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Bioactive Potential of Essential Oils: A Review

Kamaljit Sidhu, Manjeet Kaur and Gurpreet Kaur
[1]*Department of Botany, Khalsa College for Women, Civil Lines, Ludhiana-141 001, India*
E-mail: kamalkcw@gmail.com

***Abstract*:** Essential oils (EOs) are one of the main phytoproducts, extracted from different plant parts like flower, bark, stem, leaves, roots and fruits by different methods. These are also known as ethereal oils or volatile oils with low molecular weight, highly aromatic, pale yellow or colourless, with low density generally, complex mixture of different compounds and are multifunctional which harbor an immense wealth of biological properties such as antibacterial, antifungal, anti-cancerous, anti-mutagenic, anti-diabetic, antiviral, anti-inflammatory and anti-helminthic, being explored extensively in diverse fields. Essential oils are often used for aromatherapy; a form of alternative medicine useful to induce relaxation is attributed to aromatic compounds. They are usually stored as secondary metabolites in oil ducts, resin ducts, glands or trichomes (glandular hairs) of the plants. EOs also has a significant role in plant defence against the external agencies and signal sending mechanism.

***Keywords*:** Anti-cancerous, Anti-inflammatory, Bio-active potential, Essential oils, Hydro-distillation

The plant kingdom, since times immemorial has been a treasure of various phytoproducts, which due to their chemical composition attribute immensely toward the health care (Sabo and Knezevic 2019). The commercial exploitation of natural products for their relevant medicinal value and complementing it with the mainstream synthetic medicinal compounds has led to a recent upsurge in their demand and use (Blowman et al 2018). One of the main phytoproducts, are the Essential oils (EOs). These are extracted from different plant parts like flower, bark, stem, leaves, roots and fruits by different methods (Ali et al 2015). Various methods such as using microwave, pressure distillation with boiling water or steam, liquid carbon dioxide, solvent extraction, cold pressing, resin pressing and absolute oil extraction are employed to extract different EOs (Ishfaq et al 2018). Mostly the essential oils (EOs), present in the different plant parts are obtained through the process of steam or hydro distillation (Dhakad et al 2018). They are usually stored as secondary metabolites in oil ducts, resin ducts, glands or trichomes (glandular hairs) of the plants. EOs also has a significant role in plant defence against the external agencies and signal sending mechanism (Soujanya et al 2016). Around 2000 different plant species have been identified that produce about 3000 essential oils and out of these about 300 different types of essential oils are commercially exploited in pharmaceutical, food, cosmetic, sanitary and agro industries (Raveau et al 2020). These oils harbor an immense wealth of biological properties such as antibacterial, antifungal, anti-cancerous, anti-mutagenic, anti-diabetic, antiviral, anti-inflammatory and anti-helminthic which are being explored extensively in diverse fields.

Chemical Composition: The EOs also known as ethereal oils are volatile oils with low molecular weight, highly aromatic, pale yellow or colourless, with low density generally; complex mixture of different compounds and are multifunctional (Ishfaq et al 2018). Their vapour pressure at room temperature is quite high so that they are found partly in the vapour state (Dhifi et al 2016). Chemically these oils are composed of hydrocarbons which could be monoterpenes or sesquiterpenes, alcohols, ketones and aldehydes (Nieto 2017). The rich and complex composition of the EOs, on the basis of chemical constituents and their structure determine their biological properties (Gautam et al 2014). The compounds identified belong to four major categories of which terpenes and terpenoids constitute the major group with phenolic and aliphatic compounds the other two groups (Bayala et al 2018).

Major plant families producing essential Oils- About 10% of the 17,000 known plethora of plants species are aromatic (Aziz et al 2018). The genera of about 60 plant families are considered to be Essential oil producing, of these the selected plant families like Apiaceae, Asteraceae, Lamiaceae, Myrataceae, Rutaceae, Lauraceae, Cuppressaceae, Poaceae and Piperaceae produce the essential oils of medicinal and industrial importance (Raut and Karuppayil 2014). They are rich in mainly terpenoids as a main chemical component while phenylpropanoids rich plant families are Apiaceae, Lamiaceae, Myrataceae, Piperaceae and Rutaceae (Chami et al 2004). Among the 17 species of family Asteraceae evaluated, 13 species yielded essential oil from both fresh and dried samples. *Erechities valerianifolius* (wolf) DC yielded highest oil content both in fresh and dried samples (do-Amaral et al 2018). Essential oils of family verbenaceae are mainly recognized for their antimicrobial properties (Pérez et al 2018). Members of family apiaceae account for antibacterial, antifungal, anti-cancerous and antiviral properties (Raut and Karuppayil 2014) while, members of family Lamiaceae are known for antiviral, antimicrobial and anti-mutagenic activities besides being useful in treating intestinal and respiratory disorders (Nilufar et al 2017). Citrus oils of the family Rutaceae are medicinally active essential oils with major components as citral, geraniol and geranyl acetate which mainly exhibit antimicrobial and anti-cancerous properties (Raut and Karuppayil 2014). Family Rutaceae show antimicrobial potential attributed to limonene and linalool which are the main components of their essential oils. Other essential oil yielding families include Fabaceae, Pinaceae, Cupressaceae and Zygophyllaceae (Carson and Hammer 2011).

Techniques of essential oil extraction: Different plant parts (Bakkali et al 2008) like buds, flowers, leaves, stem, twigs, seeds, fruits, root and bark produce essential oils which is usually stored in glands, oil ducts, resin ducts or trichomes of the plant (Başer and Demirci 2007). Different techniques of oil extraction are steam distillation, hydro distillation microwave hydro diffusion, high pressure solvent extraction, supercritical CO_2 extraction, ultrasonic extraction and solvent free microwave extraction (Farhat et al 2010) but on commercial scale steam distillation is preferred (Masango 2005). It requires prolonged heating and stirring consuming lots of energy and time for the completion of the process with high consumption of solvent (Chemat et al 2009). Moreover, some volatile components are lost through steam distillation. In solvent free extraction method, it is not possible to obtain a solvent free product (Khajeh et al 2010). The method of oil extraction is based on its application (Rassem et al 2016). The product extracted could differ in quality, quantity and in composition depending on plant age, organ from which it is extracted, climate and soil composition (Angioni et al 2006). In order to obtain a constant composition of the oil the plant needs to be growing on the same soil and under the same environmental conditions (Bakkali et al 2008). To ensure good quality of essential oil commercially they are analyzed by GC-MS technique.

Chemical composition- Essential oils are natural, low molecular weight, highly volatile, secondary plant metabolites having 20-60 components at different concentrations (Bakkali et al 2008). These are grouped into mainly two categories of biosynthetic origin (Pichersky et al 2006). The major group includes terpenes and terpenoids and the other group is of aromatic and aliphatic compounds but, terpenes and terpenoids are found in abundance in essential to the oil (Zuzarte and Salgueiro 2015).

Terpenes: Terpenes and terpenoids are made as a result of condensation of 5 carbon base units called isoprene having two unsaturated bonds. These units are joined in one direction. Mostly essential oils are complex mixtures of monoterpenes ($C_{10}H_{16}$) and sesquiterpenes ($C_{15}H_{24}$) along with phenols, alcohols, ether, aldehydes and ketones which are responsible for their characteristic odour.

Phenylpropanoids: These are aromatic compounds derived from phenylpropane (Bakkali et al 2008) and contain one or more C_6-C_3 units with C_6 Being a benzene ring. Many phenylpropanoids are phenols which may include oxygenated hydrocarbons like eugenole, anthole and safrole (Rassem et al 2016).

Pharmacological actions of essential oils: The essential oils have been screened mainly for their various biological activities like antibacterial, antifungal, antioxidant and many more activities commercially (Ali et al 2015). Some of the pharmacological properties are discussed below.

Antibacterial property of essential oils: The essential oils exhibit antibacterial potential. These have been used since ancient Egyptian times in embalming to curb the bacterial growth. Still the serious bacterial infections are the leading cause of deaths even after the discovery of antibiotics due to several antibiotic resistant strains emerging up (Raut and Karuppayil 2014). The prolonged use of antibiotics in high doses leads to toxicity. Therefore, the plant secondary metabolites are being explored as an alternative source against the pathogenic bacteria (Galvão et al 2012). The plant essential oils are known to cover the broad spectrum

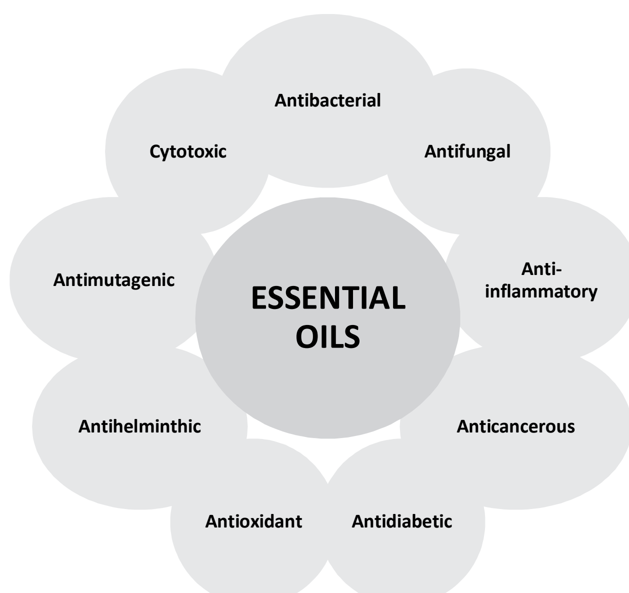

Fig. 1. Bioactive potential of essential oils

inhibitory activities of gram positive and gram negative bacteria (Teixeira et al 2013). In vitro evidences indicate that the essential oils act as antibacterial agents of different bacterial strains including *Liestera, Monocytogenes, Salmonella typhimurium, E. coli, Shigella dysenteria* and *Bacillus aureus* (Schmidt et al 2005). Among the major constituents of essential oils, the oxygenated terpenoids manifest the highest antibacterial activity (Pérez et al 2018). The antibacterial effect of essential oils of different plants vary on different bacteria like sandalwood oil (*Santalum album*), manuka oil (*Leptospermum scoparium*) and veitver (*Chrysopogon zizanoides*) oils are effective against gram positive bacteria (Hammer et al 2006). However, the essential oil of *Achillea clavennae* is effective against gram negative bacteria. The essential oils of Oregano and Thyme are known to inhibit the growth of certain bacterial strains such as *E coli, S. enteridis, S. choleraesuis and S. typhimurium* (Penalver et al 2005) due to their phenolic components carvacrol and thymol. The high phenolic content was the cause of inhibition (Chouhan et al 2017). Three species of thymus *i.e T. capitata, T. munbyanus and T. glandulosus* showed high concentration of oxygenated monoterpenes and both the phenols carvacrol and thymol showing the highest antibacterial effect of all essential oils against all bacterial strains (Moukhles et al 2018). Due to the emergence of drug resistant bacterial strains the essential oils have to target at the cellular level to alter the bacterial gene expression. Essential oils of the aromatic plants like *Carum copticum* and *Syzgium aromaticum* have been used to modify the expression of *E. coli* and *P. aeruginosa* respectively. Oxygenated terpenoids manifest the highest antimicrobial activity (Pérez et al 2018). The primary mode of action of essential oil is the membrane destabilization of the pathogen as they are lipophilic in nature and hence are permeable through the cell wall and cell membrane making the bacterial cell wall more permeable due to their components like polysaccharides, fatty acids and phospholipids resulting in the loss of ions and cellular contents leading to cell death (Saad et al 2013).

Antifungal activity: The human beings and plants both are susceptible to fungal infections. The antifungal property of essential oils has been regarded as the potential substitute for conventional synthetic fungicides (Elshafie and Camele 2017). With the emergence of fungus resistant strains, the use of synthetic fungicides has been limited as they increase toxicity levels (Lopez-Reyes et al 2013). The fungal infections being caused by eukaryotic pathogens show similarities with the host at the molecular and cellular level and hence hard to treat. Hence these infections are associated with high mortality rates (Sardi et al 2013). The antifungal activity is generally linked to high lipophilic nature and low molecular weight of terpenes and terpenoids which are capable of disrupting the cell membrane causing cell death (Nazzaro et al 2017). The various plant and human pathogenic fungi are susceptible to plant essential oils (Raut and Karuppayil 2014). The higher amount of E-cinnamaldehyde explains higher antifungal activity in *Cinnamomum aromaticum* (Szweda et al 2015). The spore development of fungi is inhibited due to essential oils rich in phenylpropanoids like eugenol and monocyclic sesquiterpenoids like alpha-bisabolol (Pragadheesh et al 2013). The Lemon grass oil with the concentration ranging from 0.006 to 0.03% is most effective against filamentous fungi (Raut and Karuppayil 2014). Essential oils of certain plants like *Eucalyptus, Meleluca* have components like citral, citronellol, gerniol and geranyl acetate which show cell cycle inhibitory activities against *Candida albicans* (Zore et al 2011). The essential oil components like eugenol, thymol and carvacrol affect Ca^{2+} and H^{+} ions leading to their loss and inhibiting growth of *S cerevisiae* (Rao et al 2010). The essential oils of many aromatic plants like *Mentha piperata, Brassica nigra, Angelica archangelica, Cymbopogon nardus, Skimmia laureola, Artemisia seiberi and Cuminium cyminum* show positive antifungal activity (Samber et al 2015). Analysing the fungal contamination of indoor air quality clove oil was found to have the maximum potential to exhibit antifungal activity (Schroder et al 2017). Membrane fluidity abnormalities result in leakage of cytoplasmic contents and hence loss of fungal viability.

Anti-inflammatory activity: Many animal and human diseases usually result in inflammations which are normally treated with non-steroidal anti-inflammatory drugs (NSAIDs) and corticosteroids which have enormous side effects. To address this problem, the anti-inflammatory potential of natural plant essential oils has been explored. Their main components like eugenol and carvacrol when evaluated showed major anti-inflammatory activity (Pérez et al 2011). Essential oils are traditionally used as anti-inflammatory, analgesic and antipyretic remedies for various infections. The monoterpenoid constituent of aromatic oils is useful in treating common cold and other respiratory infections. Free radical scavenging is one of the mechanisms of inflammation preventive activity (Miguel 2010). The plants like Aloe, Anise, Bergmot, Lavender, Juniperus, Cinnamon leaf and Thyme yield essential oils having anti-inflammatory potential. Their action is based on inhibition of Cox-2-enzyme. The anti-inflammatory activity was analysed in plants of families Capparidaceae, Euphorbiaceae and Liliaceae on stem barks of *Drypetes gossweileri*, roots of *Pentadiplandea brazzeana* and red bulbs of *Allium cepa* and *Allium sativum* showed that

Table 1. Plants from different families exhibiting anti-inflammatory potential

Plant	Family	Parts used	Major constituents	References
Afromomum melegueta	Zingiberaceae	Grains	(6)-paradol, (6)-shogoal, (6)-gingerol	Akpanabiatu et al (2013)
Afromomum denielli	Zingiberaceae	Leaf, stem, rhizome	α-pinene, β-pinene, 1,8-cineole, α-terpeniol, β-ocimene	Pérez et al (2011)
Ageratum fastigiatum	Asteraceae	Leaves	GermacreneD, α-humulene, β-cedrene	Del-Vechio-Vieira et al (2009)
Allium sativum	Liliaceae	Bulb	diallyl trisulfide, diallyl disulfide, allyl methyl trisulfide, diallyl sulfide and diallyl tetrasulfide	Foe et al (2016)
Allium cepa	Liliaceae	Bulb	diallyl trisulfide, dipropyl trisulfide, 2-methyl-3,4-dithiaheptane, methyl propyl trisulfide, dipropyl tetrasulfide and 2-propenyl propyl disulfide.	Foe et al (2016)
Aucoumea klaineana	Burseraceae	Resins from tree bark	α-pinene, α-phelandrene, p-cymene, 1,8-cineole	Dongmo et al (2010)
Bursera morelensis	Burseraceae	Young stems and pieces of bark	α-pinene, α-phelandrene, p-cymene, caryophyllene	Alina et al (2014)
Canarium scheinfurthii	Burseraceae	Resin from tree bark	γ-terpinene, α-phellandrene, α-thujene, β-phellandrene, *p*-cymene, α-pinene, sabinene, β-pinene, limonene, octyl acetate, nerolidol, *n*-octanol, and α-terpineol	Pérez et al (2011)
Calycorectes sellowianus	Myrtaceae	Leaf	Guaiol, α-caryophyllene	Apel et al (2010)
Cinnamomum insularimontanum	Lauraceae	Fruit	αpinene, αpinene, camphene, limonene, citronellal, citronellol, citral	Lin et al (2008)
Cinnamomum osmophloeum	Lauraceae	Leaf	1,8-cineole and santolina triene and the sesquiterpenes spathulenol and caryophyllene oxide	Tung et al (2008)
Chaerophyllum aromaticum	Apiaceae	Leaf	Sabinene, terpinolene, α-terpinene	Kurkcuoglu et al (2018)
Citrus aurantium	Rutaceae	Fruit peel	linolool, α-terpineol, (R)-limonene and linalyl acetate	Karaca et al (2007)
Citrus sinensis	Rutaceae	Fruit peels	limonene, β-pinene and γ-terpinene	Pérez et al (2011)
Citrus sunki	Rutaceae	Fruit peel	limonene, β-pinene and γ-terpinene,	Yang et al (2010)
Cleistocalyx operculatus	Myrtaceae	Buds	Myracene, (E)-α-ocimene, (Z)-α-ocimene, linalool	Dung et al (2009)
Cordia verbenacea	Boraginaceae	Leaf	Artemetin a flavon α-humulene, trans-caryophyllene	de-Freitas et al (2008)
Cyperus esculentus	Cyperaceae	Rhizome	Cyperene, humulene, silinene, zierone, limonene	Udefa et al (2020)
Chenopodium album	Chenopodiaceae	Leaf	p-cymene, ascaridole, pinnae-2-ol, α-pinene, α-pinene, α-terpineol	Biradar et al (2010)
Dennettia tripetala	Annonaceae	Leaf	Z-Phenylnitroethane, linalol, methyl eugenol	Oyemitan et al (2008)
Driyms brasiliensis	Winteraceae	Leaf and stem bark	GermacreneD, bicyclogermacrene cyclolorenone	Lago et al (2010)
Drypetes gossweileri	Eurphobiaceae	Stem barks	diallyl trisulfide , dipropyl trisulfide, 2-methyl-3,4-dithiaheptane, methyl propyl trisulfide, dipropyl tetrasulfide and 2-propenyl propyl disulfide	Foe et al (2016)
Fortunella japonica	Rutaceae	Fruit	dl-limonene, carvone	Pérez et al (2011)
Garcinia brasiliensis	Guttiferae	Fruit peel	γ-muurolene, spathulenol, δ-cardinene, torreyol, α-cardinol, cadalene, γ -cardinene	Martins et al (2008)
Hedychium coronarium	Zingiberaceae	Rhizome	Linalool, 1,8-cineole, α-terpineol, β-trans-ocimenone, sabinene, terpinen-4-ol, 10-epi-γ-eudesmol	Lu et al (2009)
Helichrysum italicum	Asteraceae	Flowers and leaves	β-caryophyllene, α-pinene, 1,8-cineole, p-cymene, spathulenol, germacreneD-4-ol	Bouzid and Zerroug (2018)
Illicium anisatum	*Illiciaceae*	Leaves	Eucalyptol, sabinene, a-terpinenyl acetate, kaurene, isopimaradiene, safrol, b-linalool, d-cadinene, a-cadinol and terpene-4-ol	Kim et al (2009)

Cont...

Table 1. Plants from different families exhibiting anti-inflammatory potential

Plant	Family	Parts used	Major constituents	References
Lippia sidaoides	Verbenaceae	Leaves	Thymol, p-cymene	Monteiro et al (2007)
Melaleuca alternifolia	Myrtaceae	Leaves	Terpen-4-ol, α-terpinene, γ-terpinone, α-terpineol	Vila and Cañigueral (2006)
Melissa officinalis	Lamiaceae	Leaves	Nerol, citral, isopulegol, caryophyllene, citronella	Bounihi et al (2013)
Mezoneuron benthamianim	Caesalpinoideae	Leaves and stem	3-carene, pinene, trans-nerolidol, farnesene, thujone	Olufunke et al (2009)
Myrciaria tenella	Myrtaceae	Leaves	β-caryophyllene, spathulenol	Apel et al (2010)
Nepta cataria	Lamiaceae	Leaves	Trans-nepetalactone, cis-neptalactone neptalactol	Ricci et al (2010)
Ocotea quixos	Lauraceae	Flowers	Trans-cinnamaldehyde, methyl-cinnamate	Radice et al (2017)
Olea europea	Oleaceae	Fruits	Oleuropein a phenol, α-pinene, 2,6-dimethyloctane, 2-methoxy, intraperitoneal, 3-isopropylpyrazine	Eidi et al (2012)
Origanum ehrenberghii	Lamiaceae	Leaves	Thymol, p-cymene	Loizzo et al (2009)
Origanum vulgare	Labiatae	Leaves	Trans-sabinene hydrate, thymol, carvacrol	Pezzani et al (2017)
Pelargonium graveolens	Geraniaceae	Leaves	Citronellol, citronellyl formate, linalool, geraniol, isomenthone, menthone	Asgarpanah and Ramezanloo (2015)
Pentiplandra brazzaena	Capparidaceae	Roots	diallyl trisulfide, dipropyl trisulfide, 2-methyl-3,4-dithiaheptane, methyl propyl trisulfide, dipropyl tetrasulfide and 2-propenyl propyl disulfide	Foe et al (2016)
Pogostemonis herba	Lamiaceae	Leaves	Patchoulol, delta-guaiene, alpha-guaiene, seychellene, alpha-patchoulene, aciphyllene, trans-caryophyllene	Xian et al (2011)
Pimpinella corymbosa	Apiaceae	Roots	(4-2-propenyl) phenylangelate, [4-(3-methyloxiranyl) phenyltiglate], [4-methoxy-2-(3-methyloxiranyl) phenyl isobutyrate], [4-methoxy-2-(3-methyloxiranyl)phenylangelate] and (epoxy pseudoisoeugenol-2-methylbutyrate)	Pérez et al (2011)
Plumbago zeylanica	Plumbaginaceae	Roots	Plumbagin, 1-octen-3-acetate, limonene	Vanitha et al (2020)
Psidium guajava	Myrtaceae	Leaves	β-caryophyllene, limonene, selin-7-(11)-en-4□-ol	El-Ahmady et al (2013)
Rosamarinus officinalis	Lamiaceae	Leaves	1,8-cineole, α-pinene, camphene, β-myracene	Borges et al (2019)
Sabina virginiana	Cupressaceae	Leaves	Limonene, safrole, asarone, α-pinene	Aboaba et al (2010)
Thymus vulgaris	Labiatae	Leaves	Thymol, carvacrol, α-pinene, p-cymene, limonene	Boukhatem et al (2020)
Terminalia chebula	Combretaceae	Fruits	Chebulanin, gallic acid	Zaidi et al (2012)
Zanthoxylum piperitum	Rutaceae	Fruits	Limonene, geranyl acetate	Lee et al (2017)
Zanthoxylum sclnifolum	Rutaceae	Fruit pericarp	□-phellandrene, citronellal, gernyl acetate	Kim (2014)
Zingiber officinale	Zingiberaceae	Rhizome	[6]-gingerol, [8]-paradol and [8]-shogaol	Munda et al (2018)
Zingiber zerumbet	Zingiberaceae	Rhizome	zerumbone, alpha-humulene, humulene epoxide II, caryophyllene oxide and camphene	Singh et al (2014)
Zizyphus jujube	Rhamanaceae	Seeds	13-Heptadecyn-1-ol, 7-Ethyl-4-decen-6-one, Lineoleoyl chloride, Linoleic acid, 2,5-Octadecadiynoic acid, methyl ester and Palatinol	Al-Reza et al (2010)

it was higher in in *P brazzaena* and *A cepa* as their essential oil is rich in organosulphur compounds and hence attributes to this property (Foe et al 2016). Fruits of *Piper nigrum* contain caryophyllene and Limonene as its major constituents that help in reducing carrageenan and dextran induced inflammation (Jeena et al 2014). Essential oils from the fruits *Pycnocycia bashargardiana* (Myrtaceae) had myristicin which exhibited anti inflammatory property (Fatemeh and Khosro 2012). The lipogenase activity measurement using essential oils of *Cymbopogon giganteus* and *C citratus* can give the information about its potential use as an anti-inflammatory (Bayala et al 2018). The essential oils of these two species of *Cymbopogan* have shown the cytotoxic effect on tumour cell cultures leading to identification of citral one of the major components of their essential oil showing anti-inflammatory property. Hence, treating several inflammatory disorders using herbal therapy and the bioactive constituents of essential oils is an attractive approach.

Cancer preventive property: Cancer is a complex genetic disorder posing a serious life threat and a leading cause of death claiming about 8 million lives world over annually. Supressing the malignant cell growth is one of the major challenges in the treatment of cancer. Certain essential oils tested positive for cancer suppressive activity when tested on a number of human cancer cell lines (Edris 2007). Various types of cancers like glioma, colon cancer, gastric cancer, human liver tumour, pulmonary tumour, breast cancer and leukaemia could be supressed after the treatment with plant essential oils (Hamid et al 2011). The potential of essential oils as anti cancerous agents is still in juvenile stage but about 25% of chemotherapy agents are plant based and 25% are chemically modified phytoproducts (Amin et al 2009). Paclitaxel molecule used in chemotherapy was originally derived from a bark of a tree *Toxus brevifolia* (Weaver 2014). It works at the cellular level which induces arrest of mitosis and targeting tubulin a component of cytoskeleton ultimately leading to apoptosis. A sesquiterpene hydrocarbon found in majority of essential oils used in treating Glioma increased the survival time of the patients suffering from it (Tan et al 2018). D-bisabolol a sesquiterpene in *Matricaria chamomilla* induces apoptosis in glioma cells (Edris 2007). Geraniol a natural component of essential oil of *Cymbopogon martini* reduces the amount of enzymes thymidylate synthetase and thymidine kinase (Carnesecchia et al 2004) in colon cancer cells which enhances 5-fluorouracil cytotoxicity. D-limonene is one of the major components of essential oils especially in citrus fruit peels constituting 90-95% of the total oil. About 26-34% of d-limonene is found in spearmint oil (Edris 2007). It has shown a widespread application in chemo preventive and chemotherapeutic activities in preclinical studies of breast cancer. Also d-limonene has shown anti proliferative and proapoptotic effect of cancer cells (Yu et al 2018) in lung cancer. It can induce the formation of apoptotic bodies on BCG-823 gastric cancer cells which are formed in time and dose dependent manner. The essential oils in garlic along with its organosulphur components have exhibited anticancerous potential (Thomson and Ali2003). They reduce the expression and activation of various cell growth stimulatory proteins and target the cancer cells (Petrovic et al 2018). Diallyl trisulphide (DATS) one of the major components of garlic essential oil arrests the division of human live tumour cells at G2/M phase of cell cycle (Wu et al 2004). The terpenoids and polyphenols present mostly in essential oils induce apoptosis or necrosis and hence preventing the proliferation of tumour cells (Bakkali et al 2008). Myristicin an active component of *Myristica fragrans* oil show hepato protective activity by inducing apoptosis (Lee et al 2005).

Mechanism of essential oil: The essential oils mainly operate by inducing programmed cell death better known as apoptosis, necrosis, arrest of cell cycle and dysfunctioning of main cell organelles is attributed mainly to the lipophilic nature and low molecular weight of their major components which allows them to enter the affected cell causing the increase of membrane fluidity. Due to this alteration in cell membrane, ATP production is reduced, pH gradient is altered and finally loss of mitochondrial potential leads to cell death (Sharifi-Rad et al 2017).

The mechanism operating to exhibit the anti cancerous effect of plant EOs is mainly constituent dependent which chiefly are phenols, aldehydes, and alcohols. The toxicity of EOs towards mammalians decreases with the increase of average lipophilicity of its components, while in prokaryotes the toxicity increases with increasing lipophilicity. This indicates the extraordinary role of EOs among natural compounds. The cancerous cells are sensitive to plant isoprenoids which reduce tumour cell-size in patients (Elshafie and Camele 2017).

Antidiabetic potential: There are major health issues cropping up worldwide due to the modern lifestyle changes leading to obesity which is the base line of several diseases including impaired glucose tolerance causing type2 diabetes which has affected the major portion of the population. The glucose levels have been maintained by several synthetic drugs including metformin. The alternative therapy used is plant based products like essential oils which are reported to exhibit potential anti diabetic potential. The essential oils extracted from *S aromaticum* and *C cyminium* show potent anti diabetic activity (Sahu et al 2021). Non-polar *Toona sinesis* extract also exhibit anti diabetic potential (Hsieh et al 2012). In an in vitro anti diabetic screening model based glucose consumption it is shown that using *Melissa officinalis* essential oil the glucose consumption was remarkably increased (Yen et al 2015). The anti diabetic potential of essential oil of *Hedichyium spicatum*, a member of family Zingiberaceae was explored on diabetic rats. The rhizome oil had 1,8 cineole as its key ingredient limonene was able to lower the glucose levels indicating to the potential to cure type 1 diabetes (Berbudi et al 2020). The essential oils of *Artemessia sieberi* exhibited that the blood glucose level reduction was comparable to metformin a common hypoglycemic in alloxan induced diabetic rats (Hussain et al 2017). The essential oil extracted from leaf sheath of *Cymbopogan citratus* (Graminae) supported that by molecular docking its anti diabetic nature and could be supplemented with diabetic drugs (Bharti et al 2013). The essential oil of *Pelargonium graveolans* TL when administered together with glibenclamide a known

Table 2. EOs effective in treating different types of cancers

Type of cancer	Plant essential oil	Family	Activity	Oil constituents	Refrences
Glioblastoma	*Hypericum hiricum*	Hypericaceae	Anti proliferative	cis-β-guaiene, δ-selinene and (E)-caryophyllene cis-guaiene	Quassinti et al (2013)
	Zanthoxylum tingusssuiba	Rutaceae	Apopototic	α-bisabolol	Detoni et al (2012)
	Ocimum basilicum	Lamiaceae	Cytotoxic	methyl cinnamate, linalool, β-elemene and camphor.	Kathirvel and Ravi (2012)
	Lippia multiflora	Verbenaceae	Anti-proliferative	thymyle acetate	Bayala et al (2018)
	Ageratum conyzoides	Asteraceae	Cytotoxic	precocene	Bayala et al (2018)
	Melissa officinalis	Lamiaceae	Apopototic	caryophyllene oxide, caryophyllene and β-copaene	Queiroz et al (2014)
	Salvia officinalis	Lamiaceae	Anti-proliferative	a-thujone, c-muurolene camphor, borneol, and sclareol	Russo et al (2013)
	Drimys brasiliensis	Winteraceae	Cytotoxic	cyclocolorenone	Gomes et al (2013)
	Malus domestica	Rosaceae	Cytotoxic	eucalyptol, phytol, α-farnesene and pentacosane	Walia et al (2012)
Melonoma	*Afrostyrax lepidophyllua*	Huaceae	Chemopreventive	2,4,5,7-tetrathiaoctane	Fogang et al (2014)
	Scorodopholeus zenkeri	Fabaceae	Chemopreventive	2,4,5,7-tetrathiaoctane	Fogang et al (2014)
	Athanasia brownii	Asteraceae	Chemopreventive	oxygenated sesquiterpenes with selin-11-en-4α-ol, caryophyllene oxide, humulene epoxide II and (E)-nerolidol	Rasoanaivo et al (2013)
	Neolista variabillima	Lauraceae	Cytotoxic	trans-beta-ocimene, alpha-cadinol, terpinen-4-ol, tau-cadinol, beta-caryophyllene and sabinene	Su et al (2013)
	Casearia sylvestris	Salicaceae	Cytotoxic	sesquiterpene a-zingiberene	Bou et al (2013)
	Salvia bracteata	Lamiaceae	Anti-proliferative	β-caryopyllene, y-muurolene, bicyclogermacrene, caryophyllene oxide and ot-humulene	Cardile et al (2009)
	Melaleuca alternifolia	Myrtaceae	Necrosis	Terpinene-4-ol, γ-terpinene, α-terpineole, 1-8cineole and p-cymene	Russo et al (2013)
	Salvia rubifolia	Labiatae	Apoptotic		Russo et al (2013)
	Platycladus orientalis	Cupressaceae	Antiproliferative	linalool, β-caryophyllene and α-cedrol	Loizzo et al (2008)
Breast cancer	*Satureja khuzistanica*	Lamiaceae	Cytotoxic	Carvacrol and limonene	Yousefzadi et al (2014)
	Cadrelopsis grevei	Rutaceae	Cytotoxic	β-farnesene, δ-cadinene, α-copaene and β-elemene	Afoulous et al (2013)
	Solanum spirale	Solanaceae	Cytotoxic	(E)-Phytol, n-hexadecanoic acid, beta-selinene, alpha-selinene, octadecanoic acid and hexahydrofarnesyl acetone	Keawsa-Ard et al (2012)
	Boswellia sacra	Burseraceae	Apoptosis	E-beta-ocimene, limonene, E-caryophyllene	Suhail et al (2011)
	Laurus nobilis	Lauraceae	Antiproliferative	1,8-Cineol	Al-Kalaldeh et al (2010)
	Origanum vulgare	Lamiaceae	Antiproliferative	trans-sabinene hydrate	Al-Kalaldeh et al (2010)
	Salvia triloba	Lamiaceae	Antiproliferative	1,8-Cineol	Al-Kalaldeh et al (2010)

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Table 2. EOs effective in treating different types of cancers

Type of cancer	Plant essential oil	Family	Activity	Oil constituents	Refrences
	Garcinia atroviridis	Clusiaceae	Cytotoxic	palmitoleic acid, palmitic acid, while the leaf oil (E)-β-farnesene and β-caryophyllene	Tan et al (2018)
	Origanum syriacum	Lamiceae	Antiproliferative	Carvacrol	Tan et al (2018)
	Casearia sylvestris	Flacourtiaceae	Cytotoxic	β-caryophyllene and α-humulene	Silva et al (2008)
	Melissa officinalis	Lamiaceae	Apoptosis	Citral	Dudai et al (2005)
	Salvia officinalis	Labiatae	Antiproliferative	1,8-cineole	Russo et al (2013)
	Thymus broussonetti	Lamiaceae	Cytotoxic	borneol, thymol, camphene, ρ-cymene, *α*-pinene and linalool. Camphor, *α*-terpineol, eucalyptol, germacrene D and borneol	Russo et al (2013)
	Citrus bergamia	Rutaceae	Cell death	Limonene, Linalyl acetate	Navarra et al (2015)
	Garcinia celebica	Clusiaceae	Antiproliferative	α-copaene, germacrene D and β-caryophyllene	Tan et al (2018)
	Salvia officinalis	Lamiaceae	Antiproliferative	α-thujone, 1,8-cineole and camphor	Privitera et al (2019)
	Cyperus articulatus	Cyperaceae	Cytotoxic	sesquiterpenes, anozol, monoterpenes, furanone, nootkatone, 6-methyl-3,5-heptadien-2-one, retinene, nopinone, cycloeucalenol, toosendanin, ethanone and vitamin A.	Kavaz et al (2019)
	Glandora rosmarinifolia	Boraginaceae	Cell growth inhibition	*m*-camphorene, heptacosane, nonacosane, hydroxy-methyl-naphthoquinone, 2,6-dimethyl-10-(*p*-tolyl)-2,6-(*E*)-undecadiene, cembrene C and phytol	Poma et al (2018)
	Semenovia suffruticosa	Apiaceae	Antiproliferative	Z-β-ocimen, linalool and β-bisabolol	Soltanian (2019)
	Cymbopogon flexuosus	Poaceae	Cytotoxic	Citral, Gerniol	Russo et al (2013)
	Tagetes minuta	Asteraceae	Cytotoxic	β-Ocimene, (E)-caryophyllene and germacrane D	Ali et al (2015)
Colon cancer	*Afrostyrax lepidophyius*	Huaceae	Chemopreventive	2,4,5,7-tetrathiaoctane	Fogang et al (2014)
	Sacrodopholeus zenkeri	Fabaceae	Chemopreventive	2,4,5,7-tetrathiaoctane	Fogang et al (2014)
	Athanesia brownii	Asteraceae	Chemopreventive	oxygenated sesquiterpenes with selin-11-en-4α-ol, caryophyllene oxide, humulene epoxide II and (E)-nerolidol	Rasoanaivo et al (2013)
	Neolistea variabillina	Lauraceae	Cytotoxic	trans-beta-ocimene, alpha-cadinol, terpinen-4-ol, tau-cadinol, beta-caryophyllene and sabinene	Su et al (2013)
	Satureja khuzistanica	Lamiaceae	Cytotoxic	Carvacrol and limonene	Yousefzadi et al (2014)
	Artemissia campestris	Asteraceae	Cytotoxic	β-myrcene, α-pinene, trans-β- ocimene, β-cymene and camphor	Al-Snafi (2015)
	Rosa damascena	Rosaceae	Apoptosis and necrosis	β-citronellol, nona- decane, geraniol, heni-cosane eicosane, linalool, methyl eugenol	Shokrzadeh et al (2017)

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Table 2. EOs effective in treating different types of cancers

Type of cancer	Plant essential oil	Family	Activity	Oil constituents	Refrences
	Melissa officinalis	Lamiaceae	Apopotosis	Citral	Dudai et al (2005)
	Salvia libanotica	Labiatae	Cell cycle arrest, apoptosis	Linalyl acetate, α-terpeniol, camphor	Russo et al (2015)
	Semenovia suffruticosa	Apiaceae	Antiproliferative	Z-β-ocimene, linalool and β-bisabolol	Soltanian (2019)
	Cymbopogon flexuosus	Poaceae	Cytotoxic	Citral, Gernial	Russo et al (2015)
	Citrus aurantium L. subspamara	Rutaceae	Cytotoxic	Limonene, α-pinene, β-myrcene	Odeh et al (2020)
Ovarian cancer	*Cymbopogon citratus*	Poaceae	Antiproliferative	Citral, geranial	Bayala et al (2018)
	Guatteria pogonopus	Annonaceae	Anti tumour	γ‐patchoulene, (E)‐caryophyllene, β‐pinene, germacrene D, bicyclogermacrene, α‐pinene, and germacrene B	do N Fontes et al (2013)
	Malus domestica	Rosaceae	Cytotoxic	eucalyptol, phytol, α-farnesene and pentacosane	Walia et al (2012)
	Patrinia scabra	Caprifoliaceae			
	Thymus broussonetti	Lamiaceae	Cytotoxic	borneol, thymol, camphene, ρ-cymene, *α*-pinene and linalool. Camphor, *α*-terpineol, eucalyptol, germacrene D	Russo et al (2015)
Liver cancer	*Thymus citriodorus*	Lamiaceae	Apoptosis	borneol, thymol, 3,7-dimethyl-1, 6-octadiene-3-ol, 1-methyl-4-[alpha-hydroxy-isopropyl] cyclohexene and terpenes camphor	Wu et al (2004)
	Artemissia indica	Asteraceae	Cytotoxic	ketone, germacrene B, borneol and *cis*-chrysanthenyl acetate	Rashid et al (2013)
	Pituranthos tortuosus	Apiaceae	Cytotoxic	terpinen-4-ol, sabinene, γ-terpinene and β-myrcene	Bayala et al (2018)
	Neolistea variabillina	Lauraceae	Cytotoxic	trans-beta-ocimene, alpha-cadinol, terpinen-4-ol, tau-cadinol, beta-caryophyllene and sabinene	Su et al (2013)
	Zanthoxylum schinifolium	Rutaceae	Apoptotic	geranyl acetate, citronella, sabinene	Paik et al (2005)
	Glandora rosmarinifolia	Boraginaceae	Cell growth inhibition	*m*-camphorene, heptacosane, nonacosane, hydroxy-methyl-naphthoquinone, 2,6-dimethyl-10-(*p*-tolyl)-2,6-(*E*)-undecadiene, cembrene C and phytol	Poma et al (2018)
	Cymbopogon flexuosus	Poaceae	Cytotoxic	Citral, Gerniol	Russo et al (2015)
Uterus and cervix cancer	*Casearia sylvestris*	Salicaceae	Cytotoxic	β-caryophyllene and α-humulene	Silva et al (2008)
	Liquidambar styraciflua	Altingiaceae	Cytotoxic	d-monene, α-pinene and β-pinene, and of the stem oil were germacrine D, α-cadinol, d-limonene, α-pinene, and β-pinene	El-Readi et al (2013)
	Schinus terebinthifolius	Anacardiaceae	Cytotoxic	germacreneD, bicyclogermacrene, β-pinene and β-longipinene	Santana et al (2012)
	Curcuma wenyujin	Zingiberaceae	Apoptotic	Furanodiene	Sun et al (2009)
	Aristolochia mollissima	Aristolochiaceae	Cytotoxic	(*E*)-β-santalol acetate and camphene	Bayala et al (2018)
	Melaleuca alternifolia	Myrtaceae	Necrosis	Terpinene-4-ol, γ-terpinene, α-terpineole, 1-8cineole and p-cymene	Russo et al (2015)

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Table 2. EOs effective in treating different types of cancers

Type of cancer	Plant essential oil	Family	Activity	Oil constituents	Refrences
	Salvia officinalis	Lamiaceae	Antiproliferative	α-thujone, 1,8-cineole and camphor	Privitera et al (2019)
	Lavandula angustofolia	Lamiaceae	Reduce cell viability	Linalool	Pereira et al (2018)
	Cymbopogon flexuosus	Poaceae	Cytotoxic	Citral, Gerniol	Russo et al (2015)
Lung cancer	*Xylopia futrescense*	Annonaceae	Cytotoxic	(E)-caryophyllene, bicyclogermacrene, germacrene D, δ-cadinene, viridiflorene and α-copaene	Bayala et al (2018)
	Guatteria progonopsis	Annonaceae	Anti tumour	γ ‐ patchoulene, (E) ‐ caryophyllene, β ‐ pinene, germacreneD, bicyclogermacrene, α ‐ pinene, and germacrene B	do N Fontes et al (2013)
	Neolistea variabillima	Lauraceae	Cytotoxic	trans-beta-ocimene, alpha-cadinol, terpinen-4-ol, tau-cadinol, beta-caryophyllene and sabinene	Su et al (2013)
	Tridax procumbens	Asteraceae	Apoptosis	Pinene pinene ß phellandrene and Sabinene	Manjamalai et al (2012)
	Artemissia indica	Asteraceae	Cytotoxic	ketone, germacrene B, borneol and *cis*-chrysanthenyl acetate	Rashid et al (2013)
	Listea cubeba	Lauraceae	Apoptosis	1,8-cineol, sabinene, α-terpinyl acetate α-pinene and β-pinene	Ho et al (2010)
	Solanum spirale	Solanaceae	Cytotoxic	(E)-Phytol, n-hexadecanoic acid, beta-selinene, alpha-selinene, octadecanoic acid and hexahydrofarnesyl acetone	Keawsa-Ard et al (2012)
	Melissa offcinalis	Lamiaceae	Apopotosis	Citral	Dudai et al (2005)
	Thymus broussonetti	Lamiaceae	Cytotoxic	borneol, germacrene D cymene, ρ-*α*-pinene, thymol, camphene, linalool, camphor, *α*-terpineol, eucalyptol and borneol	Russo et al (2015)
	Zingiber striolatum	Zingiberaceae	Cytotoxic	β-phellandrene, sabinene, β-pinene, geranyl linalool, terpinen-4-ol, α-pinene and crypton	Tian et al (2020)
	Lavandula angustofolia	Lamiaceae	Reduce cell viability	Linalool	Pereira et al (2018)
	Malus domestica	Rosaceae	Cytotoxic	eucalyptol, phytol, α-farnesene and pentacosane	Walia et al (2012)
Oral cancer	*Neolistea variabillima*	Lauraceae	Cytotoxic	trans-beta-ocimene, alpha-cadinol, terpinen-4-ol, tau-cadinol, beta-caryophyllene and sabinene	Su et al (2013)
	Solanum spirale	Solanaceae	Cytotoxic	(E)-Phytol, beta-selinene, n-hexadecanoic acid, alpha-selinene, octadecanoic acid and hexahydrofarnesyl acetone	Keawsa-Ard et al (2012)
	Pinus densiflora	Pinaceae	Apoptotic	beta-phellandrene and alpha-pinene	Jo et al (2012)
	Salvia officinalis	Labiateae	Antiproliferative	α-thujone, 1,8-cineole and camphor	Privitera et al (2019)

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Table 2. EOs effective in treating different types of cancers

Type of cancer	Plant essential oil	Family	Activity	Oil constituents	Refrences
Leukemia	*Neolistea variabillima*	Lauraceae	Cytotoxic	trans-beta-ocimene, alpha-cadinol, terpinen-4-ol, tau-cadinol, beta-caryophyllene and sabinene	Su et al (2013)
	Casearia sylvestris	Salicaceae	Cytotoxic	β-caryophyllene and α-humulene	Silva et al (2008)
	Artemesia indica	Asteraceae	Cytotoxic	ketone, germacrene B, borneol and *cis*-chrysanthenyl acetate	Rashid et al (2013)
	Juniperus excelsa	Cupressaceae	Cytotoxic	α-pinene and cedrol	Saab et al (2012)
	Juniperus oxycedrus	Cupressaceae	Cytotoxic	calamenene, cuparene, and cis-thujopsenal	Saab et al (2012)
	Cedrus libani	Pinaceae	Cytotoxic	germacrene D and β-caryophyllene	Saab et al (2018)
	Pinus pinea	Pinaceae	Cytotoxic	β-caryophyllene, α-terpineol, β-longipinene	Saab et al (2018)
	Malus domestica	Rosaceae	Cytotoxic	eucalyptol, phytol, α-farnesene and pentacosane	Walia et al (2012)
	Melissa officinalis	Lamiaceae	Apopotosis	Citral	Dudai et al (2005)
	Melaluca alternifolia	Myrtaceae	Necrosis	Terpinene-4-ol, γ-terpinene, α-terpineole, 1-8cineole and p-cymene	Russo et al (2015)
	Zingiber striolatum	Zingiberaceae	Cytotoxic	β-phellandrene, sabinene , β-pinene, geranyl linalool, terpinen-4-ol, α-pinene and crypton	Tian et al (2020)
	Lindera umbellata	Lauraceae	Apoptosis	Linalool	Pereira et al (2018)
Kidney cancer	*Satureja khuzistanica*	Labiatae	Cytotoxic	Carvacrol and limonene	Yousefzadi et al (2014)
	Platycladus orientalis	Cupressaceae	Antiproliferative	linalool, β - caryophyllene and α - cedrol	Loizzo et al (2008)
	Prangos asperula	Apiaceae	Antiproliferative	Sabinene, β-phellandrene, γ-terpinene and α-pinene	Loizzo et al (2008)
	Sideritis perfoliata	Labiatae	Cytotoxic	β-Phellandrene	Mesquita et al (2019)
	Aristolochia mollissima	Aristocholiaceae	Cytotoxic	(*E*)-β-santalol acetate and camphene	Bayala et al (2018)
Bone cancer	*Pyrolae herba*	Ericaceae	Antiproliferative	n-Hexadecanoic acid cedrol, 6,10,14-trimethyl-2-pentadecanone and cis-9-octadecadienoic acid	Cai et al (2013)
Pancreas cancer	*Boswellia sp*	Bursaeraceae	Apoptosis	E-beta-ocimene, limonene, E-caryophyllene	Suhail et al (2011)
	Kadsura longipedunculata	Schisandraceae	Apoptosis	Cadinene, camphene, borneol, cubenol and δ - cadinol	Bayala et al (2018)
	Angelica archangelica	Apiaceae	Antiproliferative	α-pinene, δ-3-carene, limonene and α-phellandrene	Maurya et al (2017)
Skin cancer	*Schefflera heptaphylla*	Araliaceae	Antiproliferative	pinene, phellandrene, myrcene, limonene, germacrene, caryophyllene	Li et al (2009)
Prostrate cancer	*Zingiber striolatum*	Zingiberaceae	Cytotoxic	β-phellandrene, sabinene, β-pinene, geranyl linalool, terpinen-4-ol, α-pinene and crypton	Tian et al (2020)
	Salvia officinalis	Lamiaceae	Antiproliferative	α-thujone, 1,8-cineole and camphor	Privitera et al (2019)

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Table 2. EOs effective in treating different types of cancers

Type of cancer	Plant essential oil	Family	Activity	Oil constituents	Refrences
	Lavender angustifolia	Lamiaceae	Antiproliferative	Linalool, linalyl acetate	Zhao et al (2018)
	Curcuma aromatica	Zingiberaceae	Apopotosis	xanthorrhizol, *ar*-curcumene di-epialpha-cedrene, Zingiberene, β-sesquiphellandrene and turmerone	Xiang et al (2017)
	Bursera glabrifolia	Burseraceae	Antiproliferative	α-terpineol, α-terpinene, limonene and β-pinene	Villa‐Ruano et al (2018)
	Cymbopogon citratus (DC.) and Cymbopogon giganteus Chiov.	Poaceae	Antiproliferative	C. giganteus: Limonene, Mentha-1(7), 8-dien-2-ol cis, Mentha-1(7), 8-dien-2-ol trans, trans-Mentha-2,8-diene-para-ol and Mentha-2,8-diene-1-ol, cis-para C. citratus: geranial/citral A and neral/citral B.	Bayala et al (2018)
	Iryanthera polyneura ducke	Myristicaceae	Cytotoxic	Spathulenol, α-cadinol and τ-muurolol	Martins et al (2019)

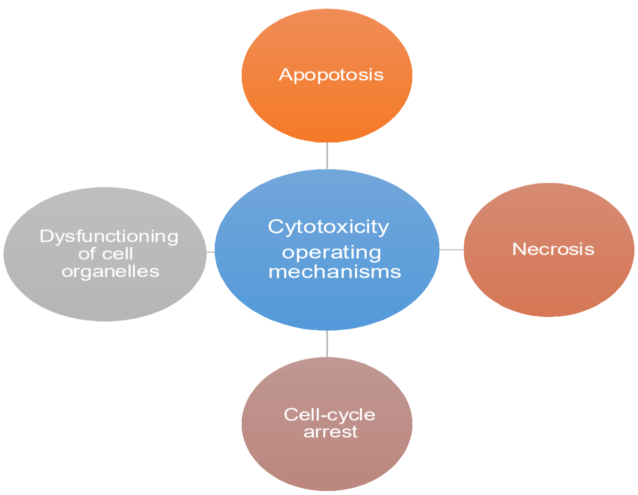

Fig. 2. Cellular mechanisms for carcinogenic prevention by EO

antidiabetic drug significantly decreased the serum glucose levels and a dose of 150mg/kg body weight was more effective than glibenclamide hence preventing diabetic complications associated with oxidative stress in alloxan induced diabetic rats. *Satureja khuzestanica* essential oil resulted in decrease of fasting blood glucose levels in diabetic rats (Abdollahi et al 2003). The combination of different essential oils of Cinnamon, Cumin, Fennel, Oregano and Myretle are known to enhance insulin sensitivity in type-2 diabetes (Talpur et al 2005). Still more research is needed to authenticate the hypoglycemic activity of essential oils.

Anti-oxidant property: The anti-oxidant property is among one of the pivotal biological properties of essential oils which manage the oxidative stress in pathology (Valgimigli 2012) when used in small quantities as compared to the amount of the material which they have to protect (Amorati et al 2013). The antioxidant potential of essential is basically explored as they are natural and non-toxic as compared to the synthetic oxidant such as butylated hydroxyl anisole or butyl hydroxyl toluene which is harmful to human health (Lanigan and Yamarik 2002). This activity depends on the rate constant of a reaction between antioxidant and the chain of free radicals. The antioxidant property is mainly attributed to particularly the phenolic component of essential oils which stop or delay the aerobic oxidation which is composed of terpenoids and phenylpropanoids (Sanchez-Vioque et al 2013). Free radicles generate oxidative stress and hence reactive oxygen species cause oxidation of biomolecules like amino acids, proteins, unsaturated lipids leading to various health issues such as ageing, arteriosclerosis, cancer, alzheimers disease, diabetes and asthma (Edris 2007). The antioxidant activity of *Thymus* and *Origanum* essential oil is attributed to thymol and carvacrol (20.5% and 58.1%) in Thymus and (35% and 32%) in *Origanum* and in essential oils of *Cympogon giganteus* and *Cymbopogon citratus* is mainly attributed to oxygenated monoterpenes. In *C giganteum*, beta caryophyllene shows antioxidant activity while limonene and citral shows anti stress activity in *C citratus* (Bayala et al 2018). The flowers of *Origanum vulgare* a flowering herb exhibited highest anti-oxidant activity among the other parts (Morshedloo et al 2018). The anti-oxidant activity from essential oil of *Lawsonia immerimis* was attributed to eucalyptol, a- pinene and linalool as its major constituents. Hence it shows the good potential of being a good natural antioxidant (Zafar et al 2018).

Antihelminthic bioactivity:Helminthesis is one of the major diseases resulting in the death of grazing animals especially in the underdeveloped countries. The essential oil of *Thymus boveri* was tested for antihelminthic property using adult earthworm and revealed that the major component of its essential oils trans geraniol, alpha-citral, beta-citral showed antihelminthic properties even higher than piperazine citrate (Jaradat et al 2016). Schistosomiasis caused by a flat worm Schistosoma was controlled with essential oil of *Tanacetum vulgare* (Asteraceae) having beta-thujone as its major constituent. *T vulgare* is a potential source of schistosomicidal compounds (Godinho et al 2014). The volatile essential oil derived from leaves of *Eucalyptus globulus* (Myrataceae) having 1,8-cineole as its major component showed antihelminthic property as compared standard drug albendazole at concentration of 10mg/ml. *Artemisia* species possess anti helminthic properties especially against the infections caused by gastrointestinal nematodes in ruminants. The effect of *Artemisia sieversiana* and *Artemisia parviflora* on *Haemonchus contortus,* a parasitic nematode that the mentholic plant extracts inihibited egg hatching, larval and adult motility thus reducing worm burden in animals (Irum et al 2017).The essential oils of three plant species *Citrus aurantifolia, Anthemis nobile and Lavendula officinalis* were evaluated for their in vitro egg hatching, larval development and adult worm motility using different concentration against *Haemonchus controtus* showed a significant antihelminthic activity (Ferreira et al 2018). The essential oil of *Albizia adiantifolia* isolated from leaves, stem, bark and roots have oxygenated mono terpenes. The anti helminthic activity of this essential oil was confirmed by using it against *E eugeniae* worm which showed a relatively higher activity as compared to albendazole an antihelminthic drug in concentration dependent manner (Akande et al 2018).

Antiviral property: Aromatic medicinal plants yield natural essential oils which exhibit exceptionally good antiviral properties (Reichling et al 2009). These antiviral activities are basically inhibition of viral replication attributed to the presence of monoterpenes, sesquiterpenes and phenylpropanoids. Herpes virus was inactivated by Eucalyptus and Thyme oils (Schnitzler et al 2001). The reoccurrence of herpes viral infections was significantly treated with *Meleluca alternifolia* (Carson et al 2001). It acts on the viral envelope structures so that adsorption into the host cell is prevented. Oregano oil exerts antiviral activity against yellow fever (Meneses et al 2009). The essential oils basically inhibit gene expression and thus prevent viral infections. *Artemissia arborescence* shows its activity against Herpes simplex virus type-1 (HSV-1) (Sinico et al 2005). The essential oil of *Melissa officinalis* L is composed of mainly of citral and citronellal (Allahverdiyev et al 2004) which inhibit the replication of HSV-2. The Lemon grass essential oil has potent anti-HSV-1 activity which inhibits viral replication. *Mentha piperata* shows virucidal activity against HSV-1, HSV-2 and acyclovir resistant strain of HSV-1 (Schuhmacher et al 2003). The essential oil of *Eryngium* species exhibits the antiviral activity on cucumber mosaic virus which affected *Chenopodium* (Dunkić et al 2013). In South East Asia Japanese encephalitis is a viral disease caused by Japanese encephalitis virus (JEV) and transmitted through *Culex* sp. of mosquito. The essential oil of *Trachyspermum ammi* (Ajwain) in vitro showed the antiviral effect on JEV (Roy et al 2015). A blend of *Eucalyptus globatus* and *Cinnamon zeylanicum* essential oil shows antiviral activity (Astani et al 2011; Vimalanathan and Hudson 2014) which was H1N1 and HSV-1. The essential oil of *Zataria multiflora* (Lamiaceae) exhibits antiviral effect on Newcastle disease virus (NDV) which causes Newcastle disease of poultry by cytotoxicity (Mohammadian et al 2015). The essential oil of Eucalyptus contains 1, 8 cineole and beta- caryophyllene interfere with virion envelope and hence limiting its entry in host cell (Amandine et al 2017). The antiviral property of essential oils is still to be evaluated.

CONCLUSION

This review summarizes the therapeautic and immunomodulatory properties of major bioactive compounds found in the essential oils. The various bioactivities attributed to different plant essential oils discussed above make them important natural products to be researched on. These essential oils are found to be safe as food preservatives as they domot posses any side effects on human health. The therapeautic properties encourage to utalize them as medications and in beauty care products.

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