ejpmr, 2017,4(7), 740-750

SJIF Impact Factor 4.161

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

Review Article

ISSN 2394-3211

EJPMR

ANTIMICROBIAL APPLICATIONS OF DIFFERNET PLANT ESSENTIAL OILS

Tahira Mohsin[1], Hira Sarfaraz[2] and Malik Umar Farooq Gohar[3]*

Institute of Industrial Biotechnology, GC University Lahore, Pakistan.

***Corresponding Author: Dr. Malik Umar Farooq Gohar**

Institute of Industrial Biotechnology, GC University Lahore, Pakistan.

Article Received on 21/05/2017 **Article Revised on 11/06/2017** **Article Accepted on 01/07/2017**

ABSTRACT

Essential oils are natural, aromatic, volatile and lipid soulble compounds. These are extracted from various methods such as hydro or steam distillation, expression method, carbon hypocritical method and solvent extraction. Major constituents of plant essential oils are terpenoids, terpenes and aromatic compounds. Almost all PEOs have antimicrobial activity as they disrupt the cellular metabolism of microbial cells by various mechanisms. PEOs also exhibit some biological effects like cytotoxicity, phototoxicity, nuclear and cytoplamic mutagenicity. Essential oils of different plants like Oregano, Cinnamon and Basil have different antibacterial, antifungal properties. PEOs have various applications in medical as well as in food industry. These are used as food preservative due to their antimicrobial activity. Due to their aromatic properties, PEOs are widely used in flavoring of foods and in making aroma and perfumes.

KEYWORDS: Essential oils, Chemical composition, Antimicrobial activity, Biological effects, Food preservative.

INTRODUCTION

Essential oils are natural, volatile, lipid soluble, odoriferous and aromatic liquids and are extracted from different organs of plants like flowers, buds, leaves, barks, seeds. Several methods are known to extract these essential oils from plants; these include hydro and steam distillation, expression method, carbon hypocritical method and solvent extraction. Steam distillation method is the commonest method for commercial scale production.[1,2] The best source of plant essential oils is aromatic plants and the flavor and odor of plant essential oils depends upon the amount and nature of constituents present in them. Additionally, price of essential oils depends upon the amount of PEOs extracted from particular plant. Plant essential oils have different colors and this color is due to the presence of many native pigments. Because of this property PEOs have major application in food industries such as food flavors.[3] Almost all parts of plants are the good sources of essential oils and extracted oils from these sources have major applications in food industries. But there are some limitations of conventional extraction methods and to overcome these limitations some modern techniques are developed in order to improve the extraction efficacy.[4]

Essential oils have antimicrobial as well as antioxidant properties and are known as effective additives in food products. As PEOs have antimicrobial activity and hydrophobic nature, these are used in food packaging in order to enhance the shelf life of food products. Essential oils are widely used in “hurdle technology” as these are natural additives. Thus, essential oils can serve as processing aid as green technology. There are approximately 3000 essential oils are known from which 300 or some of their constituents are commercially essential particularly for the pharmaceutical, agronomic, food industry, perfume, sanitary and cosmetic (Fig. 1). For example, d-limonene, geranyl acetate or d-carvone are useful in soaps, creams, perfumes, as fragrances for household cleaning products, as industrial solvents and as flavour additives for food. Moreover, essential oils have a great use in massages as combination with vegetal oil or in baths but most commonly in aromatherapy.[5]

SOURCES AND CHEMICAL COMPOSITION

Essential oils have been extracted from different components of plants like seeds, barks, leaves, roots, peels and fruits (Table 1). PEOs have both polar and non-polar natural compounds.[6] Major constituents of plant essential oils are aromatic compounds, terpenoids and terpenes.[7] There are two major groups of important components of PEOs. These two are oxygenated compounds and terpene hydrocarbons.

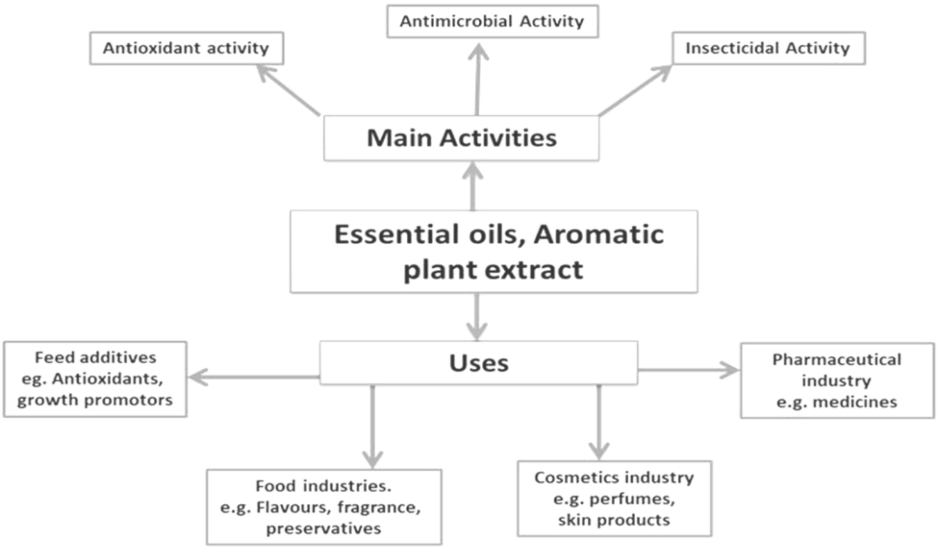

Fig. 1: Different applications of Essential oils

Terpene hydrocarbons

The most ordinary class of chemical compounds present in PEOs is terpenes hydrocarbons. Backbone of terpenes hydrocarbons is isoprene units which are the group of two isoprene units called a terpene unit. There are two important terpene hydrocarbons are sesquiterpenes (C15) and monoterpenes (C10) and have general formula (C5H8)n. Functional properties of monoterpenes are similar to the sesquiterpenes.[8] While some other terpenes molecules included diterpenes (C20), triterpenes (C30), and tetraterpenes (C40) are larger than sesquiterpenes (C15) and monoterpenes (C10) but present in low concentration.[9]

Oxygenated compounds

Oxygenated hydrocarbon compounds are the combination of C, H, and O and can be derived from the terpenesand known as "terpenoids". Some oxygenated compounds normally present in PEOs are phenols (chavicol, carvacrol, thymol, eugenol), aldehydes, ketones, esters, oxides, lactones and ethers.[4]

Table 1: Parts of plant material containing essential oils.

Parts	Plants
Fruit	Nutmeg, Xanthoxylum, black pepper
Leaf	Pine, Basil, patchouli, bay leaf, mint, cinnamon, citronella, eucalyptus, common sage, lemon grass, melaleuca, oregano, peppermint,
Roots	Ginger, plai, turmeric, valerian, spikenard, angelica, vetiver
Seed	Fennel, Almond, , Anise, Coriander, Cardamom, Carrot Celery, Caraway, Cumin, Parsley, Nutmeg
Peels	Bergamot, grapefruit, lemon, lime, orange, kaffir lime, tangerine, mandarin
Woods	Atlas cedarwood, , camphor, rosewood, sandalwood, myrtle, guaiac wood, himalayan cedarwood, Amyris
Flower	Blue tansy, manuka, chamomile, clary sage, clove, cumin, geranium, helichrysum hyssop, lavender, rhododendron anthopogon,, marjoram, orange, rose, jasmine, Baccharises, palmarosa, patchouli, rosalina, ajowan, ylang-ylang, marjoram sylvestris, tarragon, immortelle, neroli
Barks	Cinnamon, Cassia, katrafay, sassafras
Resins	Myrrh, frankincense.
Barries	Sassafras,Allspice, juniper

ANTIMICROBIAL ACTIVITY OF PLANT ESSENTIAL OILS

Foods containing antimicrobial compounds have extended shelf-life. These antimicrobial compounds reduce the growth rate and feasibility of microbes in both unprocessed and processed foods.[10] Essential (volatile) plant oils are edible, medicinal and herbal which make their safe use in food products. Antimicrobial activity of plant essential oils is determined by its chemical structure, composition and functional group. Generally, essential oils have phenolic groups show most effectiveness against microbes.[11,12] Among these, the oils of rosemary, clove, sage, oregano, vanillin and thyme have been found to be most effective against microorganisms. They have commonly more inhibitory action against Gram-positive than against Gram negative bacteria.[13] While there are some oils, included cinnamon, clove, citral and oregano, which have effective action against both Gram positive as well as gram negative bacteria.[14] While non-phenolic components of PEO's are also effective against gram negative bacteria, some of these are more affective like allyl isothiocyanate[15] and some are just quite effective for example garlic oil. Herbs and spices which show restricted antimicrobial activity include: white pepper, marjoram, bay (laurel), juniper oil, anise, mint, tarragon, cardamom, fenugreek, black pepper, spearmint, chili powder, orris root, sesame, cayene (red pepper), celery seed, curry powder, coriander, cumin, dill, ginger, mace, nutmeg and paprika.[16]

The oils with high levels of cinnamamic aldehyde (cassia oil and cinnamon bark), eugenol (cinnamon leaf, bay, allspice and clove leaf and bud) and citral are usually strong antimicrobials.[17] Antimicrobial activity shown by rosemary and sage is due to presence of borneol and other phenolics in the terpene fraction. While in oregano, volatile terpenes p-cymene, thymol and carvacrol are most likely responsible for the antimicrobial activity.[16] Pro- or post inhibitins compounds like flavonoids, flavonols, alkaloids, phenols, glycosides and polyacetylenes formed in plant tissues and help in making the substances responsible for antimicrobial activity of PEO's. These post inhibitins compounds serve as precursors and stored in inactive form and they get activated by oxidases or hydrolases. Best examples of such compounds are mustard glucosinolates and onion sulphoxides. In garlic and onion, an antimicrobial compound allicin is synthesized by action of alliinase which convert alliin into allicin and ammonia and pyruvate also generated. In horseradish and mustard, glucosinolates serve as a precursor molecule and it converted into ofisothiocyanates, nitriles, glucose thiocyanate as well as allyl which have a strong antimicrobial activity.[18]

MECHANISM OF ACTION

Mechanism of action of plant essential oils are reported in few papers.[19,20] Due to hydrophobic nature of PEOs, they interact with lipid membrane of bacterial pathogens that leads to the outflow of the inner cell components and potassium ion reflux, which causes cell death as shown in Fig. 2.[21] But these effects have not seen in Gram-positive bacteria and yeast as lipopolysaccharides get solubilized in phenolic based solvents.[22] However, there are some mechanisms of action for the antimicrobial activity of PEOs based on synergism. These mechanisms include inhibition of protective enzymes, change in permeability of cell membranes and other biochemical pathways.[23] Some components like carvacrol and monoteroenes (α-pinene, camphene, myrcene, α-terpinene and p-cymene) of PEOs showed low antimicrobial properties.[24,25] These hydrocarbons interact with cell membrane that results in entry of carvacrol into cell.[26] Synergistic effects between two hydrocarbons of PEOs enhance their antimicrobial activities. For example eugenol/carvacrol and eugenol/thymol are in synergistic relation in such a way that carvacrol and thymol disrupt outer membrane of *E. coli* which makes easy entry of eugenol into cytoplasm where it binds to proteins.[27] Synergistic effect between eugenol and cinnamaldehyde is also present and in this case these components interact with different proteins and enzymes. Synergistic effect between two components reduces the concentration needed for high yield of antimicrobial properties. For example synergistic relation between thymol and cinnamaldehyde effectively reduced the concentration of 25% against *E. coli* and *T. typhinurium*. Phenolic compounds present in plant essential oils have a major role in antimicrobial activity as these involve in the disruption of membranes, metal chelation, substrate complexity and enzyme inactivation.[28] Non-phenolic compounds like isothiocyanates are also involved in the antimicrobial activities by inactivate the extracellular enzymes through disulfide bond breakage.[18]

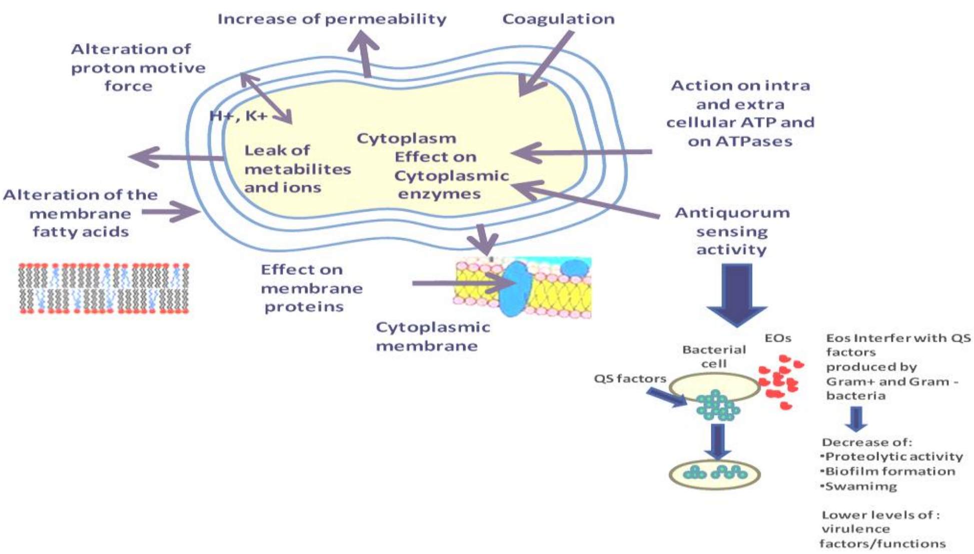

Fig. 2: Different mechanisms of action of PEOs

BIOLOGICAL EFFECTS

Cytotoxicity

As essential oils contain a number of important constituents, they have not specific cellular targets.[29] These constituents disrupt the cellular structure by interacting with fatty acids, polysaccharides and phospholipids. And this membrane damage causes the cytotoxicity. In cytoplasm essential oil could be coagulated [30] and could damage proteins and lipids.[3,26] Macromolecules leaked out from microbial cells due the disruption of cell membrane and cell wall.[31,32,33,34] Cytotoxic properties of PEOs contribute in killing the animal or human pathogens as well as in the preservation of marine and agricultural products.

Phototoxicity

There are few photoactive molecules like furocoumarins present in some PEOs. Under ultraviolet light essential oil of citrus produced mono- and bi-adducts that are highly mutagenic and cytotoxic.[35] While there is not any mutagenic and cytotoxicity produced in the dark. Cytotoxicity is observed in essential oil of Fusanus spicatus wood while there is no any phototoxic property in it.[36] Actually phototoxicity is antagonistic to cytotoxicity. In case of cytotoxicity, PEOs act as pro-oxidant on DNA and proteins after damaging cellular and organelle membranes that results in the production of reactive oxygen species. While in case of phototoxicity, cell allows PEOs directly penetrating into it without damaging the DNA, proteins and MEMBRANE. Cellular macromolecules are damaged due to the production of radicals under the exposure of light. Different constituents present in essential oils produce different types of radicals. These radicals produce either with or without light exposure and phototoxicity and cytotoxicity depends upon these molecules. Hence, cytotoxicity and phototoxicity should be under consideration when studying the PEOs.[7]

Nuclear mutagenicity

Some studies revealed that most of the essential oils didn’t show nuclear mutagenicity for any microorganism. However there are some exceptions, for example Artemisia dracunculus essential oils have nuclear mutagenicity property for *Bacillus subtilis*.[37] While in somatic mutations and recombination test (SMART) of *Drosophila melanogaster*, it was observed that *Mentha spicata* essential oil have some genotoxicity for *Drosophila melanogaster*.[38,39] In the *Drosophila melanogaster* SMART assay,essential oil of *Anethum graveolens* gave also positive results in the chromosomal aberration (CA) tests on human lymphocytes and in sister chromatid exchange (SCE) test.[40] Some isolated constituents of PEOs also have nuclear mutagenicity properties, for example the metabolic intermediates of oxidized trans-asarone trans and oxide -anethole oxide were observed for genotoxicity property induced liver and skin cancers and in the Ames test.[41] Eugenol was found genotoxic in V79 cells by inducing CA and endo-reduplications.[42]

Cytoplasmic mutagenicity

Most of the mutagenicity studies on essential oils were performed on bacteria, mammalian cells and insect cells (*Drosophila melanogaster* SMART assay). But it is impossible to distinguish the mode of action of essential oils and their targets by using these tests. While tests in yeast for example *Saccharomyces cerevisiae* have been shown to be potentially very useful. As yeast can survive with damaged mitochondria, negative effects on the respiratory system can be checked without directly affecting its cell survival. While induction of harmful effects in the respiratory system of bacteria ssss and mammalian cells, can cause their death. While studying yeast system, it is noted that cellular mitochondria is a very important target for essential oils. Presence of thyme, onion, cinnamon, clove, oregano essential oils and garlic cause hindrance in the production of ethanol by cells of *Saccharomyces cerevisiae*.[43] In the presence of a-pine`ne in plants the mitochondria could not perform oxidative metabolism.[44]

ANTIMICROBIAL APPLICATION OF DIFFERENT PLANT ESSENTIAL OILS

Cinnamon Essential Oil: Anti-bacterial Properties

One of the most renowned abilities of cinnamon essential oils is their antimicrobial effect especially against gram +ve bacteria and gram -ve bacteria. Those bacteria those are responsible for infection in humans and also common reason behind the spoilage and degradation of foods and cosmetics.

Antibacterial effect of Cinnamon EO towards those bacteria that cause human infectious disease

In 2011 the antibacterial activity of cinnamon barks extract held in laboratory against different bacteria that extract contain different organic solvents, like menthol, acetone etc. The extracts are tested against the bacteria like *Klebsiella pneumonia, Bacillus megaterium, Pseudomonas aeruginosa, Staphylococcus aureus, Escherichia coli, Enterobacter cloacae, Corynebacterium xerosis,* and *Streptococcus faecalis* by disc diffusion method. When 30ul extract that are applied on discs express zone of inhibition and the range of zone is 7 to 18mm in diameter that shows a high antibacterial activity against the organisms.[45] The extract from the C. zeylanicum also shows antibacterial activity against the MRSA (Methicillin Resitant *Staphylococcus aureus*) from Kolkata india. The antibacterial activity of cinnamon EOs that showed a 22 to 27 mm diameter zone of inhibition are said to bactericidal after 6 hours of incubation. So the authors determined that the C. zeylanicum are the valuable medicinal effects in the infection of MRSA.[46] The antibacterial activity of cinnamon hydro ethanolic extract and the clove powder tested against two clinical strains of *Moraxella catarrhalis* by broth dilution method. The results defined that cinnamon extract are effective against the both strains. Hence it signifies a good natural antibacterial element to clinically treat the infection caused by *M. cattarhalis*.[47]

The authors presented that the combination of pipracilin and the cinnamon bark EOs induce the significant decrease in the registered minimum inhibitory concentration value. These are against the clinical strain of beta lactamase producing *E.coli*. Their use helps in reduce the side effects of the antibiotic and reverse the beta lactam antibiotic resistance in patients.[48] Cinnamon bark EO cinamaldehyde and euginolin 0.1% (v/v) markedly reduces the biofilm of EHEC (enterohemorhagic *E.coli* O157:H7) that cause bloody diarrhea. These essential oils are also helpful in the treatment of antibiotic resistant bacteria. Cinnamon Eos is also effective against oral infections. Some scientists defined that cinnamon EO was effective against *Streptococcus mutans* and concluded that this good replacement than other antibacterial compound against the bacteria that cause infection.[49] *E. faecalis* showed a great growth on cellulose nitrate membrane and on tooth model system that act as a good substrate and favors their growth and cause perriapical and pulp disease in oral cavity. *C. zeylanicum* fresh leave essential oils show antibacterial activity against *E. faecalis*.the test was performed by agar diffusion microdillutions method. And showed that zone of inhibition may vary with increasing concentration (5% to 20%). It is also effective against the acne causing bacteria. The phonolic compounds that are the constituents of Essential oil such as cinamaldehyde and euginol are antibacterial and their formulations are used for the treatment of acne.[50] The antibacterial activity of cinnamon bark EO is also against the *Mycoplasma hominis* that cause pelvic inflammation and vaginiosis and pyelonephritis. The cinamaldehyde have bactericidal activity against *M.hominis* and their “MIC” value ranges from 250 to 1000 µg/mL.[51]

Toxicity caused by cinnamon Essential oils

Cinnamon application in food and cosmetics and in medicine is common according to the above study but along with its antibacterial activity of essential oil against the bacteria have always been recommended to use the concentration of essential oils less than 2% before oral use. Furthermore, it is recommended that not to use incorporation of cinnamon bark oil per as for those people who are suffering from liver conditions, also in incident of alcohol take up and while taking paracetamol. This endorsement is because of the ability of cinnamaldehyde to diminish glutathione. Well it’s suitable for most of the people when it ingested from mouth and the concentration is approximately to 6 grams for six weeks or less. It is recommended that not to use antibiotic namely tetracycline when using cinnamon because it retard the in vitro suspension of TTC. When cinnamon essential oil is ingested it may cause CNS depression, and influencing the patient to aspiration pneumonia.[52] While using cinnamon topically it should be in our mind that, cinnamon is typically used as a component of particular sanitization product, as toilette soap, mouthwash, toothpaste, as constituents of drinks and baking foodstuffs and as additive of gums. Consequently infection and change in the epidermal surface should happen after the interaction with those products that containing cinnamon. The side effects like pain ulceration difficulty in breathing hyper pigmentation may occur. Cinnamaldehyde and their derivatives are supposed to be the main purpose for these adverse effects because they act as membrane irritants. The severity may vary with the passage of time they contact with the membrane and systemic reaction nausea and abdominal pain are rare.[53]

Essential oils of basil

Basil is the communal dietary herb naming *Ocimum basilicum* and belonging to the family Lamiaceae according to the classification. This family is important in medicinal purpose because of their extracted essential oils and their applications.[54] Their distribution and some commonly used specie of family Lamiaceae are described in fig. 3. Basil leaves produce 0.2-1% essential oils and their active constituents are linalool and estragole as well as o-cymene, citral, alpha-pinene, camphene, beta-pinene, geraniol, and geranial.[55] Basil oils are divided into two types: the Reunion type that mostly contain estragole 80% and the European kind that contain linolol 35 to 50%.[56] Basil is known because of their anti-inflammatory and painkiller property and is used for the treatment of cephalelgia, diarrhea, constipation, indigestion, and cough.[57] It is a good antioxidizing agent[58] and are commonly used as a spice in food items and used to inhibit the growth of acid resistant bacteria in tomato based products. Basil also has the antiseptic effects and is used in dental preprations and solution. But the basil oils have toxicity and are responsible for cytotoxic damage by icreasing the concentration so according to the council of Europe it should not surpass the quantity of 0.05% mg/kg in food items.[56]

Essential Oil of Oregano

This herb is from the family of Lamiacea. Oregano species is *Oreganum vulgare* and the essential oils that produce from this herb is around 0.5-2%[59] and upto 7%.[60] The main constituents of the essential oils are isomer phenols carvacrol and thymol, also contain precursors of monoterpenes p-cymene and γ-terpinene at a lower proportion. The two most well-known species of oregano is *O.vulgare* sub spp. *hirtum* and Turkish *O.onites.* Since ancient time oregano is widely used as a flavoring agent and their essential oils is known because of their antiseptic and antispasmodic quality.[61] Because of the high content of thymol and carvacrol they show the antioxidant property that prevents the oxidation of fats. Oregano has strong antibacterial property against the foodborne pathogens.[62]

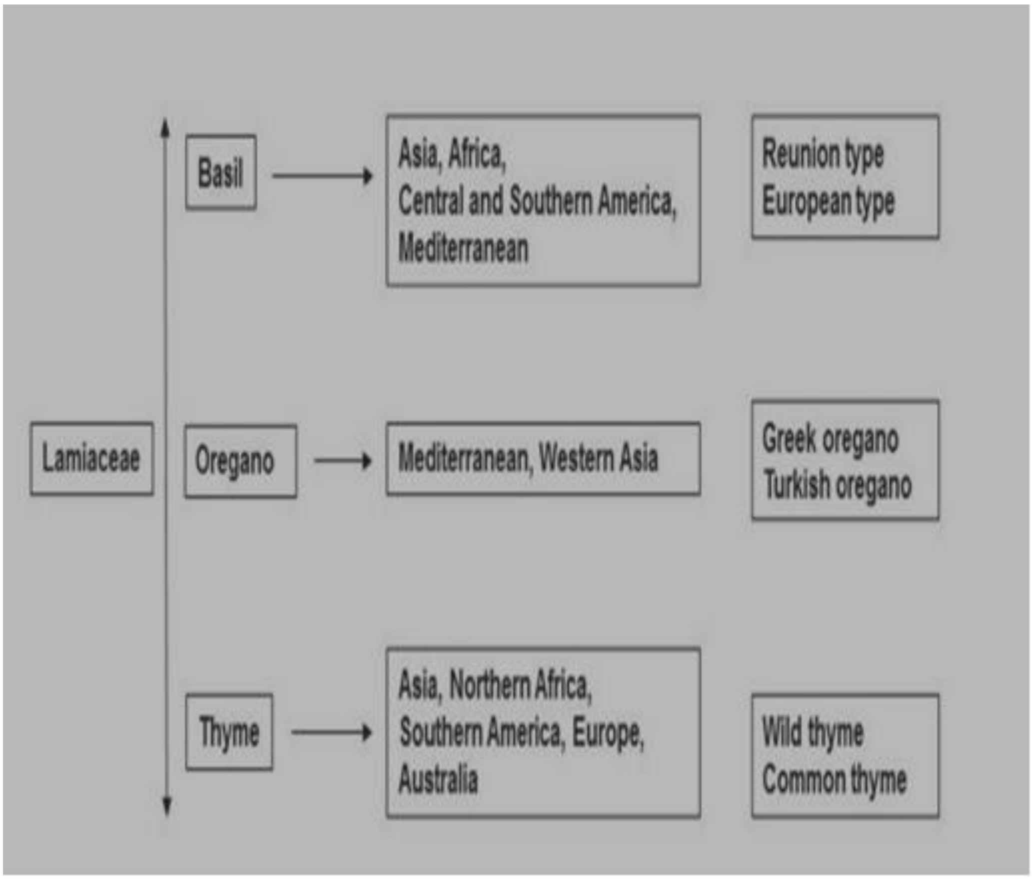

Fig. 3: Distribution and their viable representative species: basil thyme and oregano

Thyme Essential Oil

As well as the other herbs thyme also belong to the family of Lamiaceae. It is a medicinal plant and has commercial intreast specifically with the two main species thyme such as *Thymus serpyllum* and *T. vulgaris*.[63] *T.vulgaris* essential oils contain 30 monoterpenes with the different chemical composition of the compound that are extracted from the same plants.[64] Thyme has antifungal antibacterial and antioxidant property and is commercially used in a variety of foods and drinks as a food preservative and aromatic additive.[65]

Antibacterial effect of thyme, basil and oregano essential oils

The presence of phenolic compounds in essential oil present in oregano and thyme herb exhibited the significant antibacterial activity. In one study it is described that the carvacrol, thymol, euginol, cinnamaldeyde and isoeugenol in the essential oils has the strong effect against the *Listeria monocytogenes.*[66] The thyme and oregano EO show activity against *E.coli* O157:H7 that cause bloody diarrhea.[67] Total 11 EOs tested against the Bascilus subtilis that cause food poisoning, showed that after the cinnamon essential oils the oregano and thyme EO were most effective against the *Bascilus subtilis*.[68] A study was done with twenty one essential oils and 5 pathogenic bacteria showed that these herb (thyme, laurel, cinnamon and clove) essential oils had the powerful bactericidal and bacteriostatic effects against "*Campylobacter jejuni, E. coli, Salmonella enteritidis, L. monocytogenes* and *S. aureus*".[69] Essential oils from three species of Origanum (*O. vulgare L., O. onites L., O. majorana L.*) and from two species of Thymus (*T. vulgaris L., T. serpyllum L.*) exhibited satisfactory inhibitory effects against the strains of *E. coli, E. coli O157:H7, S. aureus, and Y. enterocolitica*.

Various EOs have the bacteriostatic and bactericidal effects against gram positive and gram negative bacteria such as *S. aureus, E. coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Acinetobacter baumannii, Aeromonas sobria, Enterococcus faecalis, Salmonella Typhimurium, Serratia marcescens.* By comparing with other oils like sage, peppermint, chamomile, and hyssop oil etc oregano EOs have both cidal and static effects while other have only low bacteriostatic effects.[70] *Ocimum basilicum* oil contained estragol and didn't have thymol and carvacrol in their active constituents that why they are less potent than the *O. vulgare* and *T. vulgaris* oils which shows the high bacteriostatic effects against the 5 G +ve and 8 G –ve bacteria.[71] Moreover, the oregano, thyme, and basil oils presented adequate effects against the multi-resistant clinical isolates of *A. baumannii, E. coli, K. pneumoniae,* and *P. aeruginosa* as shown in Fig 4.

Antifungal effects of thyme, basil and oregano essential oils

The essential oils that mainly have phenolics constituents are capable to change the penetration and role of the cell membrane by binding with the proteins of the membrane and blocked the normal function so permeability of the bacterial cell wall has been disrupted. Because of the lipophilic and hydrophobic characteristic of the EO they separate the cell membrane from the cell content and leakage start and cell death may occur. Essential oils affect the microbial cell through different mechanisms like attack on various inner or outer site of the microbial cell membrane, cytoplasm may effect on their metabolic pathways.The phenolic component in oils is basic constituent that shows antifungal.[72] In a study 16 different EOs are tested against the fungus that are isolated from the bakery products. Only the EO from thyme show characteristic inhibitions against fungi.[73] It has determined that the essential oils from thyme spp *Thymus vulgaris* that contain thymol and from orgenano the spp *O.vulgare* that contain high content of carvacrol showed inhibitory effects *against Candida albicans* however the influence of other thyme chemical components that have low phenolic components have poor effect.[74]

Carvacrol, thymol, euginol and 1,8-cineol in the different thyme spp show antifungal activity. Thymus spp (T. poulegioides) contain thymol and euginol in high concentration that show potent inhibitory effects against *Aspergillus spp*., and *Dermatophyte*. Thyme essential oil considered as one of the best effective antifungals further than 12 essential oils that was verified against *Aspergillus flavus, Aspergillus parasiticus, Aspergillus ochraceus, and Fusarium moniliforme*.[75] The antimicrobial effect of oregano oils is ascribed to carvacrol and thymol. And they have broad microbial spectrum including bacteria (*K. pneumoniae, methicillin-resistant S. aureus, E. coli O157:H7, Bacillus subtilis, P. aeruginosa, B. cereus, A. baumannii, Y. enterocolitica*), fungi (*Aspergilus spp. Candida spp*) and parasite (Blastocystis hominis, Endolimax nana).

Common name	Botanical name	Chemotype
Basil oil	*O. micranthum*	Eugenol
	O. basilicum	Linalool
	O. basilicum	Estragole
Oregano oil	*O. vulgare*	Thymol
	O. vulgare	Carvacrol, thymol
	O. scabrum	Carvacrol
	O. acutidens	Carvacrol
	O. syriacum	γ-Terpinene, carvacrol, *p*-cymene
	O. compactum	Carvacrol
	O. heracleoticum	Carvacrol
	O. majorana	Terpinene-4-ol
Thyme oil	*T. vulgaris*	Carvacrol, thymol
	T. vulgaris	Thymol
	T. vulgaris	Thymol, *p*-cymene

Fig .4: Various chemotypes of basil, oregano, and thyme essential oils with antibacterial activity

ESSENTIAL OILS AS A MEDICINE AND THEIR MEDICAL APPLICATIONS

The prooxident activity of essential oils is the cytotoxic capacity that makes them a good antiseptic and antimicrobial agent. They can be used personally like for refining air, for personal sanitization or they can use even internally via oral ingestion. One of the big advantages of essential oil is their lacking genotoxic threats. They have antimutagenic property which shows the anticarcinogenic activity. Some studies reported that prooxident activity of EO and the polyphenols constituents are competent in reducing the proliferation of tumor cell by through cell death /necrotic effects.[76]

Eugenia caryophyllata essential oil contains euginol that inhibits the growth of the cancerous cells.[77] Another constituent garniol also inhibit the growth of colon cancer cells by persuading membrane depolarization and snooping with ionic canals and signaling pathways. Garniol stop the synthesis of DNA and reduces the growth of colon tumors cells.[78] Mostly tumor cells are formed due to the severe changes in metabolic pathways, mitochondrial excess production and the lasting oxidative stress.[79] Owing to their prooxident effect they interrupt the mitochondrial functions and become the good antitumor agents. Many essential oils produce radical due to their antioxidant activity and that radical is used in antitumor treatment. Essential oils due to their radical production can be managed and targeted on the tumor cells without producing any mutation or side effects on healthy tissues. Thus essential oils are included in vectorized liposomes and make their approach from traditional to modern medical field.[80]

CONCLUSION

Essential oils are aromatic in nature and have useful properties. Because of their useful effects these are extracted from different plant sources through steam or hydro distillation, expression method, carbon hypocritical method and solvent extraction. Essential oils contain different components which are actually proved to have antimicrobial properties. Mechanism of action of PEOs is not confirmed but there are some possible modes of actions. Some of these actions included disruption of cell wall and cell membrane, inhibition of enzyme activation, change in the permeability of cell membrane which leads to leakage of cellular constituents and eventually cell death occurred. However, some essential oils have important biological properties like phototoxicity, cytotoxicity, nuclear mutagenicity and cytoplasmic mutagenicity. Different plants like Basil, Oregano and Cinnamon have different kind of antibacterial and antifungal properties. Because of these properties PEOs are widely used in medical and food industries as food preservative.

ACKNOWLEDGEMENT

The authors acknowledge the director of Institute of Industrial Biotechnology GCU Lahore, for their support and encouragement.

REFERENCES

1. Cassel E, Vargas RMF. Experiments and modeling of the *Cymbopogonwinterianus* essential oil extraction by steam distillation. J. Mexican Chem. Soc, 2006; 50: 126-9.
2. Lira PDL, Retta D, Tkacik E, Ringuelet J, Coussio JD, van Baren C, Bandoni AL. Essential oil and by-products of distillation of bay leaves (*Laurusnobilis* L.) from Argentina. Ind. Crops Prod, 2009; 30: 259-64.
3. Burt S. Essential oils: their antibacterial properties and potential applications in foods – a review. Intl. J. Food Microbiol, 2004; 94: 223-53.
4. Tongnuanchan P, Benjakul S. Essential Oils: Extraction, Bioactivities, and Their Uses for Food Preservation. Journal of food science, 2014; 79(7): R1241-R1249.
5. Hajhashemi V, Ghannadi A, Sharif B. Anti-inflammatory and analgesic properties of the leaf extracts and essential oil of *Lavandula angustifolia* Mill. J. Ethnopharmacol, 2003; 89: 67-71.
6. Masango P. Cleaner production of essential oils by steam distillation. J. Cleaner Prod, 2005; 13: 833-9.
7. Bakkali F, Averbeck S, Averbeck D, Idaomar M. Biological effects of essential oils – a review. Food Chem Toxicol, 2008; 46: 446-75.
8. Ruberto G, Baratta MT. Antioxidant activity of selected essential oil components in two lipid model systems. Food Chem, 2000; 69: 167-74.
9. Mohamed AA, El-Emary GA, Ali HF. Influence of some citrus essential oils on cell viability, glutathione-s-transferase and lipid peroxidation in *Ehrlich ascites* Carcinoma cells. J. Am. Sci, 2010; 6: 820-6.
10. Beuchat LR, Golden DA. Antimicrobials occurring naturally in foods. *Food Technol*, 1989; 43(1): 134-142.
11. Deans SG, Noble RC, Hiltunen R, Wuryani W, Penzes LG. Antimicrobial and antioxidant properties of *Syzygium aromaticum* (L.) Merr. & Perry: impact upon bacteria, fungi and fatty acid levels in ageing mice. Flav. Frag. J, 1995; 10: 323-328.
12. Dorman HJD, Deans SG. Antimicrobial agents from plants: antibacterial activity of plant volatile oils. J. Appl. Microbiol, 2000; 88: 308-316.
13. Zaika LL. Spices and herbs: their antimicrobial activity and its determination. J. Food Safety, 1988; 9: 97-118.
14. Kim J, Marshall MR, Wei C. Antimicrobial activity of some essential oil components against five food borne pathogens. J. Agric. Food Chem, 1995; 43: 2839-2845.
15. Ward SM, Delaquis PJ, Holley RA, Mazza G. Inhibition of spoilage and pathogenic bacteria on agar and pre-cooked roasted beef by volatile horseradish distillates. Food Res. Int., 1998; 31: 19-26.
16. Davidson PM, Naidu AS. Phyto-Phenols. In: Naidu, A.S. (Ed.), Natural Food Antimicrobial Systems. CRC Press, Boca Raton, London, New York, Washington. 2000; 265-294.
17. Lis-Balchin M, Deans SG, Eaglesham E. Relationship between bioactivity and chemical composition of commercial essential oils. Flav. Frag. J, 1998; 13(2): 98-104.
18. Delaquis PJ, Mazza G. Antimicrobial properties ofisothiocyanates in food preservation. Food Technol, 1995; 49(11): 73-84.
19. Hayouni E, Bouix M, Abedrabba M, Leveau JY, Hamdi M. Mechanism of action of *Melaleuca armillaris* (Sol. Ex Gaertu) Sm. essential oil on six LAB strains as assessed by multiparametric flow cytometry and automated microtiter-based assay. Food Chem, 2008; 111: 707-718.
20. Devi KP, Nisha SA, Sakthivel R, Pandian SK. Eugenol (an essential oil of clove) acts as an antibacterial agent against Salmonella typhi by disrupting the cellular membrane. Journal of ethnopharmacology, 2010; 130(1): 107-115.
21. Sikkema J, De Bont JA, Poolman B. Mechanisms of membrane toxicity of hydrocarbons. Microbiological Reviews, 1995; 59(2): 201-222.
22. Holley RA, Patel D. Improvement in shelf-life and safety of perishable foods by plant essential oils and smoke antimicrobials. Food Microbiology, 2005; 22(4): 273-292.
23. Santiesteban-Lopez A, Palou E, López-Malo A. Susceptibility of food-borne bacteria to binary combinations of antimicrobials at selected a(w) and pH. J. Appl. Microbiol, 2007; 102: 486-497.

24. Ultee A, Slump RA, Steging G, Smid EJ. Antimicrobial activity of carvacrol toward Bacillus cereus on rice. J. Food Prot, 2000; 63: 620-624.
25. de Azeredo GA, Stamford TLM, Nunes PC, Neto NJG, de Oliveira MEG, de Souza EL. Combined application of essential oils from *Origanum vulgare* L. and *Rosmarinus officinalis* L. to inhibit bacteria and autochthonous microflora associated with minimally processed vegetables. Food Res. Int, 2011; 44: 1541-1548.
26. Ultee A, Bennik MHJ, Moezelaar R. The phenolic hydroxyl group of carvacrol is essential for action against the foodborne pathogen *Bacillus cereus*. Appl. Environ. Microbiol, 2002; 68: 1561-1568.
27. Pei RS, Zhou F, Ji BP, Xu J. Evaluation of combined antibacterial effects of eugenol, cinnamaldehyde, thymol, and carvacrol against *E. coli* with an improved Method. J. Food Sci, 2009; 74: 379-383.
28. Cowan MM. Plant products as antimicrobial agents. Clin. Microbiol. Rev, 1999; 12(4): 564-582.
29. Carson CF, Mee BJ, Riley TV. Mechanism of action of Melaleuca alternifolia (tea tree) oil on Staphylococcus aureus determined by time-kill, lysis, leakage and salt tolerance assays and electron microscopy. Antimicrob. Agents Chemother, 2002; 46: 1914-1920.
30. Gustafson JE, Liew YC, Chew S, Markham JL, Bell HC, Wyllie SG, Warmington JR. Effects of tea tree oil on Escherichia coli. Lett. Appl. Microbiol, 1998; 26: 194-198.
31. Juven BJ, Kanner J, Schved F, Weisslowicz H. Factors that interact with the antibacterial action of thyme essential oil and its active constituents. J. Appl. Bacteriol, 1994; 76: 626-631.
32. Cox SD, Mann CM, Markham JL, Bell HC, Gustafson JE, Warmington JR, Wyllie SG. The mode of antimicrobial action of essential oil of Melaleuca alternifolia (tea tree oil). J. Appl. Microbiol, 2000; 88: 170-175.
33. Lambert RJW, Skandamis PN, Coote P, Nychas GJE. A study of the minimum inhibitory concentration and mode of action of oregano essential oil, thymol and carvacrol. J. Appl. Microbiol, 2001; 91: 453-462.
34. Oussalah M, Caillet S, Lacroix M. Mechanism of action of Spanish oregano, Chinese cinnamon, and savory essential oils against cell membranes and walls of *Escherichia coli* O157:H7 and *Listeria monocytogenes*. J. Food Prot, 2006; 69: 1046-1055.
35. Averbeck D, Averbeck S, Dubertret L, Young AR, Morlie`re P. Genotoxicity of bergapten and bergamot oil in Saccharomyces cerevisiae. J. Photochem. Photobiol, 1990; 7: 209-229.
36. Dijoux N, Guingand Y, Bourgeois C, Durand S, Fromageot C, Combe C, Ferret PJ. Assessment of the phototoxic hazard of some essential oils using modified 3T3 neutral red uptake assay. Toxicol. In vitro, 2006; 20: 480-489.
37. Zani F, Massino G, Benvenuti S, Bianchi A, Albasini A, Melegari M, Vampa G, Bellotti A, Mazza P. Studies on the genotoxic properties of essential oils with Bacillus subtilis rec-assay and Salmonella/microsome reversion assay. Planta Med, 1991; 57: 237-241.
38. Franzios G, Mirotsou M, Hatziapostolou E, Kral J, Scouras ZG, Mavragani-Tsipidou P. Insecticidal and genotoxic activities of mint essential oils. J. Agric. Food Chem, 1997; 45: 2690-2694.
39. Karpouhtsis I, Pardali E, Feggou E, Kokkini S, Scouras ZG, Mavragani-Tsipidou P, Insecticidal and genotoxic activities of oregano essential oils. J. Agric. Food Chem, 1998; 46: 1111-1115.
40. Lazutka JR, Mierauskien J, Slap G, Dedonyt V. Genotoxicity of dill (Anethum graveolens L.), peppermint (Mentha piperita L.) and pine (Pinus sylvestris L.) essential oils in human lymphocytes and Drosophila melanogaster. Food Chem. Toxicol, 2001; 39: 485-492.
41. Kim SG, Liem A, Stewart BC, Miller JA. New studies on trans-anethole oxide and trans-asarone oxide. Carcinogenesis, 1999; 20: 1303-1307.
42. Maralhas A, Monteiro A, Martins C, Kranendonk M, Laires A, Rueff J, Rodrigues AS. Genotoxicity and endoreduplication inducing activity of the food flavouring eugenol. Mutagenesis, 2006; 21: 199-204.
43. Conner DE, Beuchat LR, Worthington RE, Hitchcock HL. Effects of essential oils and oleoresins of plants on ethanol production, respiration and sporulation of yeasts. Inter. J. Food Microbiol, 1984; 1: 63-74.
44. Abrahim D, Francischini AC, Pergo EM, Kelmer-Bracht AM, Ishii- Iwamoto EL. Effects of a-pinene on the mitochondrial respiration of maize seedlings. Plant Physiol. Biochem, 2003; 41: 985-991.
45. Keskin D, Toroglu S. Studies on antimicrobial activities of solvent extracts of different Spices. J. Environ. Biol, 2011; 32: 251-256.
46. Mandal S, Deb Mandal M, Saha K, Pal NK. In vitro Antibacterial Activity of three Indian
47. Spices against Methicillin-Resistant Staphylococcus aureus. Oman Med. J, 2011; 26: 319-323.
48. Rasheed MU, Thajuddin N. Effect of medicinal plants on Moraxella cattarhalis. Asian Pac J. Trop. Med, 2011; 4: 133-136.
49. Yap PS, Lim SH, Hu CP, Yiap BC. Combination of essential oils and antibiotics reduce antibiotic resistance in plasmid-conferred multidrug resistant bacteria. Phytomedicine, 2013; 20: 710-713.
50. Chaudhari LK, Jawale BA, Sharma S, Sharma H, Kumar CD, Kulkarni PA. Antimicrobial activity of commercially available essential oils against Streptococcus mutans. J. Contemp. Dent. Prac, 2012; 13: 71-74.
51. Vijayan K, Thampuran RA. Pharmacology and Toxicology of Cinnamon and Cassia. In Cinnamon and Cassia: The Genus Cinnamomum; Ravindran

PN, Babu KN, Eds. CRC Press: Boca Raton, FL, USA, 2004.
52. Sleha R, Mosio P, Vydrzalova M, Jantovska A, Bostikova V, Mazurova J. In vitro antimicrobial activities of cinnamon bark oil, anethole, carvacrol, eugenol and guaiazulene against Mycoplasma hominis clinical isolates. Biomed. Pap. Med. Fac. Univ. Palacky Olomouc Czech Repub, 2014; 158: 208-211.
53. Barceloux DG. Cinnamon (Cinnamomum Species). Dis.-a-Month, 2009; 55: 327-335.
54. Hossein N, Zahra Z, Abolfazl M, Mahdi S, Ali K. Effect of Cinnamon zeylanicum essence and distillate on the clotting time. J. Med. Plants Res, 2013; 7: 1339-1343.
55. Gurib-Fakim A. Medicinal plants: traditions of yesterday and drugs of tomorrow. Mol. Aspects Med, 2006; 27: 1-93.
56. Lachowicz KJ, Jones GP, Briggs DR, Bienvenu FE, Wan J, Wilcock A, Coventry MJ. The synergistic preservative effects of the essential oils of sweet basil (Ocimum basilicum L.) against acid-tolerant food microflora. Lett. Appl. Microbiol, 1998; 26: 209-214.
57. Schulz H, Schrader B, Quilitzsch R, Pfeffer S, Kruger H. Rapid classification of basil chemotypes by various vibrational spectroscopy methods. J. Agric. Food Chem, 2003; 51: 2475-2481.
58. Kathirvel P, Ravi S. Chemical composition of the essential oil from basil (Ocimum basilicum Linn.) and its in vitro cytotoxicity against HeLa and HEp-2 human cancer cell lines and NIH 3T3 mouse embryonic fibroblasts. Nat. Prod. Res, 2012; 26: 1112-1128.
59. Trevisan MTS, Silva MGV, Pfundstein B, Spiegelhalder B, Owen RW. Characterization of the volatile pattern and antioxidant capacity of essential oils from different species of the genus Ocimum. J. Agric. Food Chem, 2006; 54: 4378-4382.
60. Kokkini S, Karousou R, Dardioti A, Krigas N, Lanaras T. Autumn essential oils of Greek oregano. Phytochemistry, 1997; 44: 883-886.
61. Gounaris Y, Skoula M, Fournaraki C, Drakakaki G, Makris A. Comparison of essential oils and genetic relationship of Origanum × intercedens to its parental taxa in the island of Crete. Biochem. Syst. Ecol, 2002; 30: 249-258.
62. Nostro A, Blanco A, Cannatelli M, Enea V, Flamini G, Morelli I, et al. Susceptibility of methicillin-resistant staphylococci to oregano essential oil, carvacrol and thymol. FEMS Microbiol. Lett, 2004; 230: 191-195.
63. Mith H, Dure R, Delcenserie V, Zhiri A, Daube G, Clinquart A. Antimicrobial activities of commercial essential oils and their components against food-borne pathogens and food spoilage bacteria. Food Sci. Nutr, 2014; 2: 403-416.
64. Badi HN, Yazdani D, Ali SM, Nazari F. Effects of spacing and harvesting time on herbage yield and quality/ quantity of oil in thyme, Thymus vulgaris L. Ind. Crop. Prod, 2004; 19: 231-236.
65. Guillen MD, Manzanos MJ. Study of the composition of the different parts of a Spanish Thymus vulgaris L. plant. Food Chem, 1998; 63: 373-383.
66. Cosentino S, Tuberoso SIG, Pisano B, Satta M, Mascia V, Arzedi E, Palmas F. In vitro antimicrobial activity and chemical composition of Sardinian Thymus essential oils. Lett. Appl. Microbiol, 1999; 29: 130-135.
67. Yamazaki K, Yamamoto T, Kawai Y, Inoue N. Enhancement of antilisterial activity of essential oil constituents by nisin and diglycerol fatty acid ester. Food Microbiol, 2004; 21: 283-289.
68. Burt SA, Reinders RD. Antibacterial activity of selected plant essential oils against Escherichia coli O157-H7. Lett. Appl. Microbiol, 2003; 36: 162-167.
69. Valero M, Salmeron MC. Antibacterial activity of 11 essential oils against Bacillus cereus in tyndallized carrot broth. Int. J. Food Microbiol, 2003; 85: 73-81.
70. Smith-Palmer A, Stewart J, Fyfe L. Antimicrobial properties of plant essential oils and essences against five important food-borne pathogens. Lett. Appl. Microbiol, 1998; 26: 118-122.
71. Marino M, Bersani C, Comi G. Impedance measurements to study the antimicrobial activity of essential oils from Lamiaceae and Compositae. Int. J. Food Microbiol, 2001; 67: 187-195.
72. Bozin B, Dukic-Mimica N, Simin N, Anackov G. Characterization of the volatile composition of essential oils of some Lamiaceae spices and the antimicrobial and antioxidant activities of the entire oils. J. Agric. Food Chem, 2006; 54: 1822-1828.
73. Cavaleiro C, Pinto E, Goncalves MJ, Salgueiro L. Antifungal activity of Juniperus against dermatophyte, Aspergillus and Candida strains. J. Appl. Microbiol, 2006; 100: 1333-1338.
74. Guynot ME, Ramos AG, Seto L, Purroy P, Sanchis V, Marin S. Antifungal activities of volatile compounds generated by essential oils against fungi commonly causing deterioration of bakery products. J. Appl. Microbiol, 2003; 94: 893-899.
75. Giordani R, Regli P, Kaloustian J, Mikail C, Abou L, Portugal H. Antifungal effect of various essential oils against Candida albicans. Potentiation of antifungal action of amphotericin B by essential oil from Thymus vulgaris. Phytother. Res, 2004; 18: 990-995.
76. Soliman KM, Badeaa RI. Effect of oil extracted from some medicinal plants of different mycotoxigenic fungi. Food Chem. Toxicol, 2002; 40: 1669-1675.
77. Paik SY, Koh KH, Beak SM, Paek SH, Kim JA. The essential oils from Zanthoxylum schinifolium pericarp induce apoptosis of HepG2 human hepatoma cells through increased production of reactive oxygen species. Biol. Pharm. Bull, 2005; 28: 802-807.

78. Yoo CB, Han KT, Cho KS, Ha J, Park HJ, Nam JH, Kil UH, Lee KT. Eugenol isolated from the essential oil of Eugenia caryophyllata induces a reactive oxygen species-mediated apoptosis in HL-60 human promyelocytic leukemia cells. Cancer Lett, 2005; 225: 41-52.
79. Carnesecchi S, Bras-Gonc AR, Bradaia A, Zeisel M, Gosse´ F, Poupon MF, Raul F. Geraniol, a component of plant essential oils, modulates DNA synthesis and potentiates 5-fluorouracil efficacy on human colon tumor xenografts. Cancer Lett, 2004; 215: 53- 59.
80. Czarnecka AM, Golik P, Bartnik E. Mitochondrial DNA mutations in human neoplasia. J. Appl. Genet, 2006; 47: 67-78.
81. Sinico C, De Logu A, Lai F, Valenti D, Manconi M, Loy G, Bonsignore L, Fadda AM. Liposomal incorporation of Artemisia arborescens L. essential oil and in vitro antiviral activity. Eur. J. Pham. Biopharm, 2005; 59: 161-168.