prev Nutr 3:185‑ 92.

Maller C, Townsend M, St Leger L, Henerson‑ Wilson C, Pryor A, Prosser L, *et al*. (2009) Healthy parks, healthy people: The health benefits of contact with nature in a park context. Soc Dev 26:51‑ 83.

Mishra M. Tulsi to Save Taj Mahal from Pollution Effects. The Times of India, Bennett Coleman and Co. Ltd.; 2008.

Mohan L, Amberkar MV, Kumari M. (2011) Ocimum sanctum linn. (TULSI)- an overview. Int J Pharm Sci Rev Res 7: 51- 3.

Mondal S, Mirdha BR, Mahapatra SC. (2009) The science behind sacredness of Tulsi (Ocimum sanctum Linn.). Indian J Physiol Pharmacol 2009; 53:291- 306.

Muthu, C., Ayyanar, M., Raja, N., Ignacimuthu, S., (2006). Medicinal plants used by traditional healers in Kancheepuram district of Tamil Nadu, India. J. Ethnobiol. Ethnomed. 2 (43).

Nagaprashantha, L.D., Vatsyayan, R., Singhal, J., Fast, S., Roby, R., Awasthi, S., Singhal, S.S., (2011). Anti-cancer effects of novel flavonoid vicenin-2 as a single agent and in synergistic combination with docetaxel in prostate cancer. Biochem. Pharmacol. 82,1100–1109.

Nagaprashantha, L.D., Vatsyayan, R., Singhal, J., Fast, S., Roby, R., Awasthi, S., Singhal, S.S., (2011). Anti-cancer effects of novel flavonoid vicenin-2 as a single agent and in synergistic combination with docetaxel in prostate cancer. Biochem. Pharmacol. 82,1100–1109

Nair, A.G.R., Gunasegaran, R., Joshi, B.S., (1982). Chemical investigation of certain south indian plants. Indian J. Chem. 21B, 979–980.

Naji-Tabasi, S., Razavi, S.M.A., (2017). Functional properties and applications of basil seed gum: an overview. Food Hydrocoll. 73, 313–325.

Namsa, N.D., Mandal, M., Tangjang, S., Mandal, S.C., (2011). Ethnobotany of the monpa ethnic group at arunachal pradesh, India. J. Ethnobiol. Ethnomed. 7, 31.

Nayak, V., Uma Devi, P., (2005). Protection of mouse bone marrow against radiation-induced chromosome damage and stem cell death by the Ocimum flavonoids orientin and vicenin. Radiat. Res. 162, 165–171.

Nazar, S., Ravikumar, S., Williams, G.P., (2008). Ethnopharmacological survey of medicinal plants along the southwest coast of India. J. Herbs Spices Med. Plants 14,219–239

Norr, H., Wagner, H., (1992). New constituents from Ocimum sanctum. Planta Med. 58, 574.

Padalia, R.C., Verma, R.S., (2011). Comperative volatile oil composition of four Ocimum species from northern India. Nat. Prod. Res. 25, 569–575.

Patil, R., Patil, R., Ahirwar, B., Ahirwar, D., (2011). Isolation and characterization of antidiabetic component (bioactivity-guided fractionation) from Ocimum sanctum L. (Lamiaceae) aerial part. Asian Pac. J. Trop. Med. 4, 278–282.

Pattanayak P, Behera P, Das D, Panda SK. (2010) Ocimum sanctum Linn. A reservoir plant for therapeutic applications: An overview. Pharmacogn R 4:95‑ 105.

Pattanayak, P., Behera, P., Das, D., Panda, S.K., (2010). A reservoir plant for therapeutic applications: an overview. Pharmacogn. Rev. 4, 95–105.

Rahman, M.M., Masum, G.Z.H., Sharkar, P., Sima, S.N., (2013). Medicinal plant usage by traditional medicinal practitioners of rural villages in Chuadanga district, Bangladesh. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 9, 330–338.

Reddy, M.B., Reddy, K.R., Reddy, M.N., (1988). A survey of medicinal plants of Chenchu tribes of Andhra Pradesh, India. Int. J. Crude Drug Res. 26, 189–196.

Richard, E.J., Illuri, R., Bethapudi, B., Anandhakumar, S., Bhaskar, A., Velusami, C.C., Mundkinajeddu, D., Agarwal, A., (2016). Anti-stress activity of Ocimum sanctum: possible effects on hypothalamic-pitutary-adrenal axis. Phytother. Res. 30, 805–814.

Saharkhiz, M.J., Kamyab, A.A., Kazerani, N.K., Zomorodian, K., Pakshir, K., Rahimi, M.J., (2015). Chemical compositions and antimicrobial activities of Ocimum sanctum L: essential oils at different harvest stages. Jundishapur J. Microbiol. 8, e13720.

Sajem, A.L., Gosai, K., (2006). Traditional use of medicinal plants by the Jaintia tribes in North Cachar Hills district of Assam, northeast India. J. Ethnobiol. Ethnomed. 2, 1–7.

Sarkar, A., Pandey, D.N., Pant, M., (1990). A report on the effects of Ocimum sanctum (Tulsi)leaves and seeds on blood and urinary uric acid urea, and urine volume in normal albino rabbits. Indian J. Physiol. Pharmacol. 34, 61–62.

Sembulingam, K., Sembulingam, P., Namasivayam, A., (1997). Effect of Ocimum sanctum Linn on noise induced changed in plasma corticosterone level. Indian J. Physiol. Pharmacol. 41, 139–143.

Sen, S., Chakraborty, R., De, B., Devanna, N., (2011). An ethnobotanical survey of medicinal plants used by ethnic people in West and South district of Tripura, India. J. For. Res. 22, 417–426.

Sharkar, P., Rahman, M.M., Haque, M.G.Z., Nayeem Md, A., Hossen Md, M., Azad, A.K., (2013). Ethnomedicinal importance of the plants in villages in Kushtia Sador and Mirpur Upozila, Bangladesh. J. Herbs Spices Med. Plants 19, 401–417.

Shivanna, M.B., Rajakumar, N., (2011). Traditional medico-botanical knowledge of local D. Singh, P.K. Chaudhuri *Industrial Crops & Products 118 (2018) 367–382*

Shukla ST, Kulkarni VH, Habbu PV, Jagadeesh KS, Patil BS, Smita DM. (2012) Hepatoprotective and antioxidant activities of crude fractions of endophytic fungi of *Ocimum sanctum* Linn. in rats. Orient Pharm Exp Med 12:81‑ 91.

Siddiqui, M.B., Alam, M.M., Husain, W., (1989). Traditional treatment of skin diseases in Uttar Pradesh, India. Econ. Bot. 43, 480–486.

Singh N, Hoette Y, Miller R. Tulsi: (2010) The Mother Medicine of Nature. 2nd ed. Lucknow: International Institute of Herbal Medicine; p. 28‑ 47.

Singh, D., Chaudhuri, P.K., (2013). Study of Some Reputed Indian Medicinal Plants and Chemical Modification of Major Bioactive Scaffold. pp. p136.

Singh, D., Chaudhuri, P.K., Darokar, M.P., (2014). New antiproliferative tricyclic sesquiterpenoid from the leaves of Ocimum sanctum. Helv. Chim. Acta 97, 708–711.

Singh, S., Majumdar, D.K., (1997). Evaluation of anti-inflammatory activity of fatty acids of Ocimum sanctum fixed oil. Indian J. Exp. Biol. 35, 380–383

Singh, S., Majumdar, D.K., (1997). Evaluation of anti-inflammatory activity of fatty acids of Ocimum sanctum fixed oil. Indian J. Exp. Biol. 35, 380–383.

Singh, S., Taneja, M., Majumdar, D.K., (2007). Biological activities of Ocimum sanctum L. fixed oil-an overview. Indian J. Exp. Biol. 45, 403–412.

Skaltsa, H., Tzakoul, O., Singh, M., (1999). Polyphenols of Ocimum sanctum from Suriname.Pharm. Biol. 37, 92–94.

Suanarunsawat, T., Anantasomboon, G., Piewbang, C., (2016). Anti-diabetic and anti-oxidative activity of fixed oil extracted from Ocimum sanctum L. leaves in diabetic rats. Exp. Ther. Med. 11, 832–840.

Suanarunsawat, T., Anantasomboon, G., Piewbang, C., (2016). Anti-diabetic and anti-oxidative activity of fixed oil extracted from Ocimum sanctum L. leaves in diabetic rats.Exp. Ther. Med. 11, 832–840.

Suanarunsawat, T., Ayutthaya, W.D.N., Songsak, T., Rattanamahaphoom, J., (2009). Antilipidemic actions of essential oil extracted from Ocimum sanctum L. leaves in rats fed with high cholesterol diet. J. Appl. Biomed. 7, 45–53.

Subramanian, M., Chintalwar, G.J., Chattopadhya, S., (2005). Antioxidant and radioprotective properties of an Ocimum sanctum polysaccharide. Redox Rep. 10, 257–264.

Sundaram, R.S., Ramanathan, M., Rajesh, R., Satheesh, B., Saravanan, D., (2012). LC-MS quantification of rosmarinic acid and ursolic acid in the Ocimum sanctum leaf extract (Holy basil). J. Liq. Chromatogr. Relat. Technol. 35, 634–650.

Superintendent Vol. 5. Government Printing, Calcutta, W.H. Allen, London, pp.443–445.

Suzuki, A., Shirota, O., Mori, K., Sekita, S., Fuchino, H., Takano, A., Kuroyanagi, M., (2009). Leishmanicidal active constituents from Nepalese medicinal plant Tulsi (Ocimum sanctum L.). Chem. Pharm. Bull. 57, 245–251.

Tripathi, D.K., Pathak, A.K., Chauhan, D.K., Dubey, N.K., Rai, A.K., Prasad, R., (2015). An efficient approach of Laser Induced Breakdown Spectroscopy (LIBS) and ICAP-AES to detect the elemental profile of Ocimum L. species. Biocatal. Agric. Biotechnol. 4,471–479.

Uma Devi, P., Ganasoundari, A., (1995). Radioprotective effect of leaf extract of Indian medicinal plant Ocimum sanctum. Indian J. Exp. Biol. 33, 205–209.

Uma Devi, P., Satyamitra, M., (2004). Protection against prenatal irradiation-induced genomic instability and its consequences in adult mice by Ocimum flavonoids, orientin and vicenin. Int. J. Radiat. Biol. 80, 653–662.

Verma, R.S., Kumar, A., Mishra, P., Kuppusamy, B., Padalia, R.C., Sundaresan, V., (2015). Essential oil composition of four Ocimum spp: from the Peninsular India. J. Essent. Oil Res. 28, 35–41

Vidhani, S.I., Vyas, V.G., Parmar, H.J., Bhalani, V.M., Hasan, M.M., Gaber, A., Golakiya, B.A., (2016). Evaluation of some chemical composition, minerals fatty acid profiles, antioxidant and antimicrobial activities of Tulsi (Ocimum sanctum) from India. Am. J. Food Sci. Technol. 4, 52–57.

Vidyarthi, S., Samant, S.S., Sharma, P., (2013). Traditional and indigenous uses of medicinal plants by local residents in Himachal Pradesh North Western Himalaya, India.Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 9, 185–200.

Vrinda, B., Uma Devi, P., (2001). Radiation protection of human lymphocyte chromosomes in vitro by orientin and vicenin. Mutat. Res. 498, 39–46.

Warrier PK. In: Longman O, editor. Indian Medicinal Plants.New Delhi, CBS publication, (1995). p. 168.

Watt, G., (1972). A Dictionary of the Economic Products of India Office of the

Wink M. Introduction Biochemistry, role and biotechnology of secondary products. In: Wink M, editor. Biochemistry of Secondary product Metabolism. Florida: CRC press, Boca Raton; (2000). p. 1-16.

Zheliazkov, V.D., Cantrell, C.L., Tekwani, B., Khan, S.I., (2008). Content, composition, and bioactivity of the essential oils of three basil genotypes as a function of harvesting. J. Agric. Food Chem. 56, 380–385.