Chapter – 1

ESSENTIAL OILS - AN OVERVIEW
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Introduction

Essential oils are highly volatile substances isolated by a physical method from plant material containing odorous constituents\(^1\). They are fragrant smelling liquids and also known as ethereal oils. Volatility, plant origin and fragrant smell are characteristic features of essential oils. These oils are termed “essential” because they were thought to represent the very essence of odor and flavor. The oil bears the name of the plant from which it is derived, e.g., rose oil, peppermint oil and vetiver oil etc.

History is witness to the fact that centuries ago, it was known that flowers, fruits, leaves, bark and roots of many plants contain large number of volatile odoriferous substances which can be isolated by gentle heating of plant portion. These oils are well known to mankind and have played a significant role in human life for centuries. Egyptians were skilled perfumers over 5,000 years ago, they taught the art of perfumery to the Hebrews. Nearly, 3,000 years old tombs of some kings of India, Persia and Egypt belonging to 20\(^{th}\) and 21\(^{st}\) dynasty were found to emit perceptible odor of certain aromatic grasses. One of the commonest essential oil, “Oil of turpentine” was known to ancient Greeks, and for more than two thousand years the odoriferous principles from plants have been an important occupation which has been developed in modern times into a large industry. The use of essential oils in the form of perfumes, spices and flavoring agent is probably as old as human civilization itself.
The essential oil industry in India dates back to the reign of mughal king Jehangir with his queen Noor-i-Johan as the discoverer of Otto of rose flowers. The industry developed so much that India acquired a prominent position as a supplier of sandalwood oil, vetiver oil, lemongrass oil, palmarosa oil and gingergrass oil. The old Indian essential oil industry remained largely indifferent to the scientific developments and consequently, resulted in the gradual fall in its production and importance.

India is very rich in aromatic plants due to wide range of soil and climatic conditions. After independence, there has been remarkable development in Science and Technology which resulted in revival and revitalization of essential oil industry also. With a view to exploit the potential of essential oils on a commercial scale, research work on a modest way was initiated. Due to these efforts essential oil industries based on sandalwood oil, turpentine oil, lemongrass oil, palmarosa oil and vetiver oil were established. Under the guidance of CIMPO, work on cultivation, processing and chemical investigation of medicinal and aromatic plants was started successfully. In 1972, the Indian Council of Agriculture Research initiated approved All India Co-ordinated Research Project for the improvement of medicinal and aromatic plants for promoting research on several aspects of crop production.

Now, India is the only one country in the Asian region that has a recognized industry producing perfumes, cosmetics, flavoring agents, synthetic aromatic chemicals and related formulations. The essential oil industry is supported by a strong R and D base. In addition, a few of the notable private manufacturers of essential oil fragrances possess their own R & D laboratories. The progress made by the Indian essential oil industries during the last decades owes much to these private laboratories as well. The activities in these laboratories include:
I. Commercial scale synthesis of many aromatic chemicals.

II. Quality control of products using instrumentation and organoleptic methods.

III. Literature searches on new synthetic methods with an eye on development of further synthesis employing basic chemicals produced in India.

IV. Fractionation of essential oils and preparation of isolates.

V. Compounding of perfumes and flavors and marketing them on worldwide basis.

Formation of essential oils

Usually a perfume is a complex mixture of naturally and synthetically produced chemical substances which are blended together to produce a typical odor. The most common ingredients of the perfumes are essential oils. In plants essential oils are formed in glands or special cells or between the cell-wall and cuticle of epidermal hairs, where the slightest breakage of the cuticle permits volatilization and brings out the characteristic fragrance. Glands frequently appear as translucent dots in leaves or tissues (termed pellucid punctuate) when viewed against light. Age, growth and climatic conditions affect the frequency of glands and quantity of essential oils contained in plant tissues.

The extensive research work on the composition of essential oils has shown that various environmental and climatic factors affect the development, yield and composition of essential oils. Fluck et al\(^2\) by studying the effect of altitude and climate on the development of essential oils in plants like Thymus vulgaris, Mentha piperita in the valley of Arosa having research studies at 600, 940, 1250, 1460 and 2600 meter heights showed a clear decrease(with an increase at 940m) in the essential oil content in the plants.
Water occurs in the form of rainfall, humidity as well as moisture. Boshartz’s experiments at nine centers during three years showed that both low and very high rainfall causes a reduction in the essential oil of peppermint. “Diurnal variation” also affects the essential oil contents in plants. Schib in case of Salvia officinalis showed maximum content of oil (34-35%) occurred in four different days in the early afternoon and minimum between midnight and early morning. However, in case of Mentha piperata, Tschivikow observed higher yield of essential oil during night. Rombaux and Laruella, Blasok and Hubik, Michaluk and Cswisainska detected maximum yield of azulenogenic substances at noon in the oil of Matricaria chamomilla.

Schib has reported that essential oil formation is enhanced in the plant at higher temperature. Peach also observed that in case of Asarum europaeum, exposure to higher temperature induced the formation of new excreting cells with the increase in the quantity of essential oils. However, it has been observed that on very hot days, shaded plants may have higher essential oil content probably due to evaporation or resinification of oil in the exposed plants.

**Biological functions and commercial uses of essential oils**

In plants, function of essential oils is apparently to attract insects necessary for pollination by their pleasing odor, or to repel hostile insects and animals by their acrid taste. Besides this, they protect the plants from microbial invasion causing various diseases. This significant property led to their application as therapeutic agents for human beings. Essential oils are used in commercial scale in following areas.
I. Perfumery, cosmetics, household and personal hygiene products either
directly as major or minor ingredients of fragrances or as raw materials for
extraction of aroma chemicals.

II. Food, drinks/ beverages and confectionery as flavoring agents.

III. Human and veterinary health care as components of pharmaceutical
preparations.

IV. Crop protection as pesticides and insect repellents.

V. Culinary as fresh or dried herbs, spices and condiments.

Use of essential oils has increased greatly over the last few years. Recent
upsurge of interest in herbal products has virtually swept the world by a “green
wave”. Consequently, the demand for essential oils of herbal origin has
tremendously gone up, which has decisively changed the trade scenario in the
international market.
Some common essential oils used in perfumery

A brief introduction of few commonly used essential oils is being given here.

Lavender oil: This oil is obtained by the process of steam distillation from the flowers of Lavandula vera. Its major components are linalool and linalyl acetate. English lavender has a distinct and special odor due to its relatively low ester content and consequently, commands a high price.

![Linalool](image1)

![Linalyl acetate](image2)

Jasmine oil: This oil, from Jasminium grandiflorum is obtained by the technique of solvent extraction. The mature jasmine flowers are usually extracted with petroleum ether. Subsequently, the solvent is removed by distillation leaving behind jasmine concrete, a waxy reddish-orange mass, which contains substantial quantities of waxes.

However, jasmine is usually used in the form of jasmine absolute. To convert the concrete into absolute, the former is repeatedly washed in warm alcohol. The insoluble waxes are removed and the alcoholic solution is then chilled, filtered to remove any precipitate and finally the alcohol is removed by gentle heating under
reduced pressure. This alcohol soluble material is known as jasmine absolute. It contains the most valuable constituents. It is a dark orange viscous material having an intensely floral, slightly waxy odor. One tone of jasmine blossom, which contains 6 to 8 million hand picked flowers, yield 2.7 kg of the concrete which subsequently produces 1.4 kg of absolute- hence the high cost of the product.

Tuberose oil: Polyanthos tuberose is the source of this oil and its extraction involves the enflleurage process. During the process the flowers are laid on a large tray of fat which absorbs the oil. Up to 36 batches, each involving 24 hours treatment are carried out on the same layer of fat. The oil saturated fat, the pommade, can be considered as being equivalent to concrete. It is subjected to alcohol extraction to get the tuberose absolute which is soft brown paste possessing a sweet honey floral odor.

Rose oil: Rose petals (Rosa damascene, etc.) are subjected to steam distillation. The distillate separates into two phases, the direct oil and rose water, which is than redistilled or cohabated; the large volume of oil which separates from this second distillation, the rose water is then mixed with the oil from first distillation to produce rose otto. This peculiar behavior is caused by the solubility of the so-called rose alcohols - geraniol, citronellol and phenylethyl alcohol.
Citrus oils: These oils are produced from peels of the citrus fruits by a technique known as expression, in which the peel is crushed to break the walls of the oil-bearing cells. Lemon oil, orange oil and lime oil are examples of the citrus oils. Citrus aurantium var amara is a particularly interesting species. Its fruit is the Seville orange whose peel is expressed to give bitter orange oil; flowers are utilized, using steam distillation to produce orange flower oil better known as neroli oil. Further more the leaves and twigs are used to make petitgrain bigarade oil. Clearly a single species is capable of producing more than one essential oil of economic importance.
Chemical composition of essential oils

Essential oils are a complex mixture of acyclic, alicyclic, aromatic and hetrocyclic compounds. Most of the compounds are monoterpenoids, sesquiterpenoids, phenylpropanoid, and benzenoid compounds. Fatty acid derivatives and a range of other chemicals, especially those including nitrogen and sulphur are also sometimes present. All these compounds are regularly defined as secondary metabolites. Monoterpenes such as linalool, limonene, myrcene and trans – β-oicimene, some sesquiterpenes, such as fernasene, nerolidol, and also some phenylpropanoids such as eugenol, methyleugenol and methylcinamate, are very common constituents of essential oils. Structures of some common constituents are given below.
Lars Tollesten and L. Gunnar Bergstrom published an excellent review summarizing over 700 compounds present in the essential oils of 60 families of plants\textsuperscript{11}.

The terpenoid compounds present in essential oils are composed of isoprene units (C-5). Based on these, classification was made as shown in Table 1\textsuperscript{12}.

**Table 1. Classification of terpenoids**

<table>
<thead>
<tr>
<th>Name of Class</th>
<th>Number of isoprene units</th>
<th>Number of Carbon atoms</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monoterpenoids</td>
<td>2</td>
<td>10</td>
<td>pinene, ocimene, limonene, citral, geraniol, linalool, camphor, menthol.</td>
</tr>
<tr>
<td>Sesquiterpenoids</td>
<td>3</td>
<td>15</td>
<td>caryophyllene, germacrene, cadinene, longifolene, santalol, aromodendrene, cedrol, thujopsene, farnesol, patchouli alcohol.</td>
</tr>
<tr>
<td>Diterpenoids</td>
<td>4</td>
<td>20</td>
<td>abietic acid, prodocarpic acid, labdanolic acid, selreol, pimarinol, devadarool, ginkolide.</td>
</tr>
<tr>
<td>Sesterpenoids</td>
<td>5</td>
<td>25</td>
<td>geranyl, farnisol, nerolidol</td>
</tr>
<tr>
<td>Triterpenoids</td>
<td>6</td>
<td>30</td>
<td>squalene, panaxatriol, jasminol</td>
</tr>
<tr>
<td>Tetraterpenerids</td>
<td>8</td>
<td>40</td>
<td>carotienes, lycopene</td>
</tr>
</tbody>
</table>

Isoprene units (C-5) are mostly attached to each other in head to tail fashion in above examples; hence they follow the Isoprene rule. Some compounds present in essential oils do not follow the isoprene rule, examples are agarospirol, hinesol, valencene, α and β- vetivones, chamigrene and many others. Large numbers of other
compounds which are not related with isoprene units have also been reported to occur in essential oils. The formation of these compounds follows different biogenetic pathways. The prominent examples of such compounds are benzaldehyde, benzyl alcohol, benzylacetate, benzylbenzoate, benzyliclylate, methylsalicylate, methyl cinnamate, cinnamaldehyde, cinnamyl alcholol, cinnamyl cinnamate, methylchavicol, eugenol, isoeugenol, eugenylacetate, isoeugenylacetate, methyleugenol, methylisoeugenol, vanillin, anisaldehyde, anethole, asarone, elemicin, dillapiole, apiole, safrole, chavibetol etc.

Nineteen sulphur compounds have been detected by Yomogida et al in various rose oils\textsuperscript{13}. similarly many nitrogen compounds such as guaiol pyridine, dihydroguaiol pyridine, guaipyridine, epiguaipyridine and patchouli pyridines in patchouli oil; methyl-N-methylanthranilate in citrus oil, indole in rose oil and pyrazine and pyridine derivatives in palmarosa oil. Thus, characterization of such trace components in essential oils has contributed to their specific role in perfumery and flavor products.

There has been a considerable interest in the chemistry of terpenoids and it is well evident in literature\textsuperscript{14-29}.
Chemical Research

Chemical research on essential oils has concentrated on the isolation and characterization of important and unusual odorous constituents. A classic example of the former is rose oxide a terpenoid ether first characterized in Bulgarian rose oil in 1959\textsuperscript{22}. This compound has a penetrating diffusive grassy green odor and is much used in soap perfumery. Regarding novelty, a series of substituted alkylalkyloxypyrazines were isolated from galbanum oil, some of which demonstrated an extremely low threshold value (1 part in $10^{12}$). Subsequently, these compounds have become important perfume and flavor ingredients\textsuperscript{23}.

\begin{center}
\begin{tikzpicture}
\node (rose) at (0,0) {Rose oxide};
\node (alkylalkyloxypyrazine) at (3,0) {Alkylalkyloxypyrazines};
\end{tikzpicture}
\end{center}
Essential oils have thoroughly been investigated for their chemical constituents. Hydrocarbons have been reported to be present in the oil of citrus and conifer. In some essential oils lactones have been found as active constituents. The presence of polacetylenes, aliphatic alcohols and aldehydes have been identified in some biologically useful essential oils.

During the last decade more than one hundred research papers are published which describe antimicrobial properties of new essential oils obtained from plants growing in Asian, African and South American countries. Many essential oil components are chiral compounds. The enantiomers usually show quite different biological activity. Reports on comparison of biological activity of the enantiomers seem to be quite scanty. 18 Out of 25 different bacteria and two out of three filamentous fungi were found to be more affected by the (+) – pinene than by its (-) – enantiomer. The activities of both optical isomers of carvone and limonene were comparable.

Synthesis from isolates

Turning to other class of compounds used in perfumery industry, the synthetic aroma chemicals, the simplest examples are isolate-products obtained from natural raw materials by either physical or chemical methods. The most commonly used physical method for preparation of an isolate is fractional distillation: when this technique is applied to lemongrass oil or Litsea cubeba oil, good yield of the terpene aldehyde citral can be obtained.
At one time citral was widely used for its fresh lemon odor but it lacks stability and consequently, its main important use today is as a synthetic intermediate. As shown in Scheme 1, citral is used for the synthesis of ionones. β-Ionone is used for the synthesis of vitamin A, while α-iso-methylionone is perfumery preferred compound.
Scheme 1. The Synthesis of Ionones

Citral (Isolate of lemon grass oil) + Ketone → Pseudo Ionone

\[
\text{Citral} \quad \text{Psedo ionone} \quad H_2SO_4 \quad \beta - \text{Ionone}
\]

\[
\alpha - \text{Ionone}
\]

\[
\text{Psedo - n - methylionone} \quad \text{Psedo - iso - methylionone}
\]

\[
\alpha - n - \text{Methylionone} \quad \beta - n - \text{Methylionone} \quad \alpha - \text{iso - Methylionone} \quad \beta - \text{iso - Methylionone}
\]

\[
\text{Methyl ethyl ketone}
\]

\[
H_3PO_4 \quad H_2SO_4
\]
Another valuable isolate obtained in contrast by a chemical process, is eugenol, a major component of clove oil. Eugenol’s phenolic character permits the formation of sodium salt that can be easily separated from the hydrocarbon constituents of the oil. Additionally, this intermediate can be treated in a variety of ways to yield close analogues such as methyleugenol and methylisoeugenol which were not previously available to perfumers (Scheme 2).
Scheme 2.
Synthetic terpenes

One example of synthesis of terpenes from essential oil constituents is as follows.

α-pinene and β-pinene are the major constituents of oil of turpentine. On hydrogenation these compounds produce pinane which is then oxidised with air or oxygen to yield pinane hydroperoxide. This compound is reduced to the corresponding alcohol, pinanol, which on pyrolysis then yields the key terpene alcohol, linalool, much used because of its floral, woody odor with citrus notes.

Allylic transposition of the hydroxyl group produces geraniol-nerol mixture that have mild, sweet floral rosaceous odor and are also used extensively. The oxidation of these primary alcohols yields citral (geranial-neral mixture) which has been shown to be key intermediate in the preparation of ionones. Reduction of the conjugated double bond of citral produces citronellal, not important as a perfumery material but vital for the manufacture of menthol, a major constituents of toothpaste and other flavors. The cycle is completed by citronellol widely used for its light, floral, rosy odor. The above mentioned synthetic approach is depicted in Scheme 3.
Scheme 3. A synthetic route to the terpenes

\[
\begin{align*}
\alpha - / \beta - \text{Pinene} & \quad \rightarrow \quad \text{Pinane} & \quad \rightarrow \quad \text{Pinanol} \\
\text{Dehydroinalool} & \quad \rightarrow \quad \text{Linalool} & \quad \rightarrow \quad \text{Linalyl esters} \\
\text{Citral} & \quad \rightarrow \quad \text{Geraniol} / \text{Nerol} & \quad \rightarrow \quad \text{Geranyl} / \text{Neryl esters} \\
\text{Citronellal} & \quad \rightarrow \quad \text{Citronellol} & \quad \rightarrow \quad \text{Hydroxyacetronellol} \\
\text{Menthol} & \quad \rightarrow \quad \end{align*}
\]
Biosynthesis of essential oils

The genetics and biochemistry of biosynthesis of essential oils is reasonably well understood in some cases. For example, it is known that limonene is synthesized from geranyl pyrophosphate in the oil glands of mentha spp. and something of the genetics of this conversion is understood. Further, it is known that various oxygenated derivatives of limonene that make up the remainder of the mentha oil are synthesized from limonene by microsomal preparation from oil glands, which show cytochrome P-450-type mixed function oxygenase activity.

The presence of essential oil biosynthetic enzyme in flower tissues was demonstrated for the first time only in 1994 by Eran Pichersky at the University of Michigan, US\textsuperscript{30}. Two years later the same laboratory isolated the gene that codes for the enzyme linalool synthase, which catalyses the formation of common essential oil constituent linalool, from Clarkia breweri, a sweet smelling wild flower native to California. Thereafter, Pichersky and coworkers identified and characterized a further three enzymes, and their corresponding genes responsible for the synthesis of methylisoeugenol, benzylacetate and methylsalicylate\textsuperscript{31}. Although, several genes coding for enzymes involved in flower color development had previously been isolated from snapdragon, virtually nothing was known about mechanism of essential oil biosynthesis. N. Dudareva et al\textsuperscript{12}, Purdue University, identified 8 to 10 volatiles among 37 different Antirrhinum majus (snapdragon). Among major components of the essential oil are two monoterpenes, myrcene and trans-β-ocimene and a phenylpropanoid volatile ester, methylbenzoate. Of these, the sweet smelling methylbenzoate was the most abundant essential oil constituents detected in most snapdragon varieties. Subsequently, these workers isolated and characterized
the gene codes for S-adenosyl-L-methionine, benzoic acid carboxyl methyltransferase (BAMT), the enzyme that catalyses the formation of methylbenzoate by transferring the methyl group of S-adenosyl-L-methionine to a free carboxylic group of benzoic acid (Scheme 4)\textsuperscript{32}.
Scheme 4. The biosynthesis of Methylbenzoate with BAMT

L-Phenylalanine → trans-Cinnamic acid → Benzoic acid → Methylbenzoate
Quality evaluation of essential oils

Despite the continuing invention of synthetic aroma chemicals, essential oils still remain the most important part of fine fragrances. Large number of components of essential oils are generally referred as safe (GRAS) in comparison to synthetic ones. Several numbers of essential oils are available now a days for use in perfumery and flavor. Therefore, it is important to adopt methods for quality evaluation of essential oils or their isolates. This involves two way approaches:

I. Determination of Physico-Chemical constants

Physico-Chemical constants come under wet methods, which are necessary requirement for quality evaluation of essential oils or their isolates. These are compared with those of standard commercial samples, specified by different organizations like International Organization for Standardization (ISO), Essential Oil Association (U.S.A), Bureau of Indian Standard (BIS), French Standards, Australian Standards, and others. Various physico-chemical methods which are generally used are as given below.

i. Appearance  
ii. Color  
iii. Odor / Flavor  
iv. Specific gravity  
v. Refractive index  
vi. Optical rotation /specific rotation  
vii. Acid number  
viii. Ester number  
ix. Ester number after acetylation  
x. Alcohol content – free, combined and total  
xi. Carbonyl value / content  
 salty. Phenol content  
xiii. Heavy metals  
xiv. Residue on evaporation  
xv. Petroleum and mineral oils  
xvi. Freezing / congealing / melting points
II. Analysis by instrumental methods

Every essential oil has one or two major chemical components (cyclic or acyclic monoterpenes) for example, citral in Cymbopogon flexuosus (lemon grass), geraniol in C. martini (palmarosa), menthol in Mentha arvensis (Japanese mint) etc. are the major components in the respective oils. Besides, many minor and trace components are also present in specific concentrations or proportions. To name a few, limonene, myrcene etc in lemon grass; geranylacetate, citronellol, linalool etc. in palmarosa; menthylacctale, menthone, pulegone etc. in Japanese mint; and so on. All these major and minor components in their respective orders constitute the chemical composition or chemical profile of the oil. It is this naturally balanced chemical profile of oil that characterizes its typical odor value and quality. Thus quality of oil is ascertained on the basis of its chemical composition which is determined by various instrumental techniques. These techniques are of two types.

Chromatographic techniques:

These include column chromatography (CC), Thin-Layer chromatography (TLC), Gas-Liquid chromatography (GLC or GC), High pressure liquid chromatography (HPLC) etc.

Spectrometry and Combined techniques:

These techniques are Infrared spectrometry (IR), Nuclear magnetic, resonance spectrometry (NMR), Mass spectrometry (MS), Gas chromatography - mass spectrometry (GC-MS) etc.

Thus, the quality assessment of an essential oil entails multifarious analyses. The first and simplest analysis is conducted by sensory organs (nose–sniffing), which defines its specific smell or odor and aesthetic value. Perhaps no other tests
based on sophisticated instruments (even the computerized super nose) can replace the sensory and aesthetic requirements of the oil quality. However, the first step in quality control commences right with the “herbiculture” i.e. production and post-harvest management of essential oils.

Present Work

From the foregoing account it is evident that the chemistry of essential oils has gained a wide attention since the ancient times due to their wide use in various areas such as perfumery, cosmetics, flavoring agents, pharmaceutical preparations and crop protection as pesticides and insect repellents etc. There is continued interest in this area and consequently, various reputed research centers throughout the world are engaged in research activities related with chemistry, biology and therapeutic properties of essential oils as indicated by some quality publications in recent years33-83.

These facts generated an interest to undertake the present work which is related with chemical investigation of essential oils. For the extraction of essential oils following plants were selected from Garhwal region.

1. Artemisia dracunculus L. (Family: Asteracea)
2. Skimmia laureola Hooks (Family: Rutaceae)
3. Ocimum gratissimum Linn. (Family: Labiatae)
4. Rosa brunonii L. (Family: Rosaceae)

These plants grow wildy in Garhwal region and are used as herbal medicines in several ailments by local people. The chemistry of essential oils varies
depending upon time of day and year, part of plant distilled, variety of plant, soil and climate. Change of climate, place and various other relevant parameters makes a remarkable effect on yield and chemical composition of essential oils\textsuperscript{54}. Due to favorable soil and climatic conditions, Garhwal region is a treasure house of aromatic and medicinal plants but these plants gained very little attention for extraction and chemical investigation of essential oils\textsuperscript{34,38,41}.

**Extraction of essential oil**

In case of *Rosa brunonii* flowers were used for extraction of essential oil. While essential oil of *Ocimum gratissimum* and *Artemesia dracunculus* were extracted from aerial parts. Leaves were used for extraction of essential oil from *Skimmia laurcola*. For extraction of essential oil in each case the method of hydrodistillation was used employing Clevenger type apparatus.

**Determination of Physico-chemical properties**

Essential oils of all the four plants were dried over anhydrous sodium sulphate and subjected to physico-chemical analysis for determination of various properties such as specific gravity, refractive index, optical rotation etc. using the usual method available in the literature. For evaluating the quality of these oils the results of physico-chemical analysis may be taken into account.

**Chemical investigation of essential oils**

Chemical investigation of all above mentioned essential oils was carried out by GC, GC/MS analysis. The essential oil of *Artemesia dracunculus* was found to contain 59 constituents, comprising 91.08% of the oil. The essential oil of *Skimmia*
laureola and Ocimum gratissimum L. on analysis indicated the presence of 37 compounds (86.33% of the total oil) and 34 compounds (92.27 % of the total oil), respectively. The number of compounds identified in the oil of Rosa brunonii is 64 which are 91.18 % of the oil. The major constituents found in these oils are given in the Table 2.

Table 2. Major constituents of essential oils

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of the oil</th>
<th>Major constituents with percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Artemisia dracunculus</td>
<td>1,8-cineole (17.90), camphor (16.22), 4-terpineol (7.71), α-terpinolene (8.81), p-cymene (4.29)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>α-carvone (2.81%), and phellandral (2.79%)</td>
</tr>
<tr>
<td>2.</td>
<td>Skimmia laureola</td>
<td>linalyl acetate (26.40), L- linalool (14.18), β-phellandrene (9.03), prejeijerene (7.06),</td>
</tr>
<tr>
<td></td>
<td></td>
<td>α-terpineol(6.25),geranylacetate(3.89) and myrcene(2.18).</td>
</tr>
<tr>
<td>3.</td>
<td>Ocimum gratissimum</td>
<td>eugenol (32.86%), α-terpinolene(22.83%),cis-8-methylbicyclo(4,3,0)-none-3-ene (9.08%),</td>
</tr>
<tr>
<td></td>
<td></td>
<td>camphene (2.65%), α- phellandrene (2.2%), and α- pinene (1.02%).</td>
</tr>
<tr>
<td>4.</td>
<td>Rosa brunonii</td>
<td>germacrene-D (9.05), iso-eugenol (7.36), heneicsane (7.19), 9-nonadecane (6.88),</td>
</tr>
<tr>
<td></td>
<td></td>
<td>geranial (6.27), α-pinene (5.24), tricosane (5.07), β- carophyllene (3.05) and heptacosane(2.52%).</td>
</tr>
</tbody>
</table>
Antimicrobial activity of essential oils

Higher plants have been exploited as a source of biologically active compounds since antiquity. In particular, the ability to inhibit the growth of spoilage and food poisoning bacteria, human and animal pathogens and a number of filamentous fungi has been of immense importance to man over the centuries.\textsuperscript{82, 83} It is worth noting that even in modern world of today 25% synthetic and semi-synthetic antibiotic pharmaceutical preparations contain at least one component originating from plant sources. In many plants exhibiting biological actions, the greatest antimicrobial power lies with the essential or volatile oil fractions. Several research groups all over world are actively engaged in evaluating the essential oils for their antimicrobial properties\textsuperscript{46, 79,84-114}.

Therefore, it was thought worthwhile to evaluate all the four essential oils for their antibacterial and antifungal activities using filter paper disc method. Following bacteria and fungi were taken for the desired study.

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xanthomonas compestis (Xcc\textsubscript{25})</td>
<td>Fusarium oxysporum</td>
</tr>
<tr>
<td>Xanthomonas compestis (Xcc\textsubscript{29})</td>
<td>Fusarium solani</td>
</tr>
<tr>
<td>(Both isolated from cabbage crop)</td>
<td>Macrophomina phaseolina</td>
</tr>
<tr>
<td></td>
<td>Rhizoctonia solani</td>
</tr>
</tbody>
</table>

Results of this study revealed that almost all the oils are having reasonably good antibacterial as well as antifungal activities under in vitro conditions.
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