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Review Article

Ocimum sanctum: Role in Diseases Management Through Modulating Various Biological Activity

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ABSTRACT

Medicinal plants are used commonly by traditional medical practitioners in their daily practice for the treatment of various diseases. The treatment based on natural products are preferred because they are more economic and have lesser side-effects. In this regards, *Ocimum sanctum* commonly known as holy basil or *tulsi* is used in the diseases cure and treatment since ancient time. *Ocimum sanctum* has been proven health promoting effect through modulation of various biological activates. *Ocimum sanctum* shows therapeutic role through its anti-oxidant, anti-inflammatory, anti-microbial, anti-diabetic, hepatoprotective and wound healing effects. Besides, the constituents of holy basil have been confirmed to have a noteworthy effect in cancer management through inhibition of cancer development and progression. Further, the synergistic effect of *Ocimum sanctum* component with anti-cancer drugs has been proven as it reduces the growth of cancer. Molecular mechanism and human clinical trials based should be performed to avail its role in diseases cure and management. This review comprehensively summarizes the role of holy basil in disease management through *in vivo* and *in vitro* study.

Key words: *Ocimum sanctum*, Health promoting effect, Anti-cancer, Anti-oxidant effect.

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INTRODUCTION

Medicinal plants are commonly used by traditional medical practitioners in their daily practice for the treatment and prevention of various diseases. The treatment based on natural products have advantage over allopath based treatment due to its reduced expensiveness and lesser side effects. In modern complementary and alternative medical practice, plants are the chief source of therapeutics and various parts of the plant, such as seeds, root, stem, leaves, as well as fruit holds various types of bioactive components[1-3] and these bioactive play a significant role in the diseases cure and prevention. Curcumin of turmeric, thymoquinone from black seed, oleuropein of olive, gingerol and shogaol of ginger and various other active compounds shows therapeutic role *via* modulating biological activities and kills various types of cancer cells.

Lamiaceae is a family of many medicinally important plants which are used for curative and preventive purposes for various disorders. Basically, 236 genera and more than 6000 species belong to this family. The largest genera of Lamiaceae family include *Salvia, Scutelleria, Stachys, Plectranthus, Hyptis, Teucrium, Vitex, Thymus, Nepeta.*[4] The therapeutic potential of plants belonging to these genera is attributed to the presence of a wide range of phytochemicals like alkaloids, saponins, flavonoids, polyphenolic contents. Many researchers have reported the several bioactive potentials of different genera of Lamiaceae shows biological activities such as antioxidant, antimicrobial, anti-inflammatory, antidiabetic, cardioprotective effects etc.[4] Genus *Ocimum* contains more than 150 species including *Ocimum tenuiflorum* L. (holy basil), *Ocimum gratissimum* (African basil), *Ocimum basillicum* (sweet basil), *Ocimumam mericanum*. The plants of this genera have been recognized to possess several medicinally important bioactivities such as antifungal, antinocicepative, anticonvulsant, antioxidant, germicidal and antimalarial activities, etc.[5] These species belonging to Genus *Ocimum* have excellent therapeutic potentials and medicinal properties. *Ocimum tenuiflorum*, is normally known as holy basil or *tulsi* (Figure 1).

The following is the classification of Tulsi[6]

Kingdom: Plantae

Order: Lamiales

Family: Lamiaceae

Genus: *Ocimum*

Species: *tenuiflorum*

Therapeutic roles of Tulsi have been noted since ancient time. Tulsi is used in various forms and it is taken as herbal tea, dried power or fresh leaf and the dried leaves of tulsi are used to be mixed with stored grains to prevent insects.[7] Various types of active compounds have been reported to be found in Tulsi. These bioactive compounds show role in the disease management through modulation of various biochemical and physiological processes. Antioxidant activity has been explained as aqueous extract increased antioxidant enzymes superoxide dismutase, catalase, glutathione peroxidase, as well as glutathione transferase.[8]

Tulsi has been found to be a chief source of many biologically active compounds like Ursolic acid, Eugenol, Rosmarinic acid, Linalool, Carvacrol, and

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β caryophyllene. The chemical structure of active compound is given below (Figure 2). Various kinds of essential oils have been prepared from Tulsi. The oils obtained from Tulsi have been reported to inhibit the growth of *bacteria*. Various compounds have been identified in Tulsi leaves, flower spikes, or essential oil and all of these three are anticipated to be accountable for such activity are camphor, eucalyptol and eugenol.[9] The role of tulsi in cancer inhibition has been proven as given of aqueous and ethanolic extracts of *Ocimum sanctum* to mice bearing Sarcoma-180 solid tumors arbitrated an important reduction in tumor volume and an increase in lifespan and this finding evidently designate *Ocimum sanctum* extracts hold anticancer activity.[10] This review comprehensively summarizes the role of Tulsi in various types of disease management through modulating various biological activities, along with special emphasis on in *vivo* and *in vitro* study.

Mechanism of action of *Ocimum sanctum*

Tulsi holds various ingredients in the different parts of plants and stem as well as leaves hold a variety of constituents such as saponins, triterpenoids, flavonoids, and tannins[11] and leaf volatile oil contains eugenol.[12] These constituents show pivotal role in disease cure and diseases management through modulating various biological activities. The possible mechanisms of action of Tulsi in health management are described as below;

Higher concentration of reactive oxygen species generates oxidative stress and damage to the macromolecules and cause the pathogenesis. Antioxidant activity of medicinal plants neutralise the free radical potentiality and act as a scavenger of free radical. Medicinal plant inhibits the pathogenesis through neutralisation of oxidative stress via antioxidant property. Free radical scavenging activity is a chief mechanism through which *Ocimum sanctum* products protect against cellular damage.[13] Its role in free radicals scavenging property has confirmed it has strong antioxidant activity and free radicals scavenging property respectively. Additional, hydrogen peroxide, hydroxyl radical and superoxide radical scavenging methods determined that extracts with concentration100 µg/ml have hydrogen peroxide (20.12%), hydroxyl radicals (12.68%) and superoxide radicals (21.68%) scavenging activity respectively.[14]

Figure 1: *O. Tenuiflorum* (Holy basil).

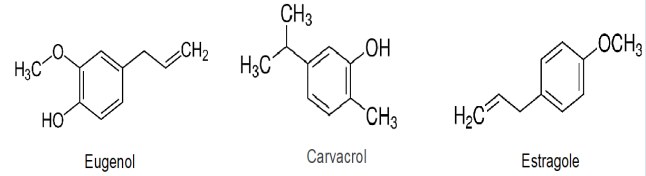

Figure 2: Chemical structure of active compound of Holy basil.

Several diseases like cancer, diabetes etc. have been reported to be linked with inflammatory processes. *Tulsi*, may help to reduce *inflammation and act as anti-inflammatory agents through modulating activities of various genes. Ocimum sanctum* essential oil at concentration 250 µg/mL and more decreased MMP-9 activity in lipopolysaccharide induced inflammatory cells and dose-dependent downregulation of MMP-9 expression was seen with the treatment of *Ocimum sanctum* essential oil compared to the control.[15] Alcoholic and water extracts of OS-dry leaves (OSAE and OSWE) (1 mg dwt/mL) pure compound EUG (60 µg/mL) and positive control IMT (20 µg/mL) showed marked inhibition on LPS induced TNF-α secretion by THP-1 cells. At the selected concentration, the plant extracts, EUG and IMT inhibited gene expression of cytokines and chemokines and translocation of NF-κB-p65 to the nuclei.[16]

Resistance to antibiotic drugs is major health problem and its remedy is urgently needed. Natural compound plays a significant role in the inhibition of bacterial growth or kill the bacteria through rupture of cell wall. Tulsi has established anti-gonorrheal efficacy against multiresistant strains of *Neisseria gonorrhoea* and clinical isolates of beta-lactamase producing methicillin resistant *Staphylococcus aureus.*[17]

Holy basil plays significant role as anti-tumour through its activity against cancer cells or inhibit the cancer cells. Moreover, anti-tumour effect of holy basil was noted through modulating cell signalling pathways. Extracts of holy basil leaves inhibit the proliferation, migration, invasion, and also play role in the induction of apoptosis of pancreatic cancer cells. The expression of genes that promote the proliferation, migration and invasion of pancreatic cancer cells such as activated ERK-1/2, FAK, and p65 was downregulated in pancreatic cancer cells after O. sanctum treatment.[18]

Pharmacological effects of holy basil

Antioxidant effect

A pioneer study was performed to examine whether *Ocimum sanctum* protects against radiation induced lipid peroxidation in liver and this study was aimedto determine the role of the inherent antioxidant system by extract. The result showed that extract of *O. sanctum* (OE) increased the important antioxidant molecule i.e., glutathione (GSH) and other antioxidant enzymes significantly above normal levels whereas radiation significantly reduced all the values. Further, pretreatment with the extract checked the radiation induced depletion of GSH and all of the antioxidant enzymes and maintained their levels within or above the control range. Study based on finding concluded that Ocimum extract (OE) protects against radiation induced lipid peroxidation and that protecta the reduction of GSH and other antioxidant enzymes. Thus, Ocimum have a significant role in the protection from oxidative damage induced by oxidative stress.[19] The antioxidant activity of holy basil and herbal powder was examined in rats with liver injury caused by administration of carbon tetrachloride mixed witholive oil. Holy basil and herbal powder was given orally and it exhibited statistically significant antioxidant activity, reported by increased levels of glutathione peroxidase, glutathione S-transferase, glutathione reductase, superoxide dismutase and catalase.[20]

A previous study was performed to evaluate the potential role of alcoholic and aqueous extracts of *Ocimum sanctum* in wound healing. The Result demonstrated that alcoholic and aqueous extract significantly increased wound breaking strength and antioxidant levels including superoxide dismutase, catalase, reduced glutathione. In addition, lipid peroxidation was found to be significantly decreased the when compared with the control group.[21]

The result of another study havereported that radiation significantly increased the lipid peroxidation rate. However, pretreatment with Ocimum extract (OE) meaningfully reduced the lipid peroxidation and enhanced recovery to normal levels. The findings detailed that Ocimum extract protects against radiation induced lipid peroxidation and that GSH and the antioxidant enzymes seem to have a significant role in the protection.[19]

Anti-inflammatory activity

The essential oil of *Ocimum sanctum* at the concentration of 250 µgram/mL and more concentration have been showed a significant decrease in the number of migrated cancer cells and suppressed Matrix metallopeptidase 9 (MM9) activity in lipopolysaccharide induced inflammatory cells. Moreover, a dose-dependent downregulation of Matrix metallopeptidase 9 expression was seen with the treatment of *Ocimum sanctum* essential oil. The finding revealed that *Ocimum sanctum* essential oil possessed antimetastatic and anti-inflammatory potentials.[22]

In a recent study, the fixed oil of *Ocimum sanctum* was established to determine its significant anti-inflammatory activity against carrageenan and several other mediator-induced paw edema. Further, a substantial inhibitory effect was also seen in castor oil-induced diarrhoea. It also inhibited arachidonic acid and leukotriene-induced paw edema and results of anti-inflammatory activity of *Ocimum sanctum* support the dual inhibition of arachidonate metabolism as designated through its activity in inflammation models that are insensitive to selective cyclooxygenase inhibitors.[23]

The result of an *in vivo* study demonstrated that newly synthesised NLCs formulation of *Ocimum sanctum* L. leaf extract showed brilliant anti-arthritic activity and the results were found to be comparable with standard drug diclofenac gel for its analgesic and anti-arthritic activities.[24]

Another study result demonstrated that essential oil extract of holy basil caused antibacterial efficacy, which improved with an increase in concentration as well as contact period. Moreover, it also showed a significant anti- inflammatory action.[25] A methanol extract and an aqueous suspension of holy basil were found to inhibit acute as well as chronic inflammation tested by carrageenan-induced pedal edema and croton oil-induced granuloma and exudate, respectively. In both test procedures, the anti-inflammatory response of 500 mg per kg of methanol extract and aqueous suspension was comparable to the response observed with 300 mg per kg of sodium salicylate.[26]

Another interesting finding based on the role of holy basil as anti-inflammatory revealed that *Ocimum sanctum* fixed oil and linolenic acid possessed significant antiinflammatory activity against PGE2, leukotriene and arachidonic acid-induced paw edema. Moreover, finding advocate that linolenic acid present in *O. sanctum* fixed oil has the capability to stop both the cyclooxygenase and lipoxygenase pathways of arachidonate metabolism and might be accountable for the anti-inflammatory activity of the oil.[27]

Anti-microbial effects

The antiviral efficacy of three different extracts each from leaves of *O. sanctum* was tested against H9N2 virus. The result demonstrated that all thre extracts of *O. sanctum* had significant virucidal activity. Likewise, therapeutic effect was seen in all three extracts of *O. sanctum* in comparison to the virus control, nevertheless, crude extract of *Ocimum* and terpenoid of *Ocimum* maintained this effect for longer period of time.[28] Another study was performed to examine the antimicrobial activity of *Ocimum sanctum* (tulsi) extract. The result revealed that 8% concentration of the tulsi extract showed maximum zone of inhibition against *A. actinomycetemcomitans and P. gingivalis*. Moreover, antimicrobial activity of tulsi extract at 6 and 8% concentrations, and 0.2% chlorhexidine against *A. actinomycetemcomitans*showed statistically significant differences between the groups. It was established that 8% concentration of *O. sanctum* (tulsi) extract showed the maximum antimicrobial activity against *A. actinomycetemcomitans* and *P.* gingivalis.[29]

An interesting study was performed to measure the *in vitro* antimicrobial activity of Tulsi leaves extract on periodontal pathogens. Result confirmed that at 5% and 10% concentrations, Tulsi extracts established antimicrobial activity against A. actinomycetemcomitans, similar to doxycycline with similar inhibition zones. Moreover, study based on finding established that tulsi demonstrated effective antimicrobial property against A. actinomycetemcomitans, advising its probable use as an in effect and reasonable "adjunct" along with the standard care in the managing of periodontal conditions.[30]

Anti-microbial activity (Minimum Inhibitory Concentration and zone of inhibition) of holy basil extract against *Actinobacillus actinomycetemcomitans* in human dental plaque was evaluated. Result of the study confirmed that at the 6% (w/v) concentration of holy basil extract, a zone of inhibition of 22 mm was obtained and it was the widest zone of inhibition observed among all the ten different concentrations tested. The zone of inhibition for positive control was 25 mm and no zone of inhibition was observed around the negative control.[31]

Antifungal activity of *Ocimum sanctum* leaves against dermatophytic fungi was measured. The result of the study demonstrated that *O. sanctum* leaves possessed antifungal activity against clinically isolated dermatophytes at the concentration of 200 µg/mL. Based on the finding of this study, it was concluded that *Ocimum sanctum* had antifungal activity, and the leaf extracts might be a useful source for dermatophytic infections.[32]

Anti-diabetic effect

A study was performed to isolate and characterize antidiabetic component from hydro alcoholic extract of *Ocimum sanctum* aerial part. The result revealed that bioactive fraction was potent antidiabetic because of its potential to improve glucose as well as lipid parameters. The finding advocate that tetracyclic triterpenoid isolated from aerial part of *Ocimum sanctum* has a pronounced anti-diabetic potential.[33] The silver nanoparticles derived from *O. sanctum* and *O. basilicum*, correspondingly showed an inhibitory effect at 89.31 ± 5.32%, and 79.74 ± 9.51%, respectively, against *Bacillus stearothermophilus* α-glucosidase enzyme model who demonstrates an improved biocatalytic potential compared to their respective crude extracts and the control.[34]

A pioneer study explained the effects of the fixed oil extracted from holy basil leaves on the blood glucose levels and serum lipid profile of streptozotocin-induced diabetic rats. The results demonstrated that fixed oil significantly decreased the elevated levels of blood glucose, the serum lipid profile and the levels of serum creatinine. Additionally, the fixed oil increased the diabetically-reduced levels of serum insulin as well as decreased the kidney weight. Besides, fixed oil decreased the elevated thiobarbituric acid reactive substances level and increased the activity of various anti-oxidative enzymes in the rat renal tissue.[35]

Another study was performed to measure the effect of *O. santalum* on three important enzymes of carbohydrate metabolism, hexokinase and phosphofructokinase along with glycogen content of insulin-dependent and insulin-independent tissue. Administration of extract at dose of 200mg per kg causes decrease in plasma glucose levels. Renal glycogen content increased by over ten folds while hepatic and skeletal muscle glycogen content decreased by 75 and 68% in diabetic controls versus controls.[36]

Oral administration of alcoholic extract of leaves of holy basil led to noticeable dropping of blood sugar level in normal, glucose fed hyperglycemic and streptozotocin induced diabetic rats. Additionally, the extract potentiated the action of exogenous insulin in normal rats.[37]

Hepatoprotective effect

A recent study was conducted to determine the hepatoprotective activity of holy basil and its combination with silymarin and to examine whether its synergistic hepatoprotection exists with silymarin. The results based on this study confirmed that *Ocimum sanctum* alcoholic leaf extract shows important hepatoprotective activity and synergism with silymarin.[38] Hepatoprotective potency of holy basil aqueous extract against butyl p-hydroxybenzoic acid toxicity in mice was examined. The result demonstrated that oral treatment of butylparaben to mice resulted in significant elevation in hepatic lipid peroxidation, which could be due to significant reduction in non-enzymatic antioxidant contents and enzymatic antioxidants activities. Co-treatment of holy basil extracts in different doses resulted in significant reduction in butylparaben-induced hepatic changes. Oral administration of *O. sanctum* with butylparaben resulted in dose-dependent and significant reduction in lipid peroxidation as compared to butylparaben alone treated group.[39]

Anti-ulcer effect

It was reported that *Ocimum sanctum*, decreased the incidence of ulcers and also enhanced the healing of ulcers. Moreover, holy basil completely healed the ulcers within twenty days of treatment in acetic acid-induced model. It was seen that that anti-ulcer effect of holy basil may be due to its cytoprotective effect.[40] The antiulcerogenic property of holy basil was examined in pyloric ligated and pyloric ligated and aspirin treated rats. The extract of holy basil reduced the ulcer index, free and total acidity on acute and chronic administration. After seven days of pretreatment with the drug increased the mucous secretion also. Finding advoc that extract has antiulcerogenic property against experimental ulcers, and it is due to its ability to reduce acid secretion and increase mucous secretion.[41]

Anti-fertility effect

Anti-fertility effect of holy basil was investigated and it was noticed that treatment of rats with a leaves extract with dose of 250 mg/kg body weight decreased total sperm count and sperm motility. Moreover, percentage of abnormal sperm increased in caudal epididymal fluid, and the fructose content decreased in the caudal plasma of the epididymis. Study based on finding revealed that this effects are due to androgen deprivation, caused by the anti-androgenic property of holy basil leaves.[42]

Anti-stress effect

Anti-stress potential of holy basil in chronic variable stress paradigm and mechanism of anti-stress was explored in vitro using cell and cell-free assays was examined. Rats were given *Ocimum sanctum* followed by chronic variable stress regimen. *Ocimum sanctum* and its constituents inhibited cortisol release. Therefore, *Ocimum sanctum* was found to be effective in the management of stress effects, and anti-stress activity could be due to inhibition of cortisol release as well as blocking CRHR1 receptor.[43]

Anti-amnesic effect

A study was conducted to investigate the anti-amnesic effect of various *Ocimum* Species extracts using *in-vitro* and *in-vivo* models. Significant antioxidant and acetylcholinesterase (AChE) inhibition activity was observed with all prepared extracts. The *in-vivo* studies showed that *O. basilicum* extract (OBE) pre-treatment reversed the memory deficit induced by scopolamine in mice, evident by significant decrease in the transfer latency time and increase in step down latency in elevated plus maze and passive shock avoidance task, respectively.[44]

Effect on nervous system

The effect of *Ocimum sanctum* leaf extract on the dietary supplementation in the parkinson's disease was investigated. Result demonstrated that supplementation of holy basil extract showed a dose dependent significant delay in the loss of climbing ability and reduction in oxidative stress in the brain of parkinson's disease model flies. Finding concluded that holy basil extract is powerful in reducing the parkinson's disease symptoms.[45] The ethanolic extract from the leaves of *Ocimum sanctum* was screened for its effects on the noise induced changes in the central cholinergic system. Result confirmed that pretreatment of the animals with ethanol extract of holy basil leaves prevented the noise induced changes in two cholinergic parameters in all areas of brain. The results of the study designate the protective nature of the plant material on the brain tissues against the detrimental effect of noise stress.[46]

Immunomodulatory effect

Immunotherapeutic potential of aqueous extract of holy basil leaf in bovine sub-clinical mastitis was examined. The results demonstrated that the aqueous extract treatment reduced the total bacterial count and increased neutrophil and lymphocyte counts with enhanced phagocytic activity.[47] A methanol extract and an aqueous suspension of holy basil leaves were investigated for their immunoregulatory profile. The results of the study demonstrated an immunostimulant capability for holy basil which may be related in clarifying the adaptogenic action of the plant[26] The result of another study demonstrated that significant increase in the levels of IFN-γ , IL-4 and percentages of T-helper cells and NK-cells were observed in the Tulsi extract intervention group in contrast to the placebo group.[48]

Another study investigated the effect of seed oil on some immunological parameters. Seed oil caused a significant increase in anti-sheep red blood cells antibody titre and a decrease in percentage histamine release, and decrease in footpad thickness and percentage leucocyte migration inhibition. Therefore, seed oil seems to modulate both humoral and cell-mediated immune responsiveness.[49]

Hypolipidemic effect

A study result confirmed that fresh leaves of Tulsi were mixed as 1 g and 2 g in 100 grams of diet given whoconveyed about noteworthy changes in the lipid profile of normal albino rabbits. Moreover, it resulted in significant lowering in serum total cholesterol, phospholipid, triglyceride and significant increase in the HDL-cholesterol and total faecal sterol contents.[50]

Another study result concluded that treatment with fixed oil during the last three weeks of high fat fed-diet diet feeding decreased the high serum lipid profile and cardioprotective actions against hyperlipidemia. The anti-hyperlipidemic action of holy basil fixed oil was chiefly resulted from the suppression of liver lipid synthesis. Linolenic acid and linoleic acid confined in holy basil fixed oil were probably accountable for both lipid-lowering and cardiac protective action against hyperlipidemia.[51]

Cardioprotective effect

An experiment was performed to search any beneficial effect of holy basil in experimental pulmonary hypertension in rats. Result confirmed that *Ocimum sanctum* at a dose of 200 mg per kg treatment improved increased lung weight to body weight ratio and right ventricular hypertrophy. Furthermore, *Ocimum sanctum* treatment was found to decrease Nox-1 expression and increased the expression of Bcl2/Bax ratio. The study validates that *Ocimum sanctum* has therapeutic

capability against pulmonary hypertension in rat which are attributed to its antioxidant effect.[52]

The effect of methanolic extract of Tulsi leaves on inflammation in isoproterenol induced myocardial infarction in rats was examined. Isoproterenol induced myocardial infarction and increased the levels of cardiac markers and phospholipid content.

Though, the same were reduced on pre-treatment with extract of holy basil leaves. The activities of 5-lipoxygenase and cycloxygenase-2 and levels of leukotriene B4 and thromboxane B2 were also elevated in isoproterenol -treated rats, which were significantly decreased in extract pre-treated rats. Study based on result demonstrated that cardioprotective effect may be due to the high phenolic content of methanolic extract of leaves.[53]

Wound healing effect

A study was performed to evaluate the wound healing effect and it was demonstrated that extract of holy basil meaningfully increased the wound breaking strength in incision wound model. The extract treated wounds were found to epithelialize faster and the rate of wound contraction was significantly increased as compared to control wounds. Finding revealed that the leaf extract promotes wound healing considerably and capable to overcome the wound healing suppressing action of dexamethasone.[54] The measurement of the wound areas was performed on the different day and then percentage of wound closures were measured consequently. By the 14th day, silver nanoparticle gel showed 96.20% wound healing activity compared with that of the standard as well as control base.

The antibacterial inhibitory efficiency of prepared nano gel was found similar to the commercial product against the Staphylococcus aureus, E. coli and Pseudomonas aeruginosa.[55] Wound healing activity of aqueous extract of holy basil leaves along with its effect on tumor necrosis factor-alpha was evaluated using excision model of wound repair. After application of the holy basil extract, rate of epithelization with an increase in wound contraction was observed. In animals, treated with 10% extract in petroleum jelly, wound healing was faster as compared to control group which were treated with petroleum jelly alone.[56]

Radioprotective effect

Vicenin-2 is a flavonoid collected from holy basil and it has been described to have radioprotective, anticancer, and radiosensitizing properties. Study evaluated the effect of Vicenin-2 on the cell viability and the effect on PTEN and Akt1 when Vicenin-2 was used alone and in combination with radiation. It was reported that Vicenin-2 was able to lower cancer cell survival and phosphorylated Akt whereas promoting the expression of pro-apoptotic genes and decreasing anti-apoptotic genes.[57]

Protective effect of two water-soluble flavonoids i.e., Orientin and Vicenin, isolated from the leaves of holy basil against radiation induced chromosome damage in cultured human peripheral lymphocytes was evaluated. Result confirmed that pre-treatment with either Orientin and Vicenin, at all concentrations significantly reduced the micronucleus count in a concentration dependent manner. Pre-treatment with Orientin or Vicenin significantly reduced the MN counts to 51-67%.[58]

A recent study was conducted to evaluate if holy basil protects against radiation induced lipid peroxidation in liver and to determine the role, if any, of the inherent antioxidant system in radioprotection by *Ocimum sanctum*. *Ocimum sanctum*, itself increased the GSH and enzymes significantly above normal levels whereas radiation significantly reduced all the values. Pretreatment with the extract checked the radiation induced depletion of GSH and all the enzymes and maintained their levels within or above the control range. Radiation significantly increased the lipid peroxidation rate after exposure. Extract pretreatment significantly reduced the lipid peroxidation and accelerated recovery to normal levels.[59]

Anti-cancer effect

Natural products or active compound of medicinal plants play a vital role in disease management including cancer through modulating various biological activities.[60-69] An important study based on colon cancer was conducted to analyse the anti-proliferative effect of Vicenin-2, a component of *Ocimum sanctum* on human colon cancer cells. Vicenin-2 is a flavonoid from basil and result of the study demonstrated that Vincenin-2 caused substantial cell cycle arrest at the G_2M phase. Additionally, Vicenin-2 treatment increased the expression of cytochrome C, Bax as well as caspase-3 and decreased the expression of Bcl-2.[70]

Another study was performed to define the efficacy of vicenin-2, an active constituent of holy basil, as a single agent and in combination with docetaxel in carcinoma of prostate. Result demonstrated that vicenin-2 efficiently induced anti-proliferative, anti-angiogenic as well as pro-apoptotic. In this respect, vicenin-2 in combination with docetaxel synergistically inhibited the growth of prostate tumors. Based on finding, the study concluded e that vicenin-2 is effective against prostate cancer progression and indicated that vicenin-2 and docetaxel co-administration is more powerful than either of the single agents in androgen-independent prostate cancer.[71] Vicenin-2 either in single form or in combination with radiation reduced the surviving cancer cells.

In addition, it increased DNA fragmentation and increased caspase-3 activity and decreased levels of MMP-2 as well as p21 proteins.[57] Ethanol extracts of holy basil showed anti-metastatic activity through activation of anti-oxidative enzymes. Extract caused cytotoxicity against lung carcinoma cells and significantly inhibited cell adhesion and invasion as well as activities of matrix metalloproteinase-9. Moreover, extract significantly reduced the tumor nodule formation, lung weight and inhibitory effect of extract on metastasis was confirmed.[72]

CONCLUSION

Medicinal plants and their products have been reported to offer protection against different diseases and have been used by traditional medical practitioners in their daily practice for the treatment and prevention of various diseases. In modern complementary and alternative medical practice, plants are the chief source of therapeutics and various parts of the plant, such as seeds, root, stem, leaves, as well as fruit holds various types of bioactive components. Holy basil has been shown to have a significant therapeutic role through modulating various biological activities. Holy basil holds various types of constituents and such ingredients play role in diseases cure. Various kinds of phytochemicals like flavonoids, phenolic compounds, saponins etc., are reported to be present in Tulsi that are supposed to be responsible for various biological activities of tulsi including antioxidant, anticancer, anti-microbial, anti-inflammatory, wound healing, cardioprotective effects. Howecer, antioxidant and antimicrobial properties of basil make it a potential source of antimicrobial and antioxidant agents. The natural products obtained from Tulsi are expected to serve as promising new pharmaceutical leads or dietary supplements to combat various diseases, and thus, they provide an explanation for the use of Tulsi in traditional medicines. Further, the holy basil receiving much attention of researcher/clinicians as its role in cancer prevention and treatment. Laboratory research confirmed that holy basil shows role in the inhibition of cancer. Details study should be performed to evaluate the mechanism of action in diseases management.

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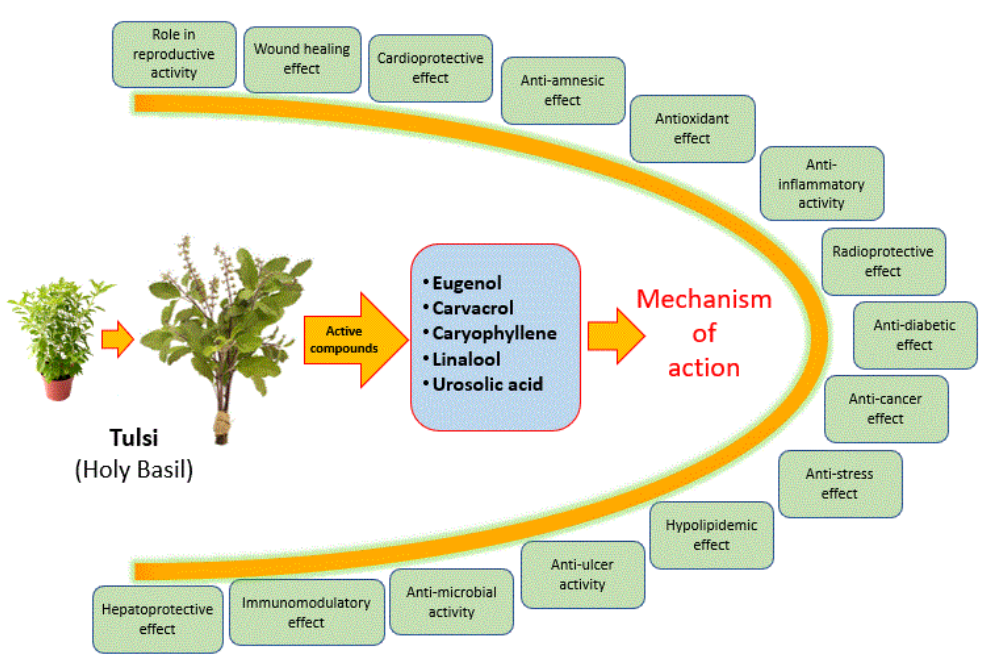
GRAPHICAL ABSTRACT



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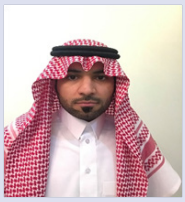

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