Review on Chemical Composition of Essential Oil Extracted from Aromatic Plants by Hydrodistillation and Steam Distillation

Akanksha Yadav[1], Ashok Kumar Ranjan[1], Sunil Kumar Yadav[2*]

[1] *Department of Chemistry, C.M.P. Degree College, University of Allahabad, Prayagraj, Uttar Pradesh, India.*

[2] *Department of Chemistry, SRM Institute of Science and Technology Delhi-NCR Campus, Modinagar, Ghaziabad, India.*

Correspondence e-mail:

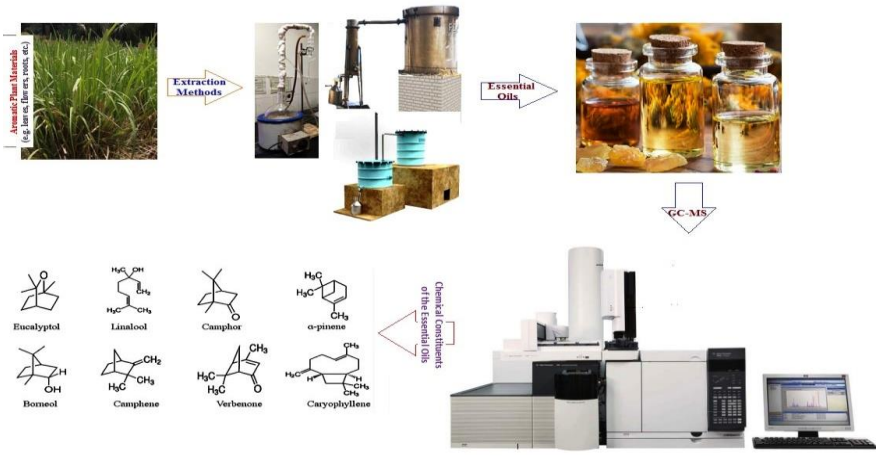
skyhbtu@gmail.com *and* akranjanhbtu@gmail.com

Abstract:

This study presents systematic data on the major percentage of compounds from aromatic plants, the yield of oil, the method used to extract oil, the scent profile, and their uses. Since then, essential oils have gained popularity due to the high potential of their novel properties, i.e. as fragrant raw materials for many products such as toothpaste, hand soap, shampoos, hair oils, bath soap, cosmetic products, floor cleaner, mosquito repellents, incense sticks, food products, therapeutic products, herbal medicines, etc. Therefore, before using some raw materials that are naturally fragrant in products, it is crucial to understand their features, such as the percentage of molecules from aromatic plants, the percentage of oil yield, the used process for oil extraction, and their fragrance profiles. It will be highly beneficial in the development of new, high-quality products items. Researchers, scientists, business owners, farmers, and industries will all benefit at the same time when new fragrance goods are developed.

Keywords: Essential oils, Yield, Composition, Distillation, Aroma

Graphical Abstract



Introduction

The secondary metabolites, volatile, fragrant oils known as essential oils (EOs) are derived from the different parts of plants and are utilised by them as defence mechanism against attacks by herbivore (Blowman, K., et.al., 2018). The hydrophobic liquids that make up these complex, concentrated combinations of terpenoid hydrocarbons,

oxygenated terpenes, and sesquiterpenes give them their distinctive scent. Terpenes and phenylpropanoids are the two separate chemical classes into which plant EO components are categorised. The three primary categories of terpene compounds are monoterpenes, sesquiterpenes and diterpenes, oxygenated derivatives, consisting of ketones, esters, alcohols, aldehydes, acids, oxides, phenols, acids and lactones. According to the functional groups listed below, some typical molecules found in essential oils are categorised (Moghaddam, M., et.al., 2017) (Table 1). Due to inherent plant characteristics (climate, plant development, and harvest time) as well as extrinsic factors (extraction method and environment), the composition of essential oils exhibits great diversity (Dhifi, W., et.al., 2016).

Table 1: Chemical components of Essential Oils

Hydrocarbon	Terpenoids	Monoterpene	Camphene, β-myrcene, γ-3-carene, *p*-cymene limonene, β-ocimene, α-pinene, sabinene, α-phellandrene, α-thujene, α-terpinene, terpinolene
		Sesquiterpene	β-himachalene, β-isabolene, germacrene-D, α-copaene, α-cadinene, β-caryophyllene, α-zingiberene, β-cedrene, α-farnesene, α-humulene, γ-muurolene,
	Phenylpropanoid		Anethole, myristicin, α-asarone, methyl eugenol, cinnamaldehyde, eugenol, chavicol, cinnamic alcohol, elemicin, estragole, safrole
Functional groups	Alcohols and phenols		Nerol, cinnamyl alcohol, geraniol, carvacrol, eugenol, thymol
	Carboxylic Acids		Benzoic acid, valerenic acid, cinnamic acid
	Aldehydes		Cinnamaldehyde, geranial cumin aldehyde, citral.
	Ketones		Camphor, piperitone, menthone.
	Carboxylic esters		Methyl salicylate, benzyl acetate, linalyl acetate, eugenyl acetate.
	Ethers and oxides		Ethers: anethole, estragole, myristicin. Oxides: β-caryophyllene oxide; geranyl oxide; 1,8-cineole.
	Lactones		Coumarin, nepetalactone, alantolactone.
	Alkenes		α-Cedrene, α-pinene, eugenol, β-pinene, safrole, β-myrcene, β-ocimene.

	Peroxides		Ascaridole
	Furans		Agarofuran, Menthofuran.
Other compounds	Inorganic compounds		Hydrocyanic acid.
	Nitrogen compounds		Methyl anthranilate, indole, pyrazine, skatole, pyridine.
	Sulphur compounds		Allyl propyl disulfide, dimethyl disulphide, methyl disulphide.

The various plant parts that can be used to make essential oils include the flowers (rose, ylang-ylang, clove), seeds (fennel), leaves (peppermint, lemongrass), fruits (lemon, orange), root and rhizomes (ginger, vetiver), wood (cedarwood), bark (cinnamon), gum (frankincense), bulbs (garlic), etc. (Tisserand, R., et.al., 2013). They have been there for a while, but their motivation and inherent abilities in day-to-day life have boosted their research and experimental activities. Essential oils must first be collected from plants before they may be utilised or studied. There are numerous techniques for extracting essential oils from aromatic plants, including hydro-distillation, steam-distillation, supercritical CO_2 extraction, microwave hydro-diffusion and gravity, solvent extraction, microwave-assisted extraction, high-pressure solvent extraction, enfleurage and solvent-free microwave extraction (Farhat, A., et.al., 2010; Okoh, O.O., et.al., 2010). For the industrial extraction of essential oils, steam-distillation is the technique of choice (Masango, P., 2005). Distillation is typically performed using the Clevenger or Dean-Stark, which involves constantly heating and mixing in water or solvent. (Moghaddam, M., et.al., 2017). Depending on the variety of plant material, distillation takes three to four hours (Dhifi, W., et.al., 2016). The main technique used to investigate the characteristics of essential oils and their makeup is gas chromatography/mass spectrometry (GC-MS). Acquiring precise and thorough information on chemical constituents helps researchers to explore the qualities of essential oils more thoroughly since chemical constituents are the key parts determining the varied properties of essential oils. (Chen, K., et.al., 2020).

At least 2,000 plant species, of which 300 are significant commercially, have yielded about 3000 essential oils (Djilani, A., et.al., 2012). These oils exhibit antioxidant, antiproliferative, and antibacterial activity, and are widely utilised in medicine, cosmetics, and perfumes due to their pleasant aroma (Pasias, I.N., et.al., 2021). By inhibiting the growth of pathogen organisms (Pasias, I.N., et al., 2021), or by exhibiting effectiveness against antibiotic-resistant bacteria and chemotherapy resistant tumours (Viktorová, J., et al., 2020), they have shown beneficial in a range of applications. They may also serve as alternatives to antibiotics (Chaves, A.V., et. al., 2008). They are also used to provide flavour and fragrance in the food and cosmetics industries, where several herbal and spice ingredients are components in the production of shampoos, skin creams, soaps, perfumes, and lip balms (Safrudin, I., et.al., 2015). The purpose of this literature review is to examine the yield, makeup, and applications of the various plants' essential oils (Table 2).

Table 2. Extraction yield, composition, and aroma profile of essential oils.

S. No.	Name of plant	Part used for oil extraction	*Oil extraction method	Yield (%)	Major chemical molecules	Aroma profile	Use	Ref.
1.	*Rosmarinus officinalis* L. (Rosemary)	Whole aerial parts.	HD	1.02 %	23.9-33.2% Camphor; 20.4-23.9% 1,8-cineole; 8.5-14.4% α-pinene; 6.9-10.1% verbenone; 3.5- 6.9% camphene; 2.3-2.8% limonene; 2.5-3.2% β-pinene; 1.9-2.8% α-terpineol; 1.7-2.5% borneol and 0.9-2.0% linalool.	Woody, camphor fragrance	Perfume, cosmetic, pharmaceutical foodstuffs, food flavouring, antimutagenic, antibacterial, antioxidant, and chemo-preventive.	Verma, R. S., et.al., 2020.
2.	*Thymus serpyllum L*. (Thyme)	Whole aerial parts.	HD	0.22%	58.8% Thymol; 5.7% p-cymene; 4% thymol methyl ether; 3.8% borneol; 3.4% sabinene; 3.4% γ-terpinene and 3.2% carvacrol methyl ether.	Spicy odour	Antiviral, antifungal, anti-parasitic, antioxidant, and antimicrobial activities.	Verma, R. S., et.al., 2011.
3.	*Achillea millefolium* (yarrow or milfoil)	Whole aerial parts.	HD	0.70%	17.58% sabinene; 13.04% 1,8-cineole; 12.41% borneol; 7.98% bornyl acetate; 6.28% α-	Sweet, warm/cool, pungent, earthy	Medicines, lotions, and ointments.	Nadim M.M., et.al., 2011.

					pinene; 6.26% β-pinene; 6.17% terpinine-4-ol and 5.28% chamazulene.			
4.	*Cymbopogon citratus* (Lemongrass)	Whole aerial parts.	SD	0.35 to 0.6%	25–53% geranial; 20–45% neral; 1.3–7.2% caryophyllene oxide and 0.3–2.2% *t*-caryophyllene.	Lemony scent strong, sharp, pungent & fresh – grassy herbaceous or tea like odour.	Pharmaceutical, perfumery, cosmetics, pesticides, antifungal, and antibacterial.	Zheljazkov, V. D., et.al., 2011
5.	*Citrus limon* L. (Lemon)	Fruit peel	HD	0.41 %	55.4% limonene; 10.39 % neral; 6.43% *trans*-verbenol; 3.25 % decanal; 2.21% ethyl cinnamate; 2.21% ethyl p-methoxycinnamate; 1.6% *cis*-bergamotene; 1.48% geraniol; 1.33 % *trans*-carveol; 1.19% nonanal; 1.16 % linalool; 1.07 % α-terpineol.	Fresh and elegant lemon	Food, pharmacological, in cure of piles, ulcers, scurvy, and urinary infections.	Paw, M., et.al., 2011.
6.	*Ocimum basilicum* L. (Basil)	Stems, leaves, and flowers.	SD	0.40% - 0.75%	30-38% linalool; 8–30% eugenol; 0.5-3% δ-cadinene; 0.8-1.3% iso-bornyl acetate;	Herb sweet, fruit, lemon	Food, pharmaceutical, cosmetic, and aromatherapy	Zheljazkov, V. D., et.al., 2008.

					camphor; trans-caryophyllene and methyl eugenol.		industries.	
7.	*Coriandrum sativum* L. var. *microcarpum* (Coriander)	Seeds	HD	0.31-0.43%	63.5-71.0% linalool; 6% hexa decanoic acid; 7.7 -3.4% tetra decanoic acid; 3.2% geranyl acetate.	Warm, mild sweet, and aromatic flavour.	Flavouring sweets, tobacco products, beverages baked goods, and ingredient for curry powder.	Telci, et.al., 2006; Priyadarshi, et.al. 2014.
8.	*Foeniculum vulgare* Mill. (Fennel)	Leaves	HD	0.65% - 2.03%	41.19-56.61% trans-anethole; 0.21-4.18% *cis*-anethole; 1.7-10.23% fenchone; 11.5-31.7% limonene; 0-13.4% α-phellandrene; 0.61-16.89% α- pinene and 1.24-5.9% β-ocymene.	Aromatic, spicy odour	Flavouring of food stuffs such as liqueurs, bread, etc., in cosmetic and pharmaceutical products.	Rahimmalek, et.al., 2014.
9.	*Amomum subulatum* Roxb. (Large cardamom)	Seeds	HD	0.98-1.95%	50.55-60.46% 1,8-cineole; 14.88-16.48% *α*-terpineol; 5.49–11.76% limonene; nerolidol; 2.6–5.39% 4-terpineol; 2.86–3.35% *δ*-terpineol; 1.22-2.18% *δ*-3-carene; 1.16–2.36% *β*-myrcene; 0.52–	-	Flavouring of food, beverages, confectionery, and cosmetics, medicine for gastric ulcers and gastrointestinal disorders, as a liver tonic, hypnotic,	Joshi, et.al., 2013

					2.28% germacrene D; 0.7–1.14% α-terpinene and 0.32–1.5% longifolenaldehyde.		appetizer, etc.	
10.	*Cotula cinerea* (Guertofa)	Aerial parts (leaves and stems)	HD	0.282 %	24.01% (E)-citral; 18.26% limonene epoxide; 15.04% thymol methyl ether; 15.03% carvacrol, 13.79% trans-carveol; 3.06% carvone and 2.54% trans-piperitol.	-	Medicine for diseases like cough, colic, diarrhoea, digestive disorders and headache.	Djellouli, et.al., 2015.
11.	*Anethum graveolens* L. (Dill)	Flower, herbs, and fruits.	HD	Flower (0.36 %), herb (0.90 %) and fruit (3.61 %).	*Herb oil*: 21.83 % α-phellandrene; 20.85 % carvacrol; 18.96 % limonene; 12.31 % 3,9-oxy-*p*-menth-1-ene; 8.40 % carvone; 7.11 % myristicin and 3.34 % p-cymene. *Flower oil*: 23.24 % myristicin; 22.04 % carvacrol; 18.93 % carvone; 11.2% limonene; 7.59 % 3,9-oxy-*p*-	Odor of the fruit and a hot, acrid taste	Flavouring in foods, antimicrobial and antioxidant activities and pharmacological properties.	Dimov, et.al., 2019.

					menth-1-ene; 6.5% *α*-phellandrene and 4.63 % dihydro-carvone. *Fruit oil*: 33.57 % carvone; 24.21 % myristicin; 15.02% limonene; 13.13 % dihydro-carvone and 4.92 % carvacrol.			
12.	*Petroselinum crispum* Mill. (Parsley)	Leaves	HD	0.28%	26.41% myristicin; 11.61% β-phellanderene; 10.54% α-phellandrene; 9.41% 1,3,8-p-menthatriene; 8.63% p-cymene; 6.12% myrcene; 1.79% α-pinene and 1.09% p-cymene.	Sweet, warm spicy scent	Fragrance for perfumes, creams and soaps.	Farouk, et.al., 2017.
13.	*Mentha piperita* L. (Peppermint)	Aerial part (mixture of leaves and inflorescences)	HD	3.24–4.01%	48–50 % menthol; 8-10% menthone, 18.51–19% iso menthone; 8–18% menthyl acetate; 0.24% 1.8-cineole and 0.16-0.14% pulegone.	Cooling, minty, sweet fresh	Astringent, antiseptic, antipyretic, antispasmodic, and antimicrobial properties.	Shelepova, et.al., 2017.
14.	*Lavandula*	Leaves	HD	4.58%	36.62% 1,8-	-	Antibacter	Fernánde

	latifolia Medik. (Spike lavender)	and flowers.			cineole; 26.74% linalool; 17.23% camphor; 2.36% borneol; 0.88% α-terpineol.		ial, antifungal, sedative and antidepressant properties, in aromatherapy, phyto-therapy, and perfume industry.	z, et.al., 2020
15.	*Syzygium aromaticum* (Clove)	Bud	HD	14.45 %	72.4% eugenol; 12.61% β-caryophyllene and 9.59 % eugenyl acetate.	Spicy, warm scent.	Disinfect the body, toothpaste, soaps, perfumes, cigarettes, and relieve toothache.	Safrudin, et.al., 2015.
16.	*Zingiber officinale* Roscoe (ginger)	Rhizome	HD	1.2%	46.71% zingiberene; 7.61% valencene; 3.09% β-funebrene; 1.03% selina-4(14),7(11)-diene; 19.34% citronellyl *n*-butyrate; 3.7% β-phellandrene; 2.59% camphene and 1.09% α-pinene.	Fresh, warm, woody, sweet bright top note spicy lemon-lime woody-balsamic - sweet base note.	Flavouring agent and herbal remedy to cure diseases such as nausea, vomiting, asthma, palpitation, etc.	Sharma, et.al., 2016.
17.	*Salvia officinalis* L. (Sage)	Aerial part	HD	1.11-2.76%	21.43-40.1% α-thujone; 2.06- 7.41% β-thujone; 11.31-	Warm camphoraceous, thujone-	Possess carminative, antispasm	Raina, et.al., 2013.

					37.67% camphor; 4.47 -9.17% 1,8-cineole; 4.58-9.51% α-humulene; 1.89 -7.04% camphene; 2.14-5.56% viridiflorol; 1.55 -6.17% α-pinene; 1.68 -3.49% β-pinene and 1.06-5.59% β-caryophyllene.	like odour.	odic, antiseptic, and astringent properties.	
18.	*Eucalyptus dives*	Leaves	SD	2.97%	40.5% piperitone; 17.4% α-phellandrene; 8.5% p-cymene and 4.7% terpin-4-ol.	Strong, herbaceous, woody & minty	Heal wounds and fungal infections, food additives, cosmetics.	Gilles, et.al., 2010.
19.	*Melissa officinalis* L. (Lemon balm)	Aerial part	HD	0.18 %	6.84–7.78 % geranial; 3.02–3.52 % neral; 1.67–5.36 % piperitenone oxide and 1.54–2.15 % caryophyllene oxide.	Lemony, fresh, herbaceous scent.	Medicine for gastric conditions, insomnia, migraines, hypertension and anxiety.	Ilić, et.al., 2021.
20.	*Dracocephalummoldavica* L. (Moldavian balm)	Aerial part	HD	0.43-0.57%	20.89-42.13% geraniol; 12.57-26.6% geranyl acetate; 16.74-24.67% geranial; 15.33-21.04% neral and 1.1-3.1% neryl acetate.	-	Food flavouring, pharmaceutical and cosmetic	Vafadar, et.al., 2019.

21.	*Ruta Montana* (Clus.) L	Aerial parts	HD	Sub-humid Region: 1.0 % semi-arid region: (4.5 %).	*Sub-humid region*: 60.1 % 2-undecanone; 8.6% 2-nonanone; 6.4 % monoethylhexyl phthalate; 6.2% decanone. *Semi-arid region:* 90.4 % 2-undecanone; 4% 2-nonanone; 1.4% decanone.	-	As a cure for emmenagogue, and echarrotic powder, antifungal, antioxidant, depressant, and anti-inflammatory.	Amar, et.al., 2012.
22.	*Cinnamomum. zeylanicum (C*innamon)	Bark	HD	1.3%	62.09% cinnamic aldehyde; 11.56% para methoxy cinnamic aldehyde; 6.98% alpha-copaene and 4.32% α-murolene.	-	Perfumes, soaps, toothpaste, flavouring agent for liquors and medicine.	Kamaliroosta, et.al., 2012.
23.	*Origanum vulgare (*Oregano)	Flowers and leaves	HD	2.7% (Krib population). 4.3-4.8% (Nefza population),	p-cymene, γ-terpinene, thymol, and carvacrol	Pale-dark yellow	Antimicrobial, antifungal, insecticidal, and antioxidant activities.	Mechergui, et.al., 2016.
24.	*Satureja bachtiarica* Bunge (Bakhtiari savory)	Aerial parts	HD	1.4%	14.03% p-cymene; 12.65% γ-terpinene; 2.71% linalool; 28.61 thymol;	-	Antibacterial, antifungal, antioxidant, and immune-	Memarzadeh, et.al., 2015.

					24.98% carvacrol and 2.713% β-caryophyllene.		modulatory effects.	
25.	*Aquilaria malaccensis* Benth. (Agarwood oil)	Wood	HD	0.2%	32.1% 4-phenyl-2-butanone; 6.5% jinkoh-eremol and 5.8% α-guaiene.	Oriental-woody and very soft fruity-floral notes.	Potential income-generating crop, improves digestion, stress relief.	Tajuddin, et.al., 2010.
26.	*Carum copticum* (Ajwain)	Aerial parts	HD	2.8%	49% thymol; 30.8% γ-terpinene; 15.7% p-cymene and 2.1% β-pinene.	-	Therapeutic effects include analgesic, diuretic, anti-dyspnea effects and antiasthma.	Khajeh, et.al., 2004.
27.	*Cladanthus mixtus* Chevall (Moroccan chamomile)	Whole aerial parts	HD	0.1-0.8%	14–27% camphor; 3–17% β-myrcene and 3–15% santolina triene.	Aromatic herbal fragrance with green and spicy nuances	Medicine, perfume and pharmaceutical industries.	Elouaddari, et.al., 2013.
28.	*Piper longum* Linn. (pippali)	Stem, root, fruit.	HD	fruit (0.1 %), root (0.054 %), stem (0.026 %).	*Fruit:* 43.1% β-pinene; 0.7% camphene; 15.3% α-pinene; 9.6% limonene. *Root:* 26.4% β-pinene; 13.9% camphene; 11.8% α-pinene; 6.3% limonene. *Stem:* 34.8% β-pinene; 6.6%	-	Used as a carminative, treatment of inflammation and respiratory tract diseases.	Varughese, et.al., 2016.

					camphene; 14% α-pinene and 10.3% limonene.			
29.	*Pimpinella anisum* (Anise)	Fruit	HD	1-5.36 %	Trans-anethole (76.9–93.7%), methyl chavicol (0.5–2.3%), anis aldehyde (0–5.4%), γ-himachalene (0.4–8.2%), and pseudoisoeugenyl 2-methylbutyrate (0.4–6.4%).	-	Perfumes, toothpaste, food processing, and medicine.	Orav, et.al., 2008.
30.	*Melaleuca alternifolia (*tea tree)	Leaves	HD	1.05 %	21.64 % α-pinene; 21.09 % γ-terpinene; 17.31 % terpinen-4-ol; 9.37 % limonene and 6.54 % o-cymene.	Fresh camphoraceous	Antibacterial, antifungal, antiviral, and antiprotozoal activities.	Sevik, et.al., 2001.
31.	*Mentha spicata* L. (spearmint)	Aerial plant	HD	0.566 %	76.65% carvone; 9.57% limonene; 1.93% 1,8-cineole.	Minty	Food, cosmetics, confectionery, toothpaste, and pharmaceutical industries.	Chauhan, et.al., 2009.
32.	*Citrus bergamia* Risso (Bergamot)	Fruit peel	HD	9.7%	59.21% limonene; 9.51% linalool and 16.83% linalyl acetate.	-	Cosmetic, pharmaceutical and food industries.	Bouzouita, et.al., 2010.
33.	*Citrus paradisi* Macf.	Leaves	HD	0.04% – 0.30%	1.3–60.2% sabinene; 2.4–56.1% γ-	Orange-tinted, citrus-	Aromatherapy, medicinal	Paoli, et.al., 2016.

	(Grapefruit)				terpinene; 3-30.9% β-pinene; 0.3–17.3% terpinen-4-ol; 3.7–15% *(E)*-β-ocimene; 12.5% p-cymene; 0.9–12.0% linalool; 0.2–5.6% citronellal; 2.3–3.8% limonene; 1.1–3.8% α-pinene and 0.8–3.6% myrcene.	scented	benefits.	
34.	*Cymbopogon winterianus* (Java Citronella)	Leaves	SD	0.79%.	29.15% citronellal; 22.52% geraniol; 7.43% citronellol; 2.63% geranyl acetate; 6.52% neral; 5.2% geranial; 1.92% elemol and 1.27% limonene.	Citric, fresh, lemongrass	Cosmetics, flavouring, and perfumery industry, therapeutic properties, anti-fungal property.	Singh, et.al., 2017.
35.	*Cyperus articulates* (priprioca or piriprioca)	Rhizome	HD	0.5-1%	0.7-12.9% α-pinene; 7.3-14.5% mustakone and 4.6 -28.5% caryophyllene oxide.	-	Treat many diseases, effective against *Pseudomonas aeruginosa* and *Staphylococcus aureus*, treat dysentery,	Zoghbi, et.al., 2006.

							and headaches.	
36.	*Artemisia annua* (sweet sagewort, sweet Annie, annual wormwood, sweet wormwood)	Shoot	HD & FDU	0.35% (HD) and 0.26% (FDU).	*HD oil:* 36.6% camphor; 11.1% 1,8-cineole; 5.7% β-caryophyllene and 5.9% germacrene D. *FDU oil:* 23.6% camphor; 16.6% β-caryophyllene; 5.4% α-humulene and 17% germacrene D.	-	Perfumery, cosmetics, aromatherapy, pharmacological, antioxidant, antibacterial, and antifungal.	Rajeswara, et.al., 2014.

* HD=Hydro distillation, SD= Steam distillation, FDU= Field distillation unit

Conclusion

This review describes the essential oil yields, major component percentages, extraction techniques used, aroma profile, and various applications, such as cosmetics and food preservatives, from aromatic plants like peppermint, rosemary, thyme, coriander, lemon, basil, fennel, grapefruit, tea tree, etc. The ability to produce essential oils that are intense in compounds known for their biological activities under ideal conditions requires an understanding of these factors, and the findings of this research are of great interest to the industries, scientists, and new entrepreneurs who produce essential oils and make other products.

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