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Himalayan (Himachal region) cedar wood (*Cedrus deodara*: Pinaceae) essential oil, its processing, ingredients and uses: A review

Sandeep Kumar, Ashwani Kumar and Randhir Kumar

Abstract

EO's (Essential oils) are the complex mixtures of volatile compounds, synthesized as secondary metabolites from plant parts by steam/ Hydro distillation, solvent-less extraction and other physical means such as cold pressing. The demands of EO's are increasing drastically in food and beverage; fragrances; cosmetics; flavoring agents in air fresheners and deodorizers; household and aromatherapy. *Cedrus deodara* (Pinaceae) EO is one of the important oil, which has great pharmacological activities and demand in the market. C. Deodara EO has wide applications, mainly in antimicrobial, insecticidal, mollusicidal, germicidal, anti-tubercular activities in Pharmacology. C. Deodara oil has high demand in fragrance industries because of its specific characteristics. Himalayan C. Deodara consists of α-Himachalene, β-Himachalene, γ-Himachalene, α and γ atlantone as its major constituents. This paper presents the details of *Cedrus deodara* of Himachal (India) region, its production in small scale industries using steam/Hydro distillation, ingredient and uses. This article will facilitate the science students and small scale EO's industries to improve their productivity with latest techniques.

Keywords: Essential oils (EO's); *Cedrus deodara* (Pinaceae), processing, chemical constituents, recent extraction techniques.

Introduction

Essential Oils (Aromatic oils) are synthesized as secondary metabolites from various parts of plants and employed for flavors, perfumes, disinfectants, medicines and stabilizers. EO's are also utilized for making undesirable odors and as raw materials for making other products. [CM, Cook *et al* 2016] [16]. The secondary metabolites are classified into terpenoids, shikimates, polyketides and alkaloids. EO's are mainly concerned with terpenoids and shikimates. EO's are also called volatile oils because of their ease of solubility in alcohol to form essence. EO's evaporates when exposed to air at ordinary temperature. EO's are made up of isoprene units (empirical formula C_6H_8) and are usually mono-terpenes (C_5H_8), sesqui-terpenes ($C_{10}H_{16}$) and diterpenes ($C_{15}H_{20}$; $C_{20}H_{32}$) respectively. EO's are classified into four major categories: (a) Pinene or terpenes; (b) Oxygenated oils; (c) Nitrogenerated oils and, (d) Sulfurated oils. Pinene and terpenes (e.g. Turpentine oil) contains carbon and hydrogen and Empirical formula $C_{10}H_{16}$. Oxygenated EO's (e.g. Cassia oil) contains carbon, hydrogen and nitrogen. Nitrogenerated EO's (e.g. Almond oil) contains carbon, hydrogen, oxygen and nitrogen. Sulphurated EO's (e.g. Mustard oils) contains carbon, hydrogen and sulphur. [*et al*] EO's are isolated by traditional technique mainly hydro/steam distillation from the leaves, buds, flower, roots, seeds and other part of the plant.

Himalayan cedar (*Cedrus deodara*, deodar) and Sandlewood EO's are distilled from the stem and roots of the plants. Himalayan *Cedrus deodara* grows in the slope of the Himalayas and at the elevation of 1650m to 2400m above the sea level. *Cedrus deodara* common name in English as Himalayan cedar, deodar cedar and deodar and in the Hindi local name is Diar, deodar and debdar. In Himachal Pradesh, the total 68,872 hectare area is covered under under *Cedrus deodara* forest. *Cedrus deodara* is found in Chamba, Manali, Kinnaur, Sirmour, Shimla, Kangra (Bada Bhangal & Chota bhangal) and Mandi region of Himachal Pradesh. The height of Cedrus deodars is approximately 65-85 m tall and 4 m diameter at breast height (DBH). The leaves of *Cedrus deodara* are stiff, sharp pointed having length of 23-37 mm long and the bark is grayish brown, dark in color [Orwa *et al*, 2009]. The extracted oil from *Cedrus deodara* have been used as antiseptic, insecticides, herbal remedies against animal diseases, anti-fungal activity, anti-inflammatory, molluscidal activity, pharmacological and biological activities, etc. The sizable stumps and roots of the plant left after cutting of trees are utilized for the Hydro/Strem distillation of EO's.

In India, the production of *Cedrus deodara* EO's begun in late 1950's and estimated to be around 150 tonnes per annum of the world's production. [Coppen *et al*, 1995] [19]. The *Cedrus deodara* leaves are utilized for flavoring foods, beverages and for the treatment of diseases such as rheumatism, diabetes, cancer, stomach disease, inflammation in tuberculous glands, etc. The wood and bark extracts of *Cedrus deodara* are used for medicinal purposes. The extracted root oil form *Cedrus deodara* is utilized as an anti-ulcer drug. [Atwal *et al*, (1976); Zhang *et al*, (2011); Krishnappa *et al* (1978); Mukherjee *et al*. (2011)] [20, 21, 23, 24] The Himalayan *Cedrus deodara* plant species are illustrated in Fig. 1. The taxonomical classification and chemical composition of Cedrus deodar species is presented in Table 1 and Table 2 respectively. The botanical and common names of *Cedrus deodara* are given in Table 3.

Fig. 1: *Cedrus Deodara* plant (Himalayan deodar, Mandi region)

Table 1: Taxanomical Classification of *Cedrus Deodara* (Gupta *et al*, 2011) [7]

Taxonomical Classification (Cedrus deodara)	
Division	Pinophyta
Kingdom	Plantae
Class	Pinopsida
Order	Pinales
Family	Pinaceae
Genus	Cedrus
Species	C. Deodara

Table 2: *Cedrus deodara* Plant Chemical Composition (Tewart LN *et al*, 2011) [25]

Chemical Composition in %age (Cedrus deodara)	
Organic Carbon (C)	1. 83.50
Nitrogen (N)	2. 0.28
Phosphorus (P)	3. 0.055
Potassium (K)	4. 0.06
Calcium (Ca)	5. 2.60
Magnesium (Mg)	6. 0.017

Table 3: *Cedrus Deodara* botanical and common name (Orwa *et al*, 2009)

Botanical Name	***Common Name***	***Trade Name***
Cedrus deodara	In English: Himalayan cedar, deodar cedar, deodar	Diar, Deodar
	In Hindi: Diar, deodar, debdar	
	In French: cedar del'himalaya	
	In German: himalaja-Zeder	
	In Italian: cedro dell'Himalaia	
	In Spanish: Cedro del Himalaya, cedro de la India	

The characteristics of *Cedrus deodara* are illustrated in Table 4.

Table 4: Margin specifications

Species	***Ripe color***	Length (cm)	Width (cm)
Cedrus Deodara	Cone Size		
	Reddish brown	7813	589
	Seed Size		
	Length (mm)		Width (mm)
	104815		587
	Leaf Size		
	Length (cm)		No. of Whorls

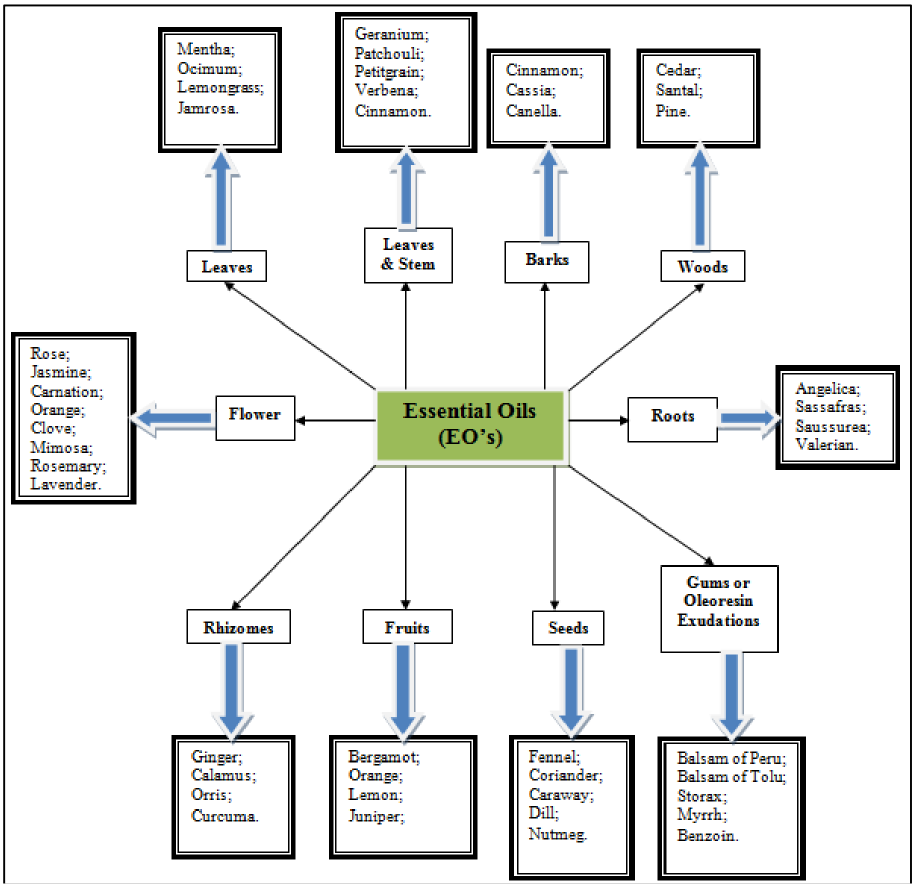


Fig. 2: Plant organs containing EO's

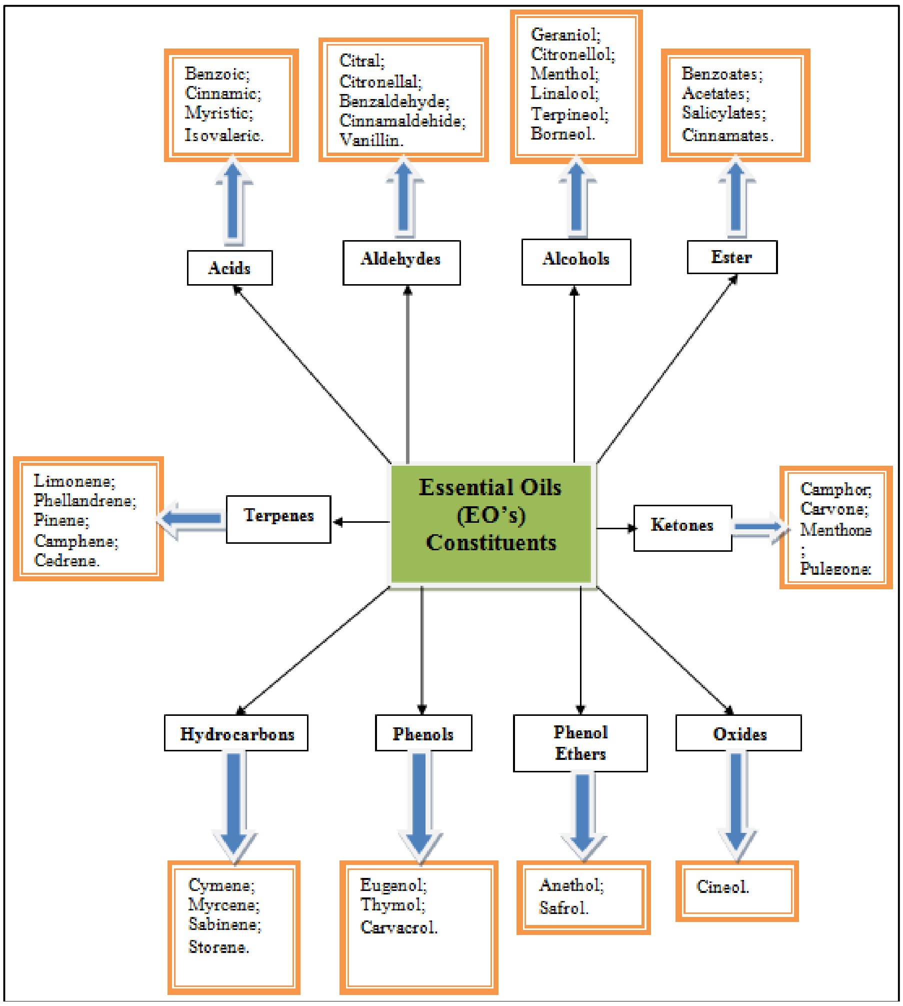


Fig. 3: Chemical groups present in EO's

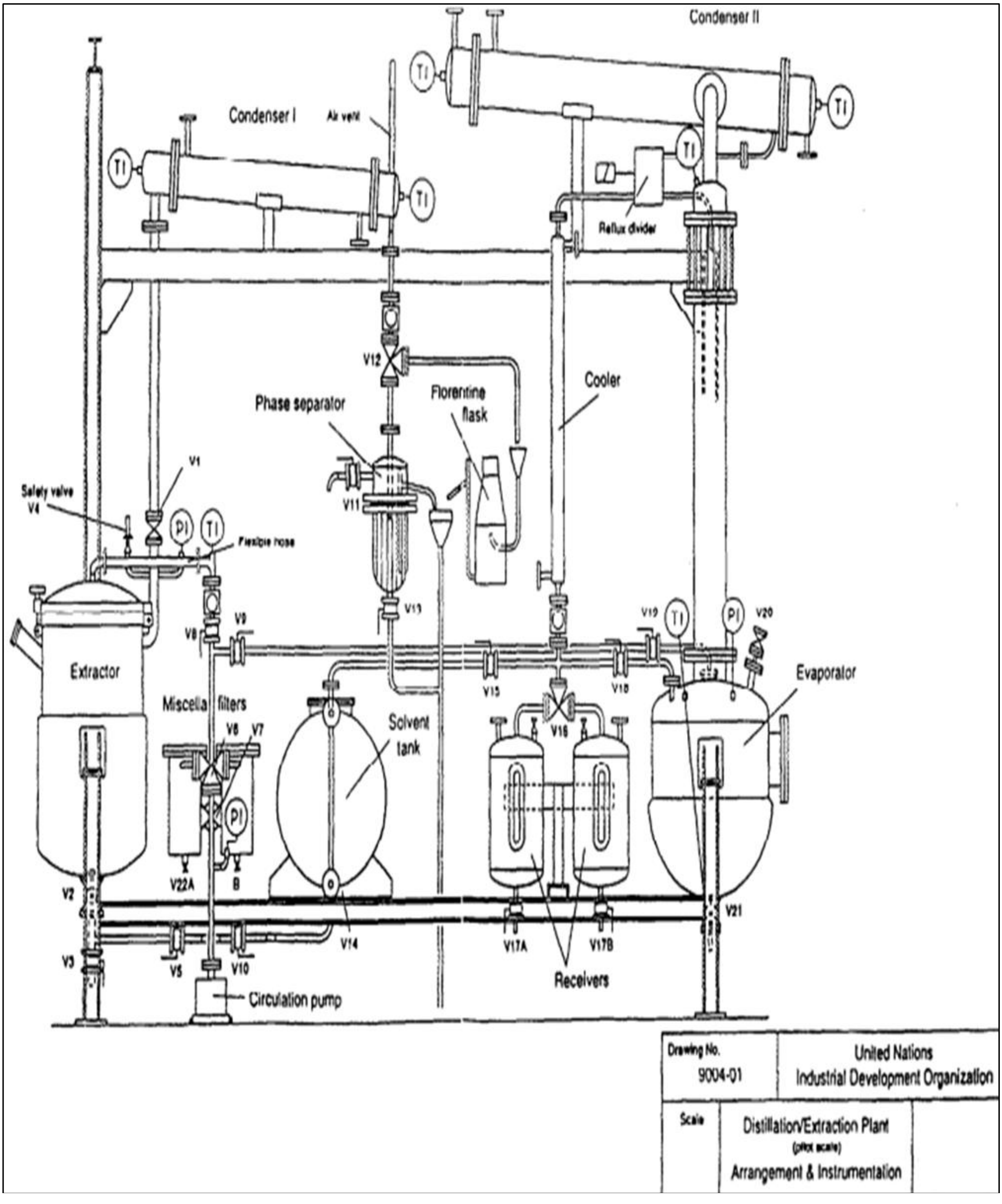


Fig. 4: Steam Distillation Plant arrangement and Instrumentation. [K. Tuley DE SILVA, 1995]

2. Processing of *Cedrus deodara*

The stumps and roots of the plants (left after cutting) are collected from the forest areas. The wood is reduced into small pieces and subjected to the continuous Hydro/Steam distillation process in Industries. In small scale industries, traditional Hydro/steam distillation process is employed for the processing of *Cedrus deodara*. Before starting of hydro distillation process, *Cedrus deodara* wood is chopped into small pieces. These pieces are processed through a grinder to convert chips into powder form. This powder material is filled into the still or containers where the plant material rests on a perforated tray for quick removal after extraction. The schematic of the steam distillation process is illustrated in Figure 5.

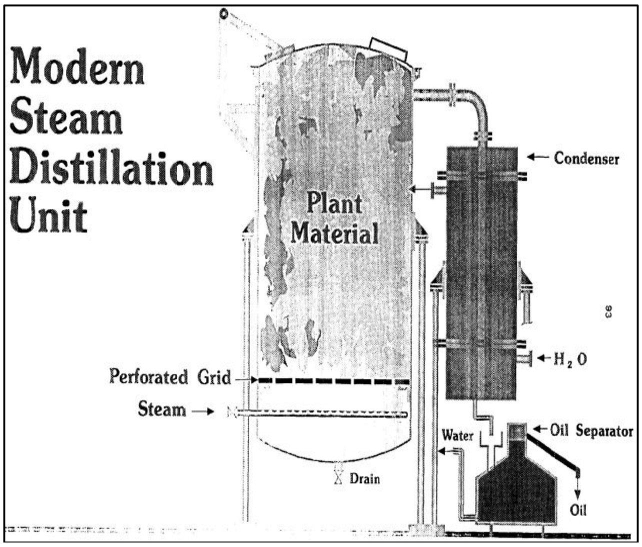


Fig. 5: Schematic of processing of *Cedrus deodara* using Hydro/Steam distillation process

In the Steam distillation process, the steam is produced in a steam boiler and the generated steam is blown through a pipe into the bottom of the still. 70-75 psi pressure is maintained in the boiler. High-pressure steam distillation is often applied and the time of distillation the applied increased temperature significantly reduces. The steam carries volatile oil constituents along with it and passes through a condenser. The condenser converts the vapors into liquid and the condensed distillate consists a mixture of water and oil. The mixture of oil and water is separated in a Florentine flask or receptacle made of SS (stainless steel) whose one outlet near the base and another at the top from which oil and water can be separately withdrawn. Since the density of *Cedrus deodara* EO's is lighter than the water, therefore, the oil is collected from the top end of the Florentine flask or receptacle.
For large scale production of *Cedrus deodara* EO's, this method is most widely preferred. For higher yield of EO's, the processing time approx. 8 to 9 hours is preferred. After distillation, the crude oil is stored in plastic drums. The *Cedrus deodara* EO sample obtained after Hydro/Steam distillation is shown in Figure 6.

Fig. 6: Sample of *Cedrus deodara* Essential Oil

Table 5: Physical properties of *Cedrus Deodara* oil [Walker (1968); Adams (1991)] [1]

Physical properties (Cedrus deodara oil)	
Specific gravity at 15°C (or 20°C)	0.94-0.99
Optical rotation	-16° to -60°
Refractive Index at 20°C	1.48-1.51
Solubility (at 20°C)	90%-95% in ethanol

3. Various parameters affecting Yield & Quality of C. Deodara

During steam distillation, the various factors such as steam pressure and temperature, equipment's materials etc. affects the quality and yield of C. Deodara which may lead to change the characteristics of distillation. To avoid these distillation characteristic changes, the list of major factors should be taken into consideration during steam/Hydro distillation are as follows:
- Distillation mode (Steam pressure and temperature)
- Design of the equipments
a.) Design of still, condenser and separator
b.) Design of furnace and chimney
c.) Ratio of tank Height and diameter of cylinder
- Fabrication and Materials of equipments
- Raw material condition
- Distillation time
- Loading and unloading of raw material
- Condition of still and water tank

4. Purification of *Cedrus deodara* Crude oil

Cedrus deodara crude oil is obtained from the oil separator after steam distillation. It contains moisture content and impurities in it which degrades the characteristics of C. Deodara. The impurities and moisture accelerate the undesirable chemical reaction and polymerization.
The high speed centrifugation process is most commonly used to remove the impurities and moisture contents. Another method is the addition of anhydrous sodium sulphate in the oil and standing it for overnight and filtered help to remove the impurity and moisture.
EO's are frequently rectified or re-distilled to remove impurities. The steam distillation process is carried out under vacuum condition by keeping the temperature within limits.

5. Chemical constituents of *Cedrus deodara*

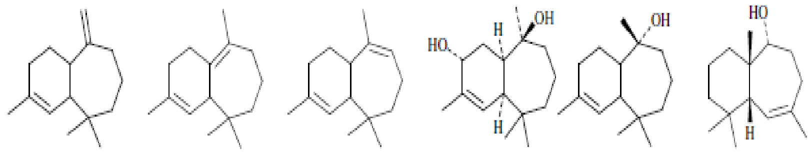
Cedrus deodara EO is utilized as perfume fixative in essence, cosmetic, soap and perfume Industries. Generally, the *Cedrus deodara* is characterized by a high percentage of *himachalenes* [Bhushan, *et al*, (2006)]. EO enriched in atlantones is known as "*Perfumery Grade*" and the EO enriched with himachalene is called as "*Super Rectified Oil*". Sesquiterpenes are partially being ascribed from Cedrus species.
Abha Chaudhary *et al*. (2011) [9] investigated and characterized the constituents of *Cedrus deodara* for the use of pest management. The authors identified the fractions of forty components using GC and GS-MS analysis. In *Cedrus deodara*, the major constituents includes α-Himachalene, β-Himachalene, γ-Himachalene, (Z)-γ-atlantone, (E)-γ-atlantone, (Z)-α-atlantone and (E)-α-atlantones. The identified chemical constituents of *Cedrus Deodara* by Chaudhary Abha *et al*, 2011 [9] are shown in Fig. 7 where A5 represents: Pentane Fraction; A4: Himachalene enriched fraction; A3: Atlantone enriched fraction; A6 : Acetonitrile Fraction and A2 represents Crude Oil.

The sesquiterpenes and their chemical structure available in *Cedrus deodara* are presented in Figure 8 as himachalenes (α, β and γ) (1-3), isocentdarol (4), Himachalol (5), allohimachalol (6), aryl Himachalene (7), (E)-α-atlantone (8), (E)-γ-atlantone (9), (Z)-α-atlantone (10), (Z)-γ-atlantone (11), deodarone (12), oxidohmachalene (13), β-himachalene monoepoxide (14), atlantolone (15), deodardione (16), diosphenol (17), limonene carboxylic acid (18). (Nigam *et al*. 1990, Bhushan, *et al* 2006) [25, 26]

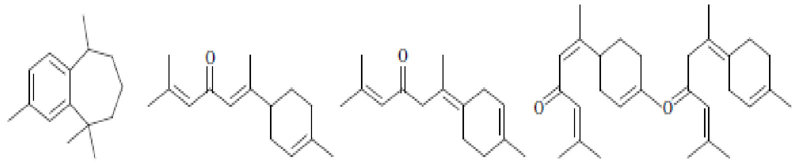
Compounds	KI	A5 (%)	A6 (%)	A4 (%)	A3 (%)
4-Acetyl-1-methylcyclohexene	1499	-	2.10	-	-
Longifolene	1503	0.91	-	-	-
Aromadendrene	1545	0.25	-	-	-
α-Himachalene	1579	13.29	2.56	20.33	-
α-Humulene	1617	0.48	-	-	-
γ-Himachalene	1627	11.28	2.29	17.95	-
β-Curcumene	1629	-	0.40	-	-
β-Himachalene	1651	27.78	6.85	52.61	-
3-Cyclohexene-1-methanol	1660	-	0.33	-	-
8-Cedren-13-ol-acetate	1677	0.21	-	-	-
β-Vativenene	1702	0.50	-	-	-
cis-*α*-Bisabolene	1715	1.58	0.36	-	-
3-Methylacetophenone	1716	-	1.30	-	-
4,5-Dehydroisolongifolene	1755	0.23	-	-	-
α-Dehydro-*ar*-himachalene	1791	1.94	0.96	-	-
γ-Dehydro-*ar*-himachalene	1826	1.44	1.02	-	-
Vestitenone	1860	0.55	3.00	-	-
β-Himachalene oxide	1923	9.12	1.17	-	-
Calarene epoxide	1969	0.83	1.74	-	-
Nerolidol	1977	-	0.55	-	-
Carophyllene oxide	2002	0.25	0.50	-	-
(+)-8(15)-Cedren-9-ol	2006	-	0.47	-	-
Aromadendrene oxide	2009	0.96	-	-	-
Longiborneol	2070	0.58	2.01	-	-
β-Bisabolol	2077	0.22	0.48	-	-
β-Atlantone	2097	0.94	2.71	-	1.95
(Z)-*γ*-Atlantone	2122	0.79	8.63	-	11.38
Himachalol	2129	2.04	4.51	-	-
m-Tolyldimethylactealdehyde	2137	-	0.45	-	-
(*E*)-*γ*-Atlantone	2143	0.87	8.83	-	15.70
Deodarone	2152	0.53	4.18	-	-
Deodarone isomer	2156	-	3.70	-	-
Humulane-1,6- dien-3-ol	2161	-	4.37	-	-
(Z)-*α*-Atlantone	2172	3.40	5.23	-	4.99
(*E*)-*α*-Atlantone	2248	9.45	16.00	-	61.82
Longifolenaldehyde	2303	0.47	-	-	-
2-Butyl-1-methyl-1,2,3,4-tetrahydro-naphthalen-1-ol	2345	-	1.09	-	-
8-*α*-Acetoxyelemol	2349	-	0.47	-	-
7*β*,3*α*-Dihydroxy-1*α*-2,6-cyclohimachalane	2401	-	0.36	-	-
14-Hydroxy-9-epi-(*E*)-caryophyllene	2412	-	0.62	-	-
Total identification		90.89	89.24	90.89	95.74

A5: *n*-pentane fraction; A4: himachalenes; A3: atlantones; A6: acetonitrile fraction; A2: crude oil

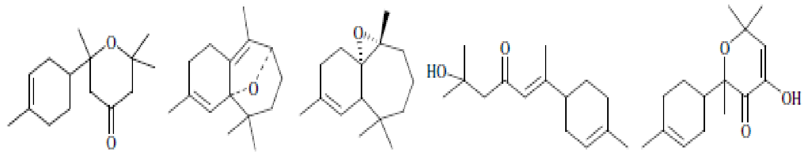
Fig. 7: Chemical constituents of fraction of *Cedrus deodara* EO [Chaudhary A. *et al*. (2011)] [9]



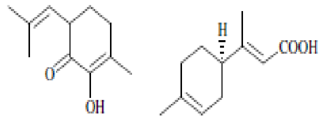
(1) (2) (3) (4) (5) (6)



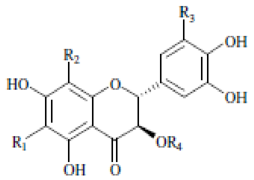
(7) (8) (9) (10) (11)



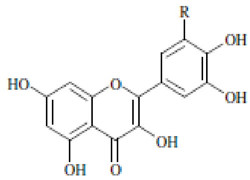
(12) (13) (14) (15) (16)



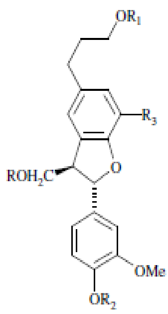
(17) (18)



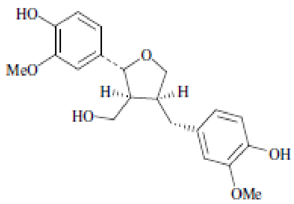
R_1	R_2	R_3	R_4	
H	H	H	H	(19)
H	H	H	glu	(20)
H	Me	H	H	(21)
Me	H	H	H	(22)
Me	H	OH	H	(23)
Me	H	OH	glu	(24)
H	H	OH	H	(46)



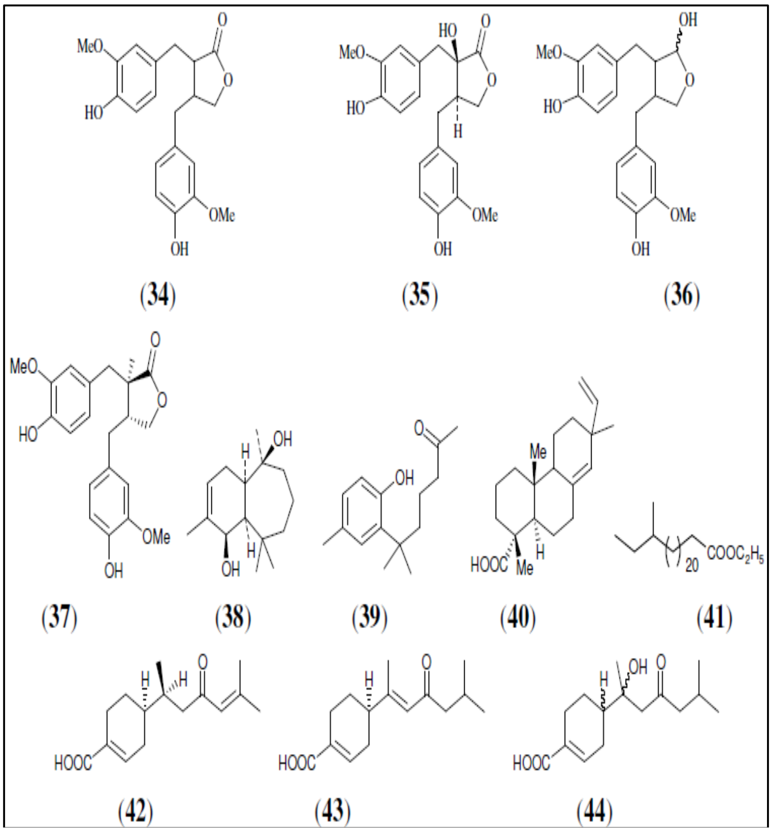
R	
H	(25)
OH	(45)



R	R_1	R_2	R_3	
H	H	H	OMe	(26)
H	H	H	OH	(27)
H	H	H	H	(28)
Ac	Ac	Ac	H	(29)



(30)



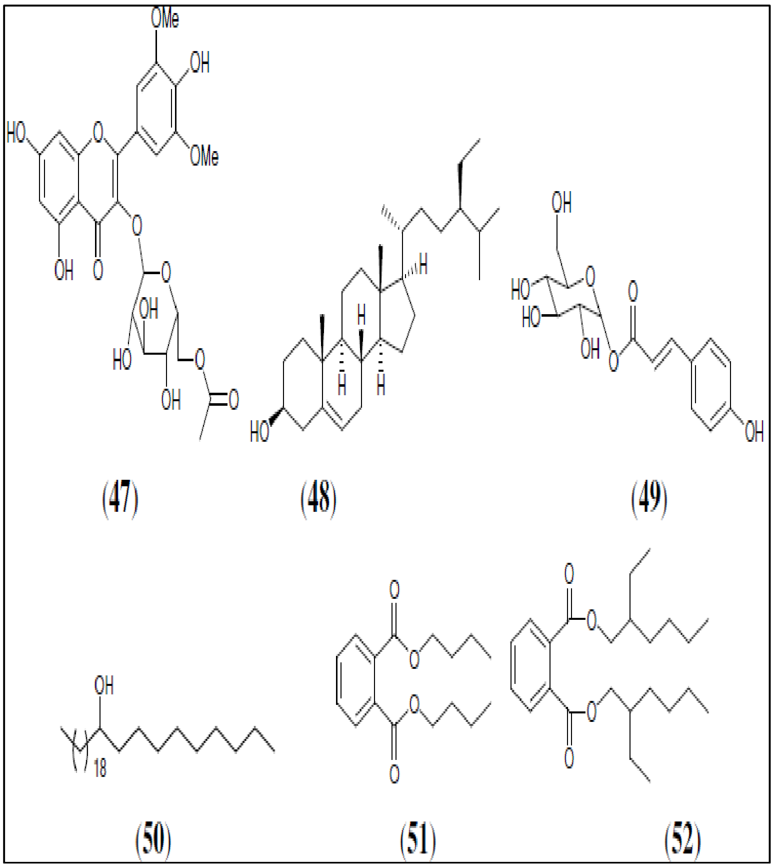


Fig. 8: Structure of constituents of *Cedrus deodara*

The chemical constituents (through ethanolic extract) found in needles of *Cedrus deodara* are taxifolin (19), quercetin (25), myricetin (45) 2R, 3R-dihydromyricetin (46), cedrusone A (47), β-sitosterol (48), 1-[3-(4-hydroxyphenyl)-2-propenoate]-α-D-glucopyranoside (49),
10-nonacosanol (50), dibutyl phthalate (51), phthalic acid bis-(2-ethylhexyl)ester (52), protocatechuic acid (53), Shikimic acid (54) and 5p-trans-coumaroylquinic acid (55). [Zhang *et al*. (2011); Liu *et al*. (2011)] Srinivastava *et al* 2001 [21, 27, 30] reported the Centdaroic acid (56) generally known as diterpene in *Cedrus deodara* roots, presented in Figure 9.

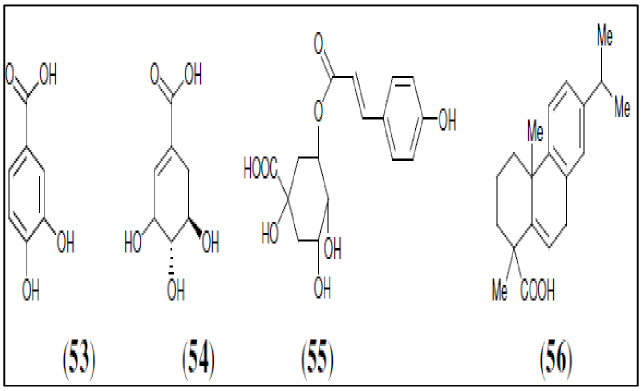


Fig. 9: Structure of the constituents of *Cedrus deodara* root diterpene Centdaroic acid (56)

4. Modern Extraction methods for EO's

Now days, it becomes easier to extract the EO's because of the continuous improvement and innovation in technologies. The green technologies have been invented which leads to:

- the decrease in extraction time;
- Reduction in solvent involvement;
- Reduction in the interaction of volatile liquid with atmospheric conditions and
- Reduction in energy.

Some of the solvent-less extraction processes are carried out in a vacuum under reduced pressure to improve the yield and quality of EO's. [Muhammad Shahzad Aslam *et al*, 2016] [10] The lists of some solvent-less extraction methods suggested by Aslam (2016) [10] are as follow;

a.) SFMS (Solvent-free microwave extraction)
b.) MHG (Microwave Hydro-diffusion and gravity)
c.) Improved solvent free microwane extraction.

The advantages of these extraction methods are as follows:

- Fast action
- Cleanliness
- Low energy output
- Green method

The schematic of these solvent-less extraction processes are shown in Fig. 10-12.

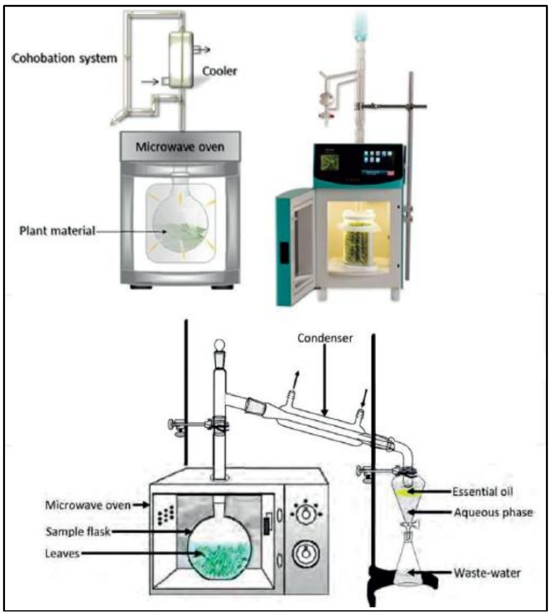


Fig. 10: Schematic of SFME [Kusuma H. *et al*, 2016] [12]

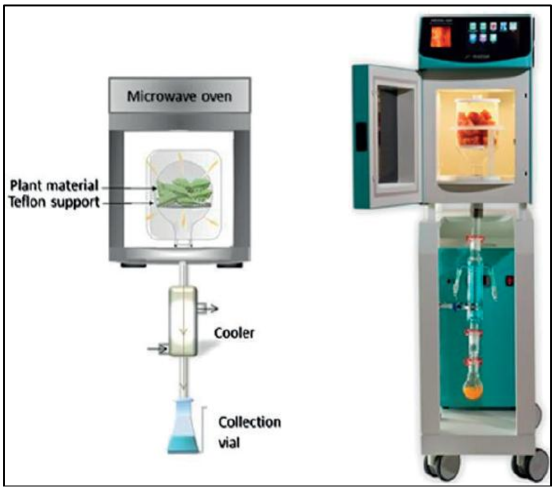


Fig. 11: Schematic of MHG [Li Y, *et al*, 2013] [14]

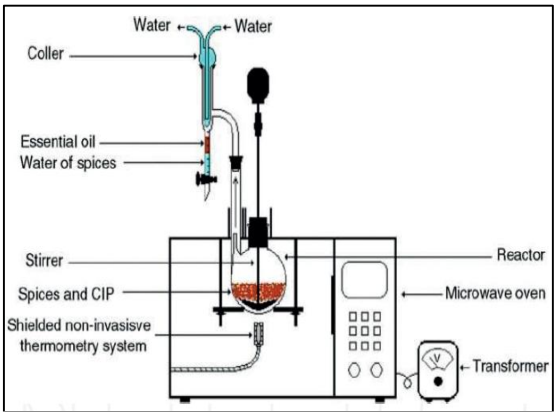


Fig. 12: Schematic of Improved SFME [Wang T. *et al*, 2006] [11]

d.) CO_2 Extraction method

Subcritical and supercritical liquid CO_2 extraction is another modern technique employed for extraction of essential EO's. The EO is extracted with liquid CO_2 in an autoclave at temperature range of 50-70^{o}C. After that the gas is distilled and pure extract remains. The extracted product through this method remains stable for long storage and more complete. For medical and biological purposes, subcritical extraction is preferred. The amount of pure extracts (Oil-soluble) from the needles of Siberian cedar with the use of subcritical extraction is about 2%. During sub-critical extraction, there is practically no destruction of the chemical structure of the components. The biological activity of such drugs is very high. The schematic of liquid CO2 extraction is illustrated in Fig. 13.

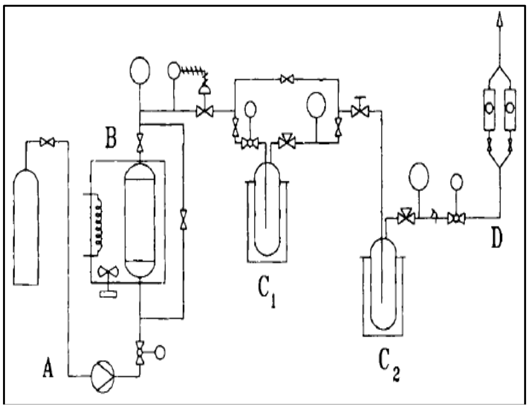


Fig. 13: Schematic diagram of the supercritical CO2 extraction. A: Pumping section; B:Extraction section; C1 and C2: Fractional section; D: Flow measurement section [E. Reverchon *et al*, 1992] [6]

e.) Modern (Non-traditional) methods of extraction of essential oils

- Headspace trapping techniques
- Solid phase micro-extraction (SPME)
- Supercritical fluid extraction (SFE)
- Phytosol (phytol) extraction
- Protoplast technique
- Simultaneous distillation extraction (SDE)
- Controlled instantaneous decomposition (CID)
- Thermomicrodistillation
- Micro distillation
- Modular spinning band distillation
- Membrane extraction

5. List of equipments required for Hydro/Steam distillation Small-scale plant

The major machinery and equipments required for the establishment of small-scale Hydro/Steam distillation EO's plant are as follows;

- Band saw (for wood cutting purposes)
- Chipper (to cut the wood into small chips)
- Grinder (to convert the chips into powder form)
- Steam Boiler (for stean generation)
- Still (to fill powder material)
- Condenser (to condense the mixture of water and volatile oil)
- Florentine flask

For the testing and characterization of EO's, the following lists of equipments are required in the laboratory;

- Laboratory balance (to determine the weight of plant samples)
- Clevenger apparatus (for essential oil extraction and estimation of EO's percentage)
- Freezer (to keep extracted volatile oils)
- Gas chromatography- Mass Spectroscopy (for the determination of essential oil components)
- Refractometer (to determine the refractive index of essential oils).

6. Applications of C. Deodara Essential oil

- Fragrance Compounding
- Source of raw components for the production of additional fragrance compounds.
- Scented soaps
- Room sprays
- Disinfectants
- Cleaning agent for microscope sections
- Technical preparation
- All branches of medicines such as in pharmacy, balneology, massage and homeopathy
- In the field of aromatherapy and aromachology
- Biocides and insect repellents and many more.

7. Market for EO's

In 2017, the worldwide production of EO's was estimated as 1,50,000 tonnes i.e. triple in volume since 1990's.[Cinzia Barbieri *et al*, 2018] [8]. Therefore the demands of EO's are increasing drastically in fragrance industries (29%), household (16%), food and breverage (35%), cosmetics, aromatherapy and pharmaceuticals (15%) [Data as per Federation of EO's]. The demands of EO's, major leading importers and exporters are shown in Fig. 14, Fig. 15 and Fig. 16 respectively.

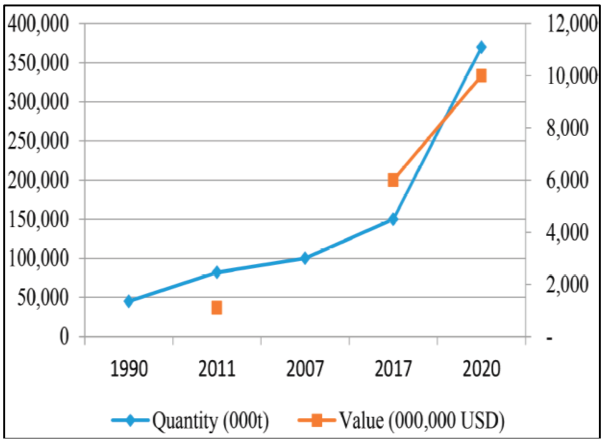


Fig. 14: World processing of EO's, [Cinzia Barbieri *et al*, 2018] [8]

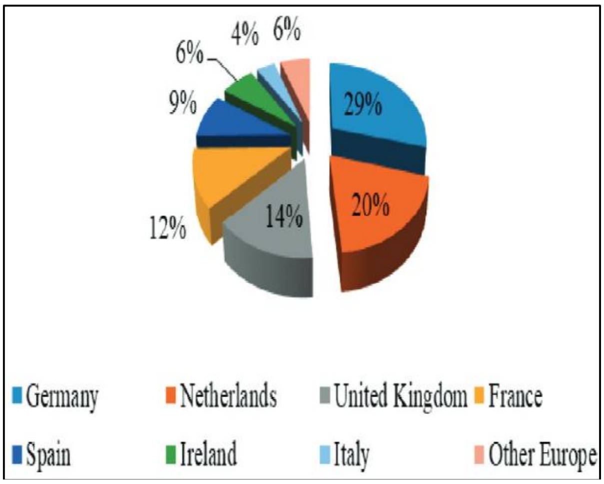


Fig. 15: Leading Importers of EO's, (2016, % volume) [Cinzia Barbieri *et al*, 2018] [8]

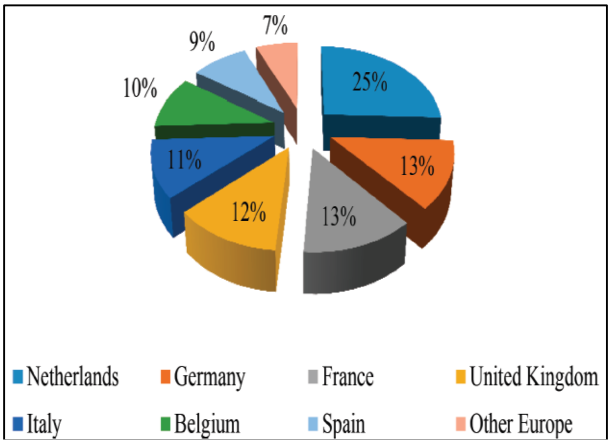


Fig. 16: Leading Exporters of EO's, (2016, % volume) [Cinzia Barbieri *et al*, 2018] [8]

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