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Ocimum sanctum L.: A Review of Phytochemical and Pharmacological Profile

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ABSTRACT

The use of natural products as medicinal agents presumably predates the earliest recorded history. *Ocimum sanctum* L. is a plant which is used in several traditional medicine systems to cure various diseases. This plant has been known to possess antibacterial activity, antianaphylactic activity, antihistaminic and mast cell stabilization activity, wound healing effect, radio-protective effect, antidiabetic effect, antioxidant activity, anti-carcinogenic properties, immunologic effects, contraceptive effect, larvicidal property, anti genotoxic effect, neuro-protective effect, cardio-protective effect and other miscellaneous activities. A wide range of chemical compounds including eugenol, euginal, urosolic acid, carvacrol, linalool, limatrol, caryophyllene, methyl carvicol, sitosterol, anthocyans etc. are found in this plant. The pharmacological studies reported in the present review confirm the therapeutic value of *Ocimum sanctum* L. Thus the use of this plant for human and animal disease therapy and reinforce the importance of the ethno-botanical approach as a potential source of bioactive substances.

Key words: Medicinal plant, *Ocimum sanctum* L., pharmacology, phytochemistry

INTRODUCTION

Nature has provided a complete storehouse of remedies to cure ailment of mankind. About 80% of the world's population depends wholly or partially on traditional medicine for its primary health care needs (Kunwar and Adhikari, 2005). According to a survey (WHO, 1993) of World Health Organization (WHO), the practitioners of traditional system of medicine treat about 80% of patients in India, 85% in Burma and 90% in Bangladesh (Siddiqui, 1993). Herbal medicines, as the major remedy in traditional medical systems (Rahman *et al*., 2011) have been used in medical practice for thousands of years and have made a great contribution to maintain human health. A majority of the world's population in developing countries still relies on herbal medicines to meet its health needs. The attention paid by health authorities to the use of herbal medicines has increased considerably, both because they are often the only medicine available in less developed areas and because they are becoming a popular alternative medicine in more developed areas (Gurib-Fakim, 2006). Today the large number of drugs in use are derived from plants, like morphine from *Papaver somniferum,* aswagandha from *Withania somnifera,* ephedrine from *Ephedra vulgaris,* atropine from *Atropa belladonna,* reserpine from *Roulphia serpent ina* etc. The

medicinal plants are rich in secondary metabolites (which are potential sources of drugs) and essential oils of therapeutic importance. The important advantages claimed for therapeutic uses of medicinal plants in various ailments are their safety besides being economical, effective and their easy availability (Atal and Kapoor, 1989; Siddiqui, 1993).

Ocimum sanctum L. has been well documented for its therapeutic potentials and described as antiasthmatic and antikaphic drugs. Although the traditional medical practitioners in Indian subcontinant have been widely using this medicinal plant for management of various disease conditions from ancient time, not much is known about the mode of action of *Ocimum sanctum* L. and a rational approach to this traditional medical practice with modern system of medicine was also not available (Prakash and Gupta, 2005). The therapeutic potential of *Ocimum sanctum* L. has been established on the basis of several pharmacological studies carried out with eugenol and steam distilled, petroleum ether and benzene extracts of different parts of *Ocimum sanctum* L. plant (Sethi *et al.*, 2003).

Plant profile: Among the plants known for medicinal value, the plants of genus *Ocimum* belonging to family Labiatae are very important for their therapeutic potentials. *Ocimum sanctum* L. (Labiatae) is a strongly scented small annual herb, up to 18 inches tall, grows into a low bush and is commonly known as holy basil, Tulsi or Tulasi (Mahmood *et al.*, 2008). *Ocimum sanctum* L. (Tulsi), *Ocimum gratissium* (Ram Tulsi), *Ocimum canum* (Dulal Tulsi), *Ocimum basilicum* (Ban Tulsi), *Ocimum kilimandscharicum, Ocimum ammericanum, Ocimum camphora* and *Ocimum micranthum* are examples of known important species of genus *Ocimum* which grow in different parts of the world and are known to have medicinal properties (Satyavati *et al.*, 1976; Gupta *et al.*, 2002; Nagarajan *et al.*, 1987; Sen, 1993; Prakash and Gupta, 2005). *Ocimum sanctum* L. is commonly cultivated in gardens in Indian subcontinent. Two types of *Ocimum sanctum* L. are met within cultivation: (1) Tulsi plants with green leaves known as Sri Tulsi and (2) Tulsi plants with green leaves known as Krishna Tulsi (Pandey and Anita, 1990).

Scientific classification:

- **Kingdom:** Plantae
- (unranked) Angiosperms
- (unranked) Eudicots
- (unranked) Asterids
- **Order:** Lamiales
- **Family:** Lamiaceae
- **Genus:** *Ocimum*
- **Species:** O. *tenuiflorum*
- **Binomial name:** *Ocimum tenuiflorum* or *Ocimum sanctum* L. (Pattanayak *et al.*, 2010)

Nutritional content: *Ocimum sanctum* L. contains Vitamin C, A and minerals like (Anbarasu and Vijayalakshmi, 2007) calcium, zinc and iron, as well as chlorophyll and many other phytonutrients. It enhances efficient digestion, absorption and use of nutrients from food and other herbs. This plant contain protein: 4.2 g, fat: 0.5 g, carbohydrate: 2.3 g, calcium: 25 mg, phosphorus: 287 mg, iron: 15.1 mg and edible portion 25 mg; Vitamin C per 100 g (Pattanayak *et al.*, 2010).

Phytochemical constituents: The chemical composition of *Ocimum sanctum* L. is highly complex, containing many nutrients and other biologically active compounds, the proportions of which may vary considerably between varieties and even among plants within the same field. Furthermore, the quantity of many of these constituents are significantly affected by differing growing, harvesting, processing and storage conditions that are not yet well understood (Pattanayak *et al.*, 2010).

The nutritional and pharmacological properties of the whole herb in its natural form, as it has been traditionally used, result from synergistic interactions of many different active phytochemicals. Its leaf contain volatile oil eugenol (Fig. 1), euginal (also called eugenic acid), urosolic acid (Fig. 2), carvacrol (Fig. 3) linalool (Fig. 4), limatrol, caryophyllene (Fig. 5), methyl carvicol (also called Estragol, Fig. 6) while the seed volatile oil have fatty acids and sitosterol; in addition, seed mucilage contains some levels of sugars and the anthocyans are present in green leaves. The sugars are composed of xylose and polysaccharides (Kelm *et al.*, 2000; Pattanayak *et al.*, 2010; Shishodia *et al.*, 2003).

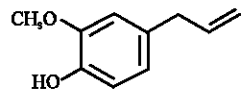

Fig. 1: Eugenol (1-hydroxy-2-methoxy-4-allylbenzene)

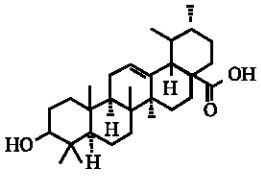

Fig. 2: Urosolic acid (2,3,4,5,6,6a, 7,8,8a,10,11,12,13, 14btetradecahydro-1H-picene-4a-carboxylic acid)

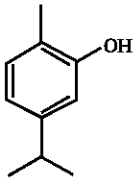

Fig. 3: Carvacrol (5-isopropyl-2-methylphenol)

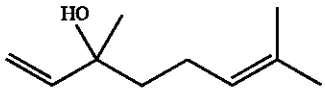

Fig. 4: Linalool (3,7-dimethylocta-1,6-dien-3-ol)

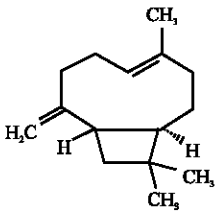

Fig. 5: Caryophylline (4,11,11-trimethyl-8-methylene-bicyclo[7.2.0] undec-4-ene)

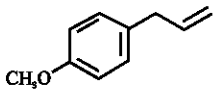

Fig. 6: Estragol (1-allyl-4-methoxybenzene)

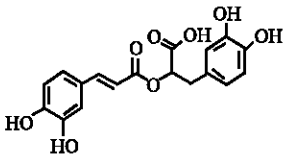

Fig. 7: Rosmarinic acid ((2R)-2-[[(2E)-3-(3,4-Dihydroxyphenyl)-1-oxo-2-propenyl]]oxy]-3-(3,4-dihydroxyphenyl)propanoic acid)

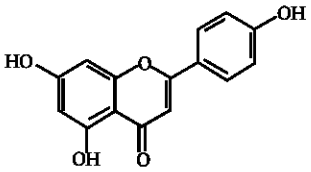

Fig. 8: Apigenin (5,7-dihydroxy-2-(4-hydroxyphenyl)-4H-1-benzopyran-4-one)

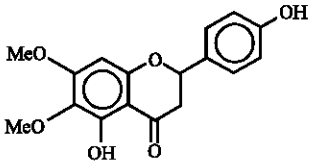

Fig. 9: Cirsimaritin (5,4'-dihydroxy-6, 7-dimethoxyflavone)

Ocimum sanctum L. is known as a general vitalizer and increases physical endurance but it do not contains caffeine or other stimulants. The stem and leaves of *Ocimum sanctum* L. contain a variety of constituents that may have biological activity, including saponins, flavonoids, triterpenoids and tannins (Jaggi *et al.*, 2003). In addition, the following phenolic compound have been also identified which exhibit antioxidant and antiinflammatory activities, rosmarinic acid (Fig. 7), apigenin (Fig. 8), cirsimaritin (Fig. 9), isothymusin (6,7-dimethoxy-5, 8, 4'-trihydroxyflavone) and isothymonin. Two water-soluble flavonoids: Orientin (8-C-β-

glucopyranosyl-3',4',5,7-tetrahydroxyflav-2-en-3-one) and Vicenin (6-C-β-D-xylopyranosyl-8-C-β-D-glucopyranosyl apigenin), Devi *et al.* (1999) have also shown to provide protection against radiation-induced chromosomal damage in human blood lymphocytes (Pattanayak *et al.*, 2010).

Pharmacological properties: Several medicinal properties have been attributed to *Ocimum sanctum* L. (Sethi *et al.*, 2003; Sarkar *et al.*, 1994). Different parts of *Ocimum sanctum* L. plant e.g., leaves, flowers, stem, root, seeds etc. are known to possess therapeutic potentials and have been used, by traditional medical practitioners, as expectorant, analgesic, anticancer, antiasthmatic, antiemetic, diaphoretic, antidiabetic, antifertility, hepatoprotective, hypotensive, hypolipidmic and antistress agents. *Ocimum sanctum* L. has also been used in treatment of fever, bronchitis, arthritis, convulsions etc.

Antimicrobial activity: In previous study, it has been showed that, organic extracts of *Ocimum sanctum* L. show wide zones of inhibition against *Escherichia coli, Staphylococci* sp., *Shigella* sp., *Staphylococcus aureus* and *Enterobacteria* sp. (Rahman *et al.*, 2010). Other researchers showed it is also potent against *Pseudomonas aernginosa, Staphylococci* sp., *Salmonella typhi, Klebsiella pneumonia, Proteus, Candida albicans, Mycobacterium tuberculosis* and *Micrococcus pyogenes* when studied by agar diffusion method (Mishra and Mishra, 2011; Farivar *et al.*, 2006). Alcoholic extract showed wider zone for *Vibrio cholera* (Geeta *et al.*, 2001). It has onetenth anti-tubercular potency of streptomycin and one-fourth that of isoniazid. Aqueous and acetone extracts of *Ocimum sanctum* L. were also found to be sensitive to many plant fungi such as *Alternaria tenuis, Helminthosporium* sp. and *Curvularia penniseli*. Essential oil of Tulsi was tested on plant pathogenic fungi as well e.g., *Alternaria solani, Candida guillermondii, Colletotricum capsici, Curvularia* sp. *Fusarium solani, Helminthosporium oryzae* and other bacterial strains like *Anthrobacter globiformis, Bacillus megaterium* (Dey and Choudhury, 1984; Mondal *et al.*, 2009). Higher content of linoleic acid in *Ocimum sanctum* L. fixed oil could contribute towards its antibacterial activity. The oil show good antibacterial activity against *Staphylococcus aureus, Bacillus pumius* and *Pseudomonas aeruginosa,* where *S. aureus* was the most sensitive organism (Singh *et al.*, 2005). Extract of *Ocimum sanctum* L. caused inhibition of *Neisseriagonorrhoeae* clinical isolates and WHO organization strains. This activity is comparable to penicillin and ciprofloxacin (Shokeen *et al.*, 2005).

Antianaphylactic, antihistaminic and mast cell stabilization activity: Sridevi *et al.* (2009) showed potent benefits of *Ocimum sanctum* L. in the treatment of asthma and related conditions. The findings from various studies reveal that the antihistaminic and antianaphylactic activity of *Ocimum sanctum* L. extract which is mainly due to its mast cell stabilizing potential, suppression of IgE and inhibition of release of inflammatory mediators. Thus use of *Ocimum sanctum* L. leaves proved the strong rationale behind the mentioned therapeutic activities.

Wound healing effect: Several study show healing property of *Ocimum sanctum* L. Wound healing activity of cold aqueous extract of *Ocimum sanctum* L. leaves along with its effect on tumor necrosis factor-α (TNF-α) was assessed using excision model of wound repair in Wistar albino rats. After application of the *Ocimum sanctum* L. extract, rate of epithelization with an increase in wound contraction was observed. In animals, treated with 10% *Ocimum sanctum* L. extract in petroleum jelly, wound healing was faster as compared to control group which were treated with

petroleum jelly alone but significant accelerated healing was noticed in animals which in addition to the topical application of 10% extract of *Ocimum sanctum* L., were prefered with 250 mg kg^{-1} b.wt., of aqueous *Ocimum sanctum* L. extract daily for 20 consecutive days (Shetty *et al.*, 2008). During wound healing phase TNF-α level was found to be up regulated by *Ocimum sanctum* L. treatment. Early wound healing may be pronounced due to *Ocimum sanctum* L. extract, by elevating TNF-α production (Goel *et al.*, 2010).

Radio-protective effect: The radioprotective property of *Ocimum sanctum* L. was first reported by Devi and Ganasoundari (1995). Thirty-day lethality studies in Swiss albino mice were carried out following treatment with single graded doses of aqueous and ethanol extracts from dried leaves of *Ocimum sanctum* L. (The dark-leafed variety of *Ocimum sanctum* L.) and it was found that the aqueous extract was more effective in increasing survival, compared with the ethanol extract. The optimal dose for protection was reported to be 50 mg kg^{-1} b.wt. (intraperitoneal administration) while the acute LD_{50} was 6 g kg^{-1} b.wt. Administration of a fractionated dose of the herbal extract via the intraperitoneal (i.p.) route (10 mg kg day^{-1} for 5 consecutive days to mice prior to irradiation) was more effective compared with a single dose (50 mg kg^{-1} b.wt.). The optimum dose (fractionated dose of 10 mg kg day^{-1} of aqueous extract of *Ocimum sanctum* L. for 5 consecutive days via the intraperitoneal route) administered to mice prior to irradiation gave a dose modification factor of 1.28. It was also found that the i.p., route of drug administration was more effective than the oral route. Ganasoundari *et al.* (1997a) studied the effect of *Ocimum sanctum* L. on the survival of mice after whole-body lethal irradiation and compared it with WR-2721, a standard radioprotector. Their results indicated that *Ocimum sanctum* L. promotes recovery and regeneration of haemopoietic progenitor cells in mice bone marrow. An intraperitoneal (i.p.) injection of an optimum dose (10 mg kg^{-1} daily for 5 days) of leaf extract of *Ocimum sanctum* L. to mice before delivering sub lethal (2 Gy) total-body ã-radiation produced a significantly higher bone marrow stem cell survival than a pre-treatment with 300 mg kg^{-1} (approx. 40% of its LD_{50}) of WR-2721 (amifostine), suggesting that in terms of the protective dose and toxicity, the herbal extract is a better radioprotector than the synthetic drug. Analysis of chromosomal aberrations in mouse bone marrow exposed to ã-radiation showed that the *Ocimum sanctum* L. extract could significantly reduce the percentage of aberrant metaphases and other chromosomal aberrations, including dicentrics and rings, induced by sublethal whole-body radiation doses (3-5 Gy). The decline in the percent aberrant metaphases by *Ocimum sanctum* L. pre-treatment was comparable to that provided by 400 mg kg^{-1} of WR-2721. *Ocimum sanctum* L. pre-treatment did not manifest any toxic side effects while WR-2721 (300-400 mg kg^{-1} b.wt.) administration prior to irradiation resulted in an increase in the percent aberrant cells at 14 days post-irradiation. Administration of a combination of *Ocimum sanctum* L. and WR-2721 to mice prior to γ-irradiation considerably enhanced the chromosome protection by nearly two-fold, compared with individual administration and also eliminated the delayed chromosome toxicity associated with the treatment of WR-2721. In addition, *Ocimum sanctum* L. extracts also protected mouse liver against radiation-induced lipid peroxidation.

The anti-lipid peroxidative effect of *Ocimum sanctum* L. was attributed to increased levels of cellular antioxidants such as reduced glutathione (GSH), GSH-transferase, GSH-peroxidase and reductase as well as Superoxide Dismutase (SOD). The study of Ganasoundari *et al.* (1997b) showed that the aqueous extract of leaves of *Ocimum sanctum* L. significantly inhibited the OH radical-induced deoxyribose degeneration. A combination of WR-2721 and *Ocimum sanctum* L.

extract produced a significantly higher inhibition of the OH radical activity compared with either agent individually (Ganasoundari *et al.*, 1998). Orientin (8-C-P-D-glucopyranosyl-luteolin) and vicenin-1(6-C-P-Dxylopyranosyl-8-C-P-D-glucopyranosyl apigenin), water-soluble compounds from *Ocimum sanctum* L. did not exhibit any systemic toxicity in mice even at a dose of 100 mg kg^{-1} b.wt. Both compounds significantly increas mouse survival when administered 30 min prior to lethal whole-body-irradiation. The optimum dose for protection was found to be 50 μg kg^{-1} b.wt., via the i.p., route. Other routes of administration, e.g., oral and intravenous were also found to be effective but to a lesser extent. Vicenin provided a slightly higher protection (DMF: 1.37), compared with orientin (DMF: 1.30) in murine model system (Devi *et al.*, 1999) and also reduced the chromosomal aberrations better than amifostine in the bone marrow of mice exposed to 2 Gy γ-irradiation (Devi *et al.*, 1998). Both the flavonoids, orientin and vicenin, were found to be equally effective in rendering protection against γ-radiation-induced lipid peroxidation in mouse liver. These compounds also significantly inhibited the Fenton reaction-induced OH radical activity under *in vitro* conditions (Devi *et al.*, 1999) and protected human lymphocyte chromosomes (Vrinda and Uma Devi, 2001). Though the role of orientin and vicenin in radiation protection has been established, it is plausible that other constitutents present in *Ocimum sanctum* L., may also be involved in the observed radioprotective effects, since radioprotection of the whole organism usually requires multifarious activities, i.e., simultaneous protection of various target tissues and organs.

Two polysaccharides isolated from *Ocimum sanctum* L. could prevent oxidative damage to liposomallipids and plasmid DNA induced by various oxidants such as iron, AAPH and gamma radiation (Subramanian *et al.*, 2005).

Antidiabetic effect: The leaf of *Ocimum sanctum* L. is claimed to possess hypoglycemic and antihyperglycaemic effects in experimental animals (Wagner *et al.*, 1994). The antidiabetic effects of Ethyl Acetate (Et-Ac), Petroleum-ether (Pet-ether) and chloroform fractions from ethanolic extract of the leaves of *Ocimum sanctum* L. were investigated in normal and Alloxan Induced Diabetic Rats (AIDRs). The effect of these fractions (200 mg kg^{-1} b.wt., i.p) on Fasting Blood Glucose (FBG), Total Cholesterol (TC), Triglyceride (TG), serum glutamate oxaloacetate transaminases, Serum Glutamate Pyruvate Transaminases (SGOT, SGPT) level and liver glycogen content were investigated in AIDRs and found significant effects. The most significant reduction of FBG level of around 80.19% was observed for Et-Ac fraction in AIDRs. A significant reduction ($p<0.01$) in serum TC and TG level of 54.49 and 79.7S%, respectively was also found for Et-Ac fraction of *Ocimum sanctum* L. The hypoglycemic and hypolipidemic activities were comparable to metformin HCl (150 mg kg^{-1}). In severely diabetic rats, liver glycogen content was decreased by 50.60%. Administration of these fractions to the AIDRs resulted in the significant elevation of liver glycogen content. In diabetic rats, SGOT and SGPT levels were significantly elevated that were further reduced after intraperitoneal administration of these fractions. These results indicate that different fractions of *Ocimum sanctum* L. have favorable effects in bringing down the severity of diabetes together with hepatoprotectivity (Khan *et al.*, 2010).

The constituents of *Ocimum sanctum* L. leaf extracts have stimulatory effects on physiological pathways of insulin secretion which may underlie its reported antidiabetic action (Hannan *et al.*, 2006). Another study suggested that *Ocimum sanctum* L. decreases the serum concentration of both cortisol and glucose and also exhibited antiperoxidative effect. Therefore, *Ocimum sanctum* L. may potentially regulate corticosteroid-induced diabetic mellitus (Gholap and Kar, 2004).

Antigenotoxic effect: *In vivo* cytogenetic assay in *Allium cepa* root tip cells has been carried out to detect the modifying effect of *Ocimum sanctum* L. aqueous leaf extract against Chromium (Cr) and Mercury (Hg) induced genotoxicity. It was observed that the roots post-treated with the leaf extract showed highly significant ($p<0.001$) recovery in Mitotic Index (MI) and Chromosomal Aberrations (CA) when compared to pre-treated (Cr Hg^{-1}) samples and the lower doses of the leaf extract were found to be more effective than higher doses. So *Ocimum sanctum* L. leaf extract possesses the protective effect against Cr Hg^{-1} induced genetic damage (Babu and Uma Maheswari, 2006). Immu-21, a poly-herbal formulation containing *Ocimum sanctum* L. and other herbal extracts inhibited both cyclophosphamide (40 mg kg^{-1} i.p.) induced classical and non-classical chromosomal aberration (Jena *et al*., 2003). *Ocimum sanctum* L. extract treated human lymphocyte culture could reduce experimentally induced mitotic index, sister chromatid exchange and replication index in a dose dependent manner (Siddique *et al*., 2007).

Antioxidant activity: In ethanol treated rats, *Ocimum sanctum* L. leaf extract (100 and 200 mg kg^{-1}) significantly decreased the levels of malondialdehyde to 2.45±0.29 and 2.40±0.14 nmole mL^{-1}, respectively in comparison to 4.87±0.06 in the diseased control. Similarly, in the histamine treated guinea pig group, the same doses of the extract significantly lowered the levels of malondialdehyde to 2.45±0.12 and 2.37±0.16 nmole mL^{-1}, respectively when compared to 4.66±0.11 in the diseased control. The extract (100 and 200 mg kg^{-1}) also increased the levels of superoxide dismutase in pyloric ligated rats to 1.78±0.12 and 1.89±0.05 U mL^{-1}, respectively when compared to 1.29±0.06 U mL^{-1} in the diseased control. In the histamine treated guinea pig group also, the same doses of the extract produced a rise in the superoxide dismutase levels to 2.10±0.11 and 2.20±0.14, respectively when compared to 1.32±0.07 in the diseased control. Since lowered levels of malondialdehyde and increased levels of superoxide dismutase signify antioxidant activity, the antiulcer activity of *Ocimum sanctum* L. might be due to this mechanism (Kath and Gupta, 2006). Aqueous extract of *Ocimum sanctum* L. inhibit the hypercholesterolemia-induced erythrocyte lipid peroxidation activity in a dose-dependent manner in male albino rabbits. Oral feeding also provides significant liver and aortic tissue protection from hypercholesterolemia induced peroxidative damage (Geetha and Vasudevan, 2004).

Anti-carcinogenic property: The anti-carcinogenic properties have been evaluated in the experimental animals induced by different types of carcinogens. *Ocimum sanctum* L. leaves when fed to experimental rats with 600 mg g^{-1} diet for ten weeks, significantly reduced the 3,4-benzo (a) pyrene [B (a) P] and 3'-methyl-4-dimethylaminoazobenzene (3'MeDAB) induced squamous cell carcinoma and hematoma incidences (Aruna and Sivaramakrishnan, 1992). In another report, juice of fresh leaves was applied on the skin of experimental mice thrice a week for 20 min along with tumor promoter agents (dimethylbenzanthracene as initiator and croton oil as promoter of cancer). No incidences of tumor were found in 20 weeks follow up period in *Ocimum sanctum* L. treated group (Serrame and Lim-Sylianco, 1995). The ethanolic extract of *Ocimum sanctum* L. leaves at a dose of 400 and 800 mg kg^{-1}, b.wt., have found to modulate carcinogen metabolizing enzymes such as cytochrome P-450, cytochrome-b5 and aryl hydrocarbon hydroxylase of mice liver (Banerjee *et al*., 1996).

Immunologic effect: The immunoregulatory profile of methanolic extract and an aqueous suspension of *Ocimum sanctum* L. leaves to antigenic challenge of *Salmonella typhosa* and sheep erythrocytes by quantifying agglutinating antibodies employing the Widal agglutination and sheep

erythrocyte agglutination tests and E-rosette formation in albino rats. The data of the study indicate an immunostimulation of humoral immunogenic response as represented by an increase in antibody titer in both the Widal and sheep erythrocyte agglutination test as well as by cellular immunologic response represented by erosette formation and lymphocytosis (Godhwani *et al.*, 1988). Compounds isolated from *Ocimum sanctum* L. extract were observed for their anti-inflammatory activity or cyclooxygenase inhibitory activity (Kelm *et al.*, 2000). Eugenol demonstrated 97% cyclooxygenase-1 inhibitory activity when assayed at 1000 μM concentration (pn). Civsilineol, Civsimavitin, Isothymonin, Apigenin and Rosavinic acid also displayed cyclooxygenase-1 inhibitory activity (Pattanayak *et al.*, 2010).

Effect on central nervous system: Different extracts of stem, leaf and stem callus were tested for anticonvulsant activity by maximal electroshock model using phenytoin as standard. It was observed that ethanol and chloroform extract of stem, leaf and stem calli were effective in preventing tonic convulsions induced by trans corneal electroshock (Jaggi *et al.*, 2003). In case of mouse methanolic extract of *Ocimum sanctum* L. root at a dose of 400 mg kg^{-1} increases the swimming time, suggesting a central nervous system stimulant and/or anti-stress activity of *Ocimum sanctum* L. (Maity *et al.*, 2000). On the other hand, *Ocimum sanctum* L. preparation could be beneficial in the treatment of cognitive disorders such as dementia and Alzheimer's disease (Joshi and Parle, 2006). Other study showed that the plant has significant effect on the central nervous system bringing about antistress and anxiolytic effect that may involve the GABA-ergic system (Nadig and Laxmi, 2005). In addition, the possible involvement of GABA-ergic and serotonergic mechanisms have been implicated in the anti-tussive action of some drugs (Nosalova, 1998).

Anthelmintic effect: The essential oil of *Ocimum sanctum* L. showed potent anthelmintic activity in the *Caenorhabditis elegans* model. Eugenol being the predominant component of the essential oil, is suggested as the putative anthelmintic principle (Asha *et al.*, 2001).

Activity against ulcer: A team of scientist at Central Drug Research Institute, Lucknow India, evaluated its anti-ulcerogenic activity in Cold-restraint (CRU), Aspirin (ASP), Alcohol (AI), Pyloric Ligation (PL) induced gastric ulcer models in rats, Histamine-induced (HST) duodenal ulcer in guinea pigs and ulcer healing activity in Acetic Acid induced (AC) chronic ulcer model (Dharmani *et al.*, 2004). *Ocimum sanctum* L. also shows positive result on pyloric-ligated rats. It may be because its ability to reduce acid secretion and increase mucus secretion (Mandal *et al.*, 1993).

Cardio-protective effect: Prolong oral administration of fresh *Ocimum sanctum* L. leaves augments cardiac endogenous antioxidants and prevents isoproterenol induced myocardial necrosis in rats (Sood *et al.*, 2005). The ethanolic extract of *Ocimum sanctum* L. found to have ameliorative effects in axotomy (experimental denervation) induced peripheral neuropathy in rats. It was observed that administration of *Ocimum sanctum* L. extract for ten days (post operative) attenuated axonal degeneration and nociceptive threshold. It also reduced thiobarbituric acid reactive species. (Muthuraman *et al.*, 2008). Oral feeding of hydroalcoholic extract of *Ocimum sanctum* L. (100 mg kg^{-1}) to male Wister rats subjected to chronic-resistant stress (6 h day^{-1} for 21 days) significantly prevented (Sood *et al.*, 2006). The generation of drug-induced oxygen

radicals in heart cells led to cardiac lipid membrane peroxidation. Urosolic acidisolated from *Ocimum sanctum* L. have been identified as a protector against Adriamycin (ADR)-induced lipid peroxidation. Protection with urosolic acid was 13 and 17% in liver and heart microsomes, respectively (Balanehru and Nagarajan, 1992). In another study effect of pre-and cotreatment of hydroalcoholic extract of *Ocimum sanctum* L. at different doses (25, 50, 75, 100, 200 and 400 mg kg^{-1}) was investigated against isoproterenol (ISO, 20 mg kg^{-1}) myocardial infarction in rats. *Ocimum sanctum* L. at the dose of 25, 50, 75 and 100 mg kg^{-1} significantly reduce glutathione, superoxide dismutase and LDH levels. In this study, it was observed that *Ocimum sanctum* L. at the dose of 50 mg kg^{-1} was found to demonstrate maximum cardioprotective effect (Sharma *et al.*, 2001).

Larvicidal property: Larvicidal activity of *Ocimum sanctum* L. was investigated using its eugenol and triglyceride on *Aedes aegypti* larvae (Kelm and Nair, 1998). When seeds of *Ocimum sanctum* L. was placed in water, it exude within one hour, a mucilaginous substance (polysaccharides) and larvae which came in contact with seeds became firmly attached to it and died due to drowning of larvae. When 100 larvae of *Culex fatigans* was spread over water containing 25, 50 and 75 *Ocimum sanctum* L. seeds m^2 surface area of water for 48 h, 100% mortality was observed in 75 seeds m^2 of water while 65 and 89% mortality observed in 25 and 50 seeds m^2 of water respectively (Hasan and Deo, 1994). Essential oil of *Ocimum sanctum L.* showed larvicidal efficacy against larvae of *A. stephensi, A. aegypti* and C. *quinquefasciatus* (Vinayagam *et al.*, 2008). Another study showed that the mosquito larvicidal property of both leaf and flower extract of *Ocimum sanctum* L. against larvae of *Aedes aegypti* and *Culex quinquefasciatus*. Compared to flower extract, leaf extracts were found to be more effective against both types of mosquitoes (Anees, 2008).

Miscellaneous activity: Khanna and Bhatia (2003) have demonstrated the antinociceptive activity of *Ocimum sanctum* L. The alcoholic extract increased the tail-flick withdrawal latency in mice which was reversed with naloxone indicating the involvement of opioid receptors in the analgesic activity (Sharma *et al.*, 2002).

It was found in a transdermal drug (Flurbprofen) delivery study on abdominal skin of rat that a combination of *Ocimum sanctum* L. oil and terpentine oil, demonstrated significantly higher drug delivery than the synthetic combination such as isopropylene and propylene glycol (Charoo *et al.*, 2008).

The effect of ethanolic extract of *Ocimum sanctum* L. was studied on the noise stress induced changes in albino rats. Acute noise stress caused leukopenia, increased corticosterone level and enhanced the neutrophil functions as indicated by an increase in the candida phagocytosis and Nitro Blue Tetrazolium (NBT) reduction. Pretreatment with the *Ocimum sanctum* L. extract brought back the stress altered values to normal levels indicating the stress alleviating effect of *Ocimum sanctum* L. (Archana and Namasivayam, 2000).

Ocimum sanctum L. fixed oil produced hypotensive effect in anaesthetised dog which seems to be due to its peripheral vasodilatory action. The oil increase blood-clotting time and percentage increase was comparable to aspirin and could be due to inhibition of platelet aggregation. The oil also increases pentobarbitone-induced sleeping time in rats indicating probable inhibitory effect of oil towards cytochromic enzyme responsible for hepatic metabolism of pentobarbitone (Singh *et al.*, 2001).

Junctachote and Berghoter have studied the antioxidant activities of *Ocimum sanctum* L. in order to preserve the packed food from rancidity (decomposition of fats, oils and other lipids by hydrolysis and/or oxidation). By taking battery of tests to assess the state of rancidity, it was found that *Ocimum sanctum* L. extract can be used as a preservative (Juntachote and Berghofer, 2005; Anbarasu and Vijayalakshmi, 2007).

Toxicological property and side effect: There have been number of scientific studies conducted to evaluate the toxic effects of this plant. Bhargava and Singh (1981) studied the toxicity to find out the lethal dose of ethanolic extract of *Ocimum sanctum* L. in adult mice. Approximate LD_{50} of *Ocimum sanctum* L. was found to be 4505±80 mg kg^{-1} b.wt., on administration by oral route and 3241±71 mg kg^{-1}, b.wt., by Intra-peritoneal (ip) routes. Aqueous and alcoholic extracts of *Ocimum sanctum* L. were injected ip in mice with graded doses (3500-6300 mg kg^{-1}, b.wt.) and mortality was observed for a period of 72 h. The administration of aqueous extract did not produce any acute toxic symptoms (100% survival) at doses up to 5 g kg^{-1}, b.wt. and the alcoholic extract was well tolerated (80% survival) up to a dose of 4 g kg^{-1}, b.wt. The acute LD_{50} values for aqueous and alcoholic extracts were found to be 6200 and 4600 mg kg^{-1}, b.wt., respectively (Devi and Ganasoundari, 1995).

Two animal studies suggested that large amounts of *Ocimum sanctum* L. might negatively affect fertility but no adverse reactions have been reported in human clinical trials (Seth *et al*., 1981; Kasinathan *et al*., 1972). Treatment of albino rats with a benzene extract of *Ocimum sanctum* L. leaves (250 mg kg^{-1} b.wt.) for 48 day decreased total sperm count, sperm motility and forward velocity. The percentage of abnormal sperm increased in caudal epididymal fluid and the fructose content decreased in the caudal plasma of the epididymis and the seminal vesicles. The results suggest that such effects are due to androgen deprivation, caused by the anti-androgenic property of *Ocimum sanctum* L. leaves. The effect was reversible because all parameters returned to normal 2 week after the withdrawal of treatment (Ahmed *et al*., 2002; Mondal *et al*., 2009).

CONCLUSION

The scientific research on *Ocimum sanctum* L. suggests a huge biological potential of this plant. It is strongly believed that detailed information as presented in this review on the phytochemical and various biological functions of the extracts might provide detailed evidence for the use of this plant in different medicines.

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