ANALYSIS OF CINNAMOMUM ZEYLANICUM LEAF ESSENTIAL OIL

CHAPTER 1

ANALYSIS OF

CINNAMOMUM ZEYLANICUM LEAF ESSENTIAL OIL

SECTION I. INTRODUCTION TO ANALYTICAL METHODS

The characterisation of essential oils depends on the resolution power of the analytical tools. Odour or colour comparison was the early method used for the characterisation of essential oils. Later analytical techniques such as specific gravity, refractive index, distillation range, determination of iodine number and gas-liquid chromatography etc. have been employed for the determination of volatile components of essential oils.

GAS CHROMATOGRAPHY (GC)

Gas chromatography is the technique of choice for the separation of thermally stable and volatile organic and inorganic compounds. In gas chromatography, the sample is vapourised and injected onto the head of a chromatographic column. Elution is brought about by the flow of an inert gaseous mobile phase. The mobile phase does not interact with molecules of the analyte, its only function is to transport the analyte through the column. Two types of gas chromatography are encountered: Gas-Solid Chromatography (GSC) and Gas-Liquid Chromatography (GLC).
Gas-liquid chromatography accomplishes the separation by partitioning the components of a chemical mixture between a mobile gas phase and a stationary liquid phase held on a solid support. Gas-liquid chromatography finds widespread use in all fields of science, where its name is usually shortened as Gas Chromatography (GC). This powerful tool finds application in analyses of varied types – gases and pollutants, petroleum and petrochemicals, oils and fats, foods and flavours, alcohols and beverages, drugs and vitamins, steroids and alkaloids, blood and serum, proteins and lipids, pesticides and fungicides, radioactive isotopes, elemental organic analysis and a number of miscellaneous purposes.

Gas-solid chromatography uses a solid adsorbent as the stationary phase. Here the retention of analytes is the consequence of physical adsorption. Due to the nonlinear character of adsorption process, this technique has not found wide application except for the separation of certain low molecular weight gaseous species.\(^1\)

The principal advantages of gas chromatography to an analyst are

(i) The technique has strong separation power and even quite complex mixtures can be resolved into constituents.

(ii) It is a micro method and only a few milligrams sample is enough for analysis and the sensitivity of the method is very high.
(iii) The speed of analysis is quite fast and gives good precision and accuracy.

(iv) It involves relatively simple instrumentation; operation of a gas chromatograph and related calculations do not require highly skilled personnel and thus the technique is very suitable for routine analysis. The cost of equipment is relatively low and its life is generally long.

COMPONENTS OF A GAS CHROMATOGRAPHIC SET UP

Carrier Gas Supply

Carrier gas should be chemically inert; include helium, nitrogen and hydrogen. Choice of the gas depends on the detector used. The main purpose of this carrier gas is to transport sample components through the column. It should not interact with samples, stationary phase or contacted hardware. Its purity is very important since impurities may react with the sample components or the stationary phase and change the retention behaviour of the substrate. This may result in high background signal and reduction of detector sensitivity.

Column

Column is said to be the heart of a GC system. Remarkable separation takes place in this magic tube. Two basic types of columns which generally used are packed column and the open tubular or capillary column. Packed columns are constructed from tubing of stainless steel, nickel or glass. Inner diameters may
range from 1.6 to 9.5 mm. Length is often 3 m. These columns are packed with an inert support. For gas-solid chromatography the columns are packed with size graded adsorbents or porous polymers whereas for gas-liquid chromatography the packing is prepared by coating the liquid phase over a size-graded inert solid support. Unlike gas-solid chromatography, gas-liquid chromatography is applicable to high molecular weight compounds since gas to liquid mass transfer rates are fairly high and separations are achieved in less time. Further, due to linear gas-liquid partition isotherms, the elution bands are symmetrical showing no tailing; this helps in both qualitative and quantitative analyses and enhances the sensitivity of the technique. Also here the choice of liquid phases is wide open and the quality of liquids could be much more reproducible than that of adsorbents. Liquid phases are classified into the following groups:

a. **Non polar**: Such phases do not have any polar or polarisable groups.

eg: hexadecane, squalane etc.

b. **Polar**: These phases contain significant proportion of polar groups and retain selectively polar or polarisable solutes. Non polar solutes are eluted quickly in one group.

eg: dimethylsulpholane, versamid-900 etc.
c. **Intermediate**: This kind of liquid phases contain relatively low proportion of polar groups and dissolve both polar and non-polar solutes with slightly more affinity for polar ones.\(^\text{18}\)

eg: didecylphthalate, benzylbiphenyl etc.

d. **Hydrogen Bonding**: In this group liquid phases involve in H-bonding type interactions with solutes.

eg: Diglycerol, tetrahydroxyethylethylene diamine (THEED) etc.

e. **Specific**: There are some stationary phases which interact with specific groups of solutes forming loose chemical complexes and are employed for specific separations only. eg: Tetracyanoethylpentaerithritol (TCEPE) is somewhat superselective for aromatics; on this phase benzene elutes out after \(C_{10}-C_{13}\) saturated hydrocarbons.

**Capillary Columns**

Capillary columns have an internal diameter of 1 mm or less. These are usually constructed of fused silica (a very high-purity glass) which has a much higher degree of cross linking within the silicon-oxygen matrix, than does ordinary glass. Capillary columns are of two types; wall-coated open tubular (WCOT) and support-coated open tubular (SCOT). WCOT columns are capillary tubes coated with a thin layer of the stationary phase. In SCOT columns the inner surface of the
capillary is lined with a thin film (≈ 30 μm) of a support material, such as diatomaceous earth. The efficiency of a SCOT column is less than that of a WCOT column but significantly greater than that of a packed column. 18

**Detectors**

A detector located at the exit of the separation column, senses the presence of the individual components as they leave the column. The detector volume must be small to prevent the remixing of components separated on the column.

**Thermal Conductivity Detector (TCD)**

In TCD a heated filament is placed in the emerging gas stream. The amount of heat lost from the filament by conduction to the detector walls depends on the thermal conductivity of the gas phase.

**Flame Ionisation Detector (FID)**

The FID detector adds hydrogen to the column effluent. Subsequently the mixture is passed through a jet where it is mixed with external air and burned. This detector is the most widely used and generally applicable detector for gas chromatography. When ionisable material from the column effluent enters the flame and is burned, the current markedly increases. The current flowing through an external resistor is sensed as a voltage drop, amplified and finally sent to a
The FID responds proportionately to the number of \(-\text{CH}_2-\) groups introduced into the flame.

Thermionic Emission Detector (TED), Sulphur-Chemiluminescence Detector (SCD), Electron Capture Detector (ECD), the Flame Photometric Detector (FPD), the Photo-Ionisation Detector (PID) are the other detectors which are used in gas chromatography.

**Some Basic Parameters and Relationships in GC**

*Retention Time (t<sub>R</sub>)*

It is the time lapsed between sample introduction and appearance of peak maxima.

*Gas Hold up Time (t<sub>M</sub>)*

It is the retention time of a solute (usually air) that has no affinity for the stationary phase.

*Adjusted Retention Time (t<sub>'R</sub>)*

It is the difference between retention time and gas hold up time.

\[ t'_{R} = (t_{R} - t_{M}) \]
**Retention Volume** ($V_R$)

Retention volume of a component is the volume of gas to carry a component maximum through the column

$$V_R = t_R \cdot F_c$$

where $F_c$ is the volume flow rate of the gas outlet corrected to the temperature of the column.

**Adjusted Retention Volume** ($V'_R$)

It is the difference between retention volume and hold up volume.

$$V'_R = V_R - V_M$$

$$V_M = t_M \cdot F_c$$

$$V'_R = (t_R - t_M) F_c$$

Subscripts $R$ and $M$ refer to species that are retained and not retained on the column.

Gas chromatography is essentially an analytical technique commonly used for qualitative analysis by comparing the retention data of the analyte with those of the compound which it is thought to be. Simple retention times are not very reproducible and it is better to use relative retentions or retention indices. The most useful system of retention indices is the one due to Kovats. It takes advantage of
the linear relation between the logarithms of the adjusted retention times of a
homologous series (n-alkanes) and the number of carbon atoms in the molecules.
The n-alkanes are used as the reference compounds because of their stability, ready
availability, low cost and wide range of boiling points. The retention of any analyte
is compared with the two n-alkanes which elute nearest to it. The adjusted retention
time of the analyte is measured at the same time as those of n-alkanes which elute
in front and behind it (containing 'Z' and 'Z+1' carbon atoms respectively) and the
retention index of the analyte I is then defined by

\[ I = 100 \left( \frac{\log t'_{R} (\text{subst}) - \log t'_{R} (n-Cz)}{\log t'_{R} (n-Cz+1) - \log t'_{R} (n-Cz)} + Z \right) \]

For n-alkanes the term \( \log t'_{R} (\text{subst}) - \log t'_{R} (n-Cz) \) reduces to zero and they have
retention indices equal to the number of carbon atoms in the molecule multiplied by
one hundred. A systematic method for expressing retention data used the Kovats
retention indices \( R_{l} \).\textsuperscript{19} The indices indicate where compounds will appear on a
chromatogram with respect to straight chain alkanes injected with the sample. By
definition the retention index for a normal paraffin is 100 times the number of
carbon atoms in the compound regardless of the columns used or the
chromatographic conditions. Thus the Retention index for pentane is 500, for
hexane 600 and so on. Of course, the type of column and the operating conditions
such as liquid loading and any pre-treatment must be specified.
Hyphenated Techniques

Gas chromatography is often coupled with the selective techniques of spectroscopy, thus giving so-called hyphenated methods that provide the chemist with powerful and pragmatic tools for identifying the components of complex mixtures. Gas Chromatography - Mass Spectrometry (GC-MS) and Gas Chromatography - Infrared Spectroscopy - Mass Spectrometry (GC-IR-MS) are the modern analytical methods used for the separation and identification of components of essential oils. Using these hyphenated techniques, identification of even trace components has become possible. The Fourier-Transform GC-IR, high resolution GC-MS and chemical ionisation GC-MS are more powerful and selective characterisation tools for the structure elucidation of components of oils. When we use GC-MS, the mass spectrometer is a universal detector for gas chromatographs since any compound that can pass through a gas chromatograph is converted into ions in the mass spectrometer. At the same time the highly specific nature of a mass spectrum makes the mass spectrometer a very specific gas chromatographic detector. Gas chromatography is an ideal separator whereas mass spectrometry is excellent for identification.

Gas chromatographic equipment can be directly interfaced with rapid scan mass-spectrometers of various types. As with GC-MS the interface between column and the detector is critical. In this instance a narrow light pipe having a length of 10 to 40 cm and an inside diameter of 1 to 3 mm is connected to the
column by means of a narrow tubing. The light pipe consists of a pyrex tube that is internally coated with gold. Often the light pipe is heated in order to avoid condensation of the sample components. Light pipes of this type are designed to maximise the path length for enhanced sensitivity while maximizing the dead volume to lessen band broadening.

The interface must provide the link between the two instruments. Almost all GC-MS interface systems contain an enrichment device. However, the high pumping speeds used in mass spectrometers may permit the total effluent from capillary GC column to be transported to the ion source of the mass spectrometer. When the chemical ionization reagent gas is used as the carrier gas, the effluent can be introduced directly into the mass spectrometer. Since the carrier gas molecules are usually much lighter than those of the sample, they can be removed by an effusion chamber.

The main advantages of a mass spectrometer as a detector for gas chromatography are its increased sensitivity and its specificity in identifying unknown or confirming the presence of suspected compounds.

GC-MS has been used for the identification of hundreds of components that are present in natural and biological systems. For example this procedure has permitted characterization of the odour and flavour components of foods, identification of water pollutants, medical diagnosis based on breath components and studies of drug metabolites.
SECTION II. ANALYSIS OF CINNAMOMUM ZEYLANICUM LEAF ESSENTIAL OIL

INTRODUCTION

The plant *Cinnamomum zeylanicum* belongs to the family Lauraceae. Lauraceae is a family of 45 genera and about 1100 species. Economically this family is important for the aromatic oils that are responsible for the fragrance of many of its members.\(^{20}\) Cinnamon (*Cinnamomum verum* J.S. Presl, Syn. *Cinnamomum zeylanicum* Blume) and Cassia are two of the oldest and most famous spices known to man. Cinnamon, camphor and many fragrant woods are used in cabinet making. Species of about seven genera of the family are cultivated domestically as ornamental plants.

Cinnamon is an evergreen tree whose bark and leaves are found to be more aromatic. Size of the tree is moderate, 8 to 18 m in height and 50 cm in diameter, with reddish brown soft bark having numerous small warts; leaves are ovate or elliptic. Flowers are small in axillary or subterminal cymes or panicles.\(^{21}\) Commercially two types of ethereal oils are extracted from cinnamon: leaf oil and bark oil. *Cinnamomum zeylanicum* is considered to be the source of true cinnamon. In addition to its culinary uses in Asian and European recipes, it has important applications in medicine too. Other varieties of cinnamon do not have as much fragrance as that of *Cinnamomum zeylanicum*. This tree is native to India and
Ceylon. For the extraction of leaf oil the leaves and tender twigs are harvested in May and November. After wilting of the leaves in shade for about 24 hours they are steam distilled for four to six hours. The essential oil content from leaves is 0.49 to 0.87%. Cinnamon oil is stomachic, carminative, emmenagogue and styptic. It is useful in anorexia, inflammations, stomachalgia, vitiated conditions of 'Vata' and tubercular ulcers.\(^{21}\) The astringency is due to tannin. The odour causing essential oil contains Cinnamic aldehyde and Eugenol. This oil acts as a stimulant and is a powerful germicide.\(^{22}\) It has been used since antiquity as a breath-sweetener, a tonic for the whole system, heart, stomach, liver, kidneys, gall and nerves. It was also considered a remedy for heart burn, nausea and diarrhoea and as a sedative for expectant mothers during child birth. In the flavouring industry, it is used as a modifier. The antiseptic nature is very effective and is very powerful to cure cold and any viral infection especially of the respiratory or intestinal system.

**ECONOMIC AND MEDICINAL IMPORTANCE OF OTHER CINNAMON SPECIES**

* Cinnamomum *camphora* (L.) Nees & Eberm, *Cinnamomum burmannii* Blume (Malay Cinnamon), *Cinnamomum loureiri* Nees (Saigon Cinnamon), *Cinnamon tamala* Nees and Eberm are the other important species in the Lauraceae family.
*Cinnamomum camphora* is a source of camphor. Twigs and leaves are used to treat rheumatism, and muscular pain. It is very useful in bronchitis and pneumonia. In conjunction with menthol it relieves itching of skin.

*Cinnamomum burmannii* Blume is native to India, China and Malaysia. The bark contains essential oil and is used as a carminative and flavour. The bark oil of *Cinnamomum loureiri* which contains cinnamic aldehyde, phenols, pinene, phellandrene and caryophyllene is used to relieve nausea, flatulence and diarrhoea. *Cinnamomum tamala* leaf is used as a carminative and spice. It is also used for the treatment of colic pain.

The bark of Ceylon Cinnamon exported as quills is used as a spice or condiment for flavouring cakes. Studies on its leaf oil is less compared to that of bark oil. Leaf oil is used in the manufacture of perfumes, used in soap, tooth pastes, hair-oil etc.

**PREVIOUS WORK**

The chemical studies on Cinnamomum concentrate mainly on the analysis of the volatile oils of bark and leaf of commercially important Cinnamomum species. *C. zeylanicum, C. cassia, C. camphora* are the species most extensively studied. As early as 1924 Glichiteh analysed the Cinnamon leaf oil and found that the oil contained about 50% eugenol. Pure linalool was identified from Indian Cinnamon leaf essential oil during its chromatographic analysis. o-Methoxy eugenol,
caryophyllene, humulene, isocaryophyllene and benzyl benzoate in the non-
phenolic portion and coniferaldehyde in the phenolic fraction. Angmor and
coworkers carried out a compositional analysis of various plant parts of
Cinnamomum zeylanicum. The major components in young and mature bark and
leaf were cinnamic aldehyde and cinnamyl acetate. Herisset and coworkers used
chromatographic analysis to differentiate Cinnamomum zeylanicum and
Cinnamomum cassia oils. A lower cinnamaldehyde content combined with the
presence of linalool and eugenol characterised Cinnamomum zeylanicum oil. In
Cinnamomum cassia, cinnamaldehyde content was higher and linalool and eugenol
were absent. The leaf essential oil of Ceylon Cinnamon was found to contain
eugenol, methyl- and ethyl cinnamate by gas chromatographic analysis.24

On account of the industrial potential of Cinnamon leaf oil, Joy and
coworkers carried out a study on the inter-relationship between the growth, yield
and quality parameters in Cinnamon and identified elite types for aromatic leaf oil
and eugenol yields.25 Studies on the essential oil from the fruit rind of
Cinnamomum cecidodaphne Meissn showed the presence of fairly good amount of
methyl cinnamate, thymol, safrole, cineole and eugenol giving it a spicy flavour.
Presence of linalool, linalyl acetate and nerol adds to its pleasantness. Possibility
of application in perfumes and flavours is higher in this case. This oil showed
considerable range of fungicidal activity.26
Pharmacological studies on the antiulcerogenic activity of Chinese Cinnamon have been reported. Chinese Cinnamon has been used in Chinese traditional medicine as a diaphoretic, an antipyretic and an analgesic. The intraperitoneal administration of the aqueous extract of Chinese Cinnamon to rats markedly prevented ulcerogenesis induced by cold-stress.

The chemistry of *Cinnamomum zeylanicum* has received the most extensive attention compared to other species. Cinnamon leaf oil is yellow to brownish-yellow in colour and possesses a spicy but rather harsh odour.

The volatile compounds of *Cinnamomum glanduliferum* (Wal.) Nees leaves collected from Almora contained 1,8-cineole, linalool, camphor and α-terpineol as the significant components contributing to the scent. The oil found application for fragrant soaps and room sprays. The pharmaceutical application of the oil could be defined by the high concentration of 1,8 cineole and camphor.

Investigation of the essential oil of Cinnamon leaf grown at Bangalore and Hyderabad was carried out by Mallavarapu and coworkers. In both oils eugenol was the major constituent. But they differed with respect to the relative amounts of linalool, cinnamaldehyde, cinnamyl acetate, β-caryophyllene and benzyl benzoate. The oil content of the Hyderabad leaf was found to be higher than that of Bangalore leaf.
Investigation of essential oils of leaves of *Cinnamomum* Schaeffer members revealed a correlation between the leaf size and eugenol content among the variants of *Cinnamomum tamala*. The variant possessing smaller leaves generally contained higher percentage of eugenol in its leaf oil. Thus smaller the leaf size higher the eugenol content. Another correlation noticed was between the refractive index and eugenol content of the oils. Higher the value of the refractive index, more will be the percentage of eugenol present.

Kiuchi and coworkers reported the nematocidal activity of *Cinnamomum zeylanicum* on screening of crude drugs used in Turkey for nematocidal activity on the larva of *Taxocara canis*. It was found that *Cinnamomum zeylanicum* was active even at a concentration as low as 0.1 to 0.2 mg/ml. It has antioxidant property also.

The leaf oil of *Cinnamomum zeylanicum* from various parts of India has been previously investigated. Although eugenol is normally found as the main component (about 80%) of *Cinnamomum zeylanicum* leaf oil, benzyl benzoate has also been found as a major component in the leaf and bark oil of *Cinnamomum zeylanicum* from the Assam area of India as well as in China.

*Cinnamomum zeylanicum* is an interesting example of which leaves, stem bark and root bark yield oils differ in composition. In this species, in root bark oil, camphor is found as a characteristic constituent, leaf oil contains principally
eugenol, whereas in the stem bark oil, cinnamaldehyde predominates. The characteristic pungent, sweet and warm taste of cinnamon bark is due to the presence of an alcohol soluble pale yellow mobile essential oil which is very rich in cinnamaldehyde, reportedly up to eighty percent. It is used for the preparation of a number of ayurvedic and other pharmaceutical products. *Cinnamomum zeylanicum* leaves can be used as a substitute of 'Tejpat'.

**PRESENT WORK**

**Plant Source and Extraction of Essential Oil**

Fresh leaves of *Cinnamomum zeylanicum* were collected from neighbouring place of Calicut University, Kerala, South India. The species was identified by A.K. Pradeep, Department of Botany, Calicut University and a voucher specimen deposited (No. 29) in the specially maintained herbarium of Calicut University Chemistry Department.

Fresh leaves (250 g) were cut into small pieces and ground to a paste with 200 mL of distilled water using an electric mixer-grinder. It was then subjected to steam distillation for two hours. The distillate was extracted twice with 50 ml portions of diethyl ether and the combined extract dried using anhydrous sodium sulphate. Ether was evaporated to get light green essential oil. The yield was (2 g) 0.8% of the fresh weight.
EXPERIMENTAL

The oil composition was analysed by a combination of GC and GC-MS. GC analysis of the oil was carried out on a Shimadzu GC-14A (FID) and a Varian GC-3700 (FID) gas chromatographs fitted with a 30 m x 0.32 mm chemically bonded non polar FSOT-RSL-200 (film thickness: 0.25 µm: Biorad) and with a 30 m x 0.32 mm stabil wax (film thickness: 0.50 µm, Restek) fused silica column, respectively. The sample was injected by splitter. Hydrogen was used as carrier gas. The column temperature was programmed from 40°C (5 min) to 280°C (20 min) at 6°C/min. The compound identification was partly possible by injection of pure compounds and correlation with published retention index data. GC/MS analysis was carried out on a Shimadzu GC-17A/QP 5000, on a HP-5890 GC/HP-5970 MSD and on a Finnigan MAT GCQ (Carrier gas: helium, EI mode, 70 eV, scan range: 40-450 amu and ion-source temperature 200°C each) equipped with Wiley/NBS and NIST libraries. For additional mass spectra correlations, published data were used. By means of these combinations more than thirty constituents of the leaf oil of *Cinnamomum zeylanicum* could be identified.

The compounds identified are listed in order of elution from a non polar FSOT-RSL column and the percentage calculated by percentage peak area calculations of GC analysis are given below.
Table 1. Chemical composition of the leaf oil of *Cinnamomum zeylanicum*

<table>
<thead>
<tr>
<th>Compound</th>
<th>Concentration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E)-2-hexenol</td>
<td>0.1</td>
</tr>
<tr>
<td>(Z)-3-hexenol</td>
<td>0.1</td>
</tr>
<tr>
<td>1-hexen-3-ol</td>
<td>0.1</td>
</tr>
<tr>
<td>hexanol</td>
<td>0.1</td>
</tr>
<tr>
<td>α-pinene</td>
<td>tr</td>
</tr>
<tr>
<td>(Z)-3-hexenyl acetate</td>
<td>0.1</td>
</tr>
<tr>
<td>(E)-2-hexenyl acetate</td>
<td>0.1</td>
</tr>
<tr>
<td>p-cymene</td>
<td>tr</td>
</tr>
<tr>
<td>β-phellandrene</td>
<td>tr</td>
</tr>
<tr>
<td>(E)-β-ocimene</td>
<td>tr</td>
</tr>
<tr>
<td>1,8-cineole</td>
<td>0.1</td>
</tr>
<tr>
<td>limonene</td>
<td>0.2</td>
</tr>
<tr>
<td>cis-linalool oxide (furanoid)</td>
<td>0.2</td>
</tr>
<tr>
<td>terpinolene</td>
<td>0.1</td>
</tr>
<tr>
<td><em>trans</em>-linalool oxide (furanoid)</td>
<td>0.1</td>
</tr>
<tr>
<td>linalool</td>
<td>85.7</td>
</tr>
<tr>
<td>nonanol</td>
<td>0.3</td>
</tr>
<tr>
<td>borneol</td>
<td>0.1</td>
</tr>
<tr>
<td>terpinen-4-ol</td>
<td>0.3</td>
</tr>
<tr>
<td>α-terpineol</td>
<td>1.1</td>
</tr>
<tr>
<td>dihydrocarveol</td>
<td>tr</td>
</tr>
<tr>
<td>linalyl acetate</td>
<td>0.1</td>
</tr>
<tr>
<td>(E)-cinnamaldehyde</td>
<td>1.7</td>
</tr>
<tr>
<td>safrole</td>
<td>t</td>
</tr>
<tr>
<td>(E)-cinnamyl alcohol</td>
<td>0.1</td>
</tr>
<tr>
<td>eugenol</td>
<td>3.1</td>
</tr>
<tr>
<td>(E)-cinnamyl acetate</td>
<td>0.9</td>
</tr>
</tbody>
</table>
\[
\begin{array}{|c|c|}
\hline
 \text{Component} & \text{Concentration} \\
\hline
 \beta\text{-caryophyllene} & 2.4 \\
 \alpha\text{-humulene} & 0.2 \\
eugenyl acetate & 0.1 \\
caryophyllene oxide I & 0.1 \\
spathulenol & 0.2 \\
benzyl benzoate & 0.3 \\
\hline
\end{array}
\]

\(tr = \text{trace (< 0.1%)}\)

**RESULTS AND DISCUSSION**

The main compounds correlation higher than 1% calculated as percentage peak area of GC-FID analysis were linalool (85.7%), eugenol (3.1%), \(\beta\text{-caryophyllene (2.4%)}, \) E-cinnamaldehyde (1.7%) and \(\alpha\text{-terpineol (1.1%)}.\)

This is the first time that linalool has been found to be present in such a concentration of more than 85% in any of the Cinnamomum species. The hitherto known highest concentration is 60% in *cinnamomum sulphuratum*\(^{30}\).

This oil sample has a very pleasant odour which can be attributed to the individual components present in it. The floral odour is due to the major component linalool and \(\alpha\text{-terpineol}.\) Due to the presence of (E)-2-hexenol, (Z)-3-hexenol and their acetates along with 1-hexen-3-ol, the oil exhibits green-fresh note. The 'green' odour is the characteristic of hexenols and their derivatives and hexenals. The most prominent among them is cis-3-hexen-1-ol leaf alcohol. When the position of the double bond is shifted or the alcoholic group is shifted they became less 'green'.
The trans-3-hexen-1-ol is less odorous than the cis isomer. Eugenol, β-caryophyllene, and (E)-cinnamyl acetate give a spicy touch while the fatty acids and their esters give fatty-moody note to this oil.

The high percentage of linalool can make this essential oil important in fine perfumery where a floral odour note is appreciated.

Structures of compounds identified in the leaf essential oil of *Cinnamomum zeylanicum* are given below.
Structures of compounds identified in the leaf essential oil of *Cinnamomum zeylanicum*

- p-Cymene
- β-Phellandrene
- 1,8-Cineol
- Limonene
- cis-Linalool oxide
- α-Terpinolene
- β-Caryophyllene
Terpinen-4-ol
Dihydrocarveol
Linalyl acetate

Safrole
Eugenol

Eugenyl acetate
Benzyl benzoate
SYZYGIUM TRAVANCORICUM