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Nature, Production and Quality of Essential Oils of Pepper, Ginger, Turmeric, Cardamom and Tree Spices

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Essential oils are defined as the volatile oils obtained by steam or hydro distillation containing variety of organic compounds generally belonging to class of acyclic, isocyclic hydrocarbons, tri-and sesquiterpenoids and their oxygenated derivatives. Four distinct groups of compounds associated with essential oils are terpenes related to isoprene or isopentene; straight chain compounds not containing any side branches; benzene derivatives and their analogues and miscellaneous compounds containing sulphur and nitrogen (Guenther, 1972). The main spice products which are often referred to the quality of spices are the oleoresin and essential oils, the former containing essential oil moeity also along with non-volatile resinous matter (Sankary Kutty et al., 1982). Nature of chemical compounds in essential oil vary from nitrogen and sulphur containing aromatic compounds e.g. allyl isothiocyanate in garlic; derivatives of benzene e.g. myristicin in nutmeg oil; terpenes e.g. α-pinene in pepper oil and the oxygenated derivatives of terpenoids e.g. citronellol in the cytronella grass. Terpene class of compounds are more related to the flavour notes of essential oils. Depending upon the number of isoprene units (5 carbon chain compounds) these are designated as mono, di, tri and tetra terpenes. If the isoprene units are more than 8 they are called polyterpenes. Different terpenoid compounds, their organic nomenclature, the plant source and the number of isoprene units in each class of compounds are presented in table 1. All the essential oils contain terpenes and their oxygenated derivatives. Elucidation of the structure of an unknown essential oil or the chemical composition of essential oils of the existing spices, is complicated. However, the chemical composition of any essential oil is invariably accomplished by Gas chromatography. Different workers used different types of columns and gas chromatographic conditions for chemical composition studies. Masada (1976) has employed capillary glass columns with authentic samples and standard mixture, and studied a variety of essential oil containing species.

In different spices the essential oil bearing part varies and it is economically more appropriate to use that particular plant part containing maximum essential oil content. The

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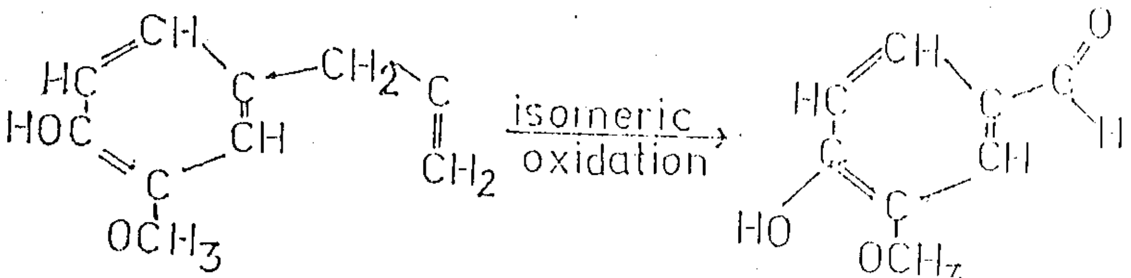
important major spices grown in India with their botanical and common names and the plant parts used for volatile oil extraction are presented in table 2.

The data generally concerning the essential oil composition and its relationship to flavour quality of spices is restricted. The flavour quality is due to complex nature of tri and sesqui terpenoids and their oxygenated derivvatives. The role played by aromaticity of benzene and its analogues add to the flavour note of the spice oils. The precursory nature of hydroxy methoxy and methylene dioxy groups connected to propyl side chain of benzene contribute to aroma profile of spices (Guenther 1972). The number of compounds that undergo transformational changes from simple chemical reaction to complex multiple degradation, isomerisation and polymerisation give rise to flavouring principles. The following are the examples of each type of reaction involved in aroma enrichment of essential oils.

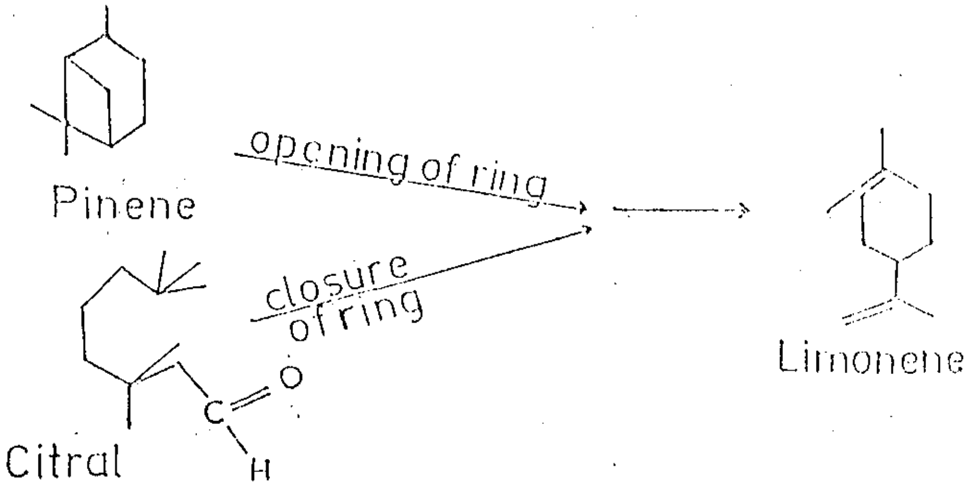
(a) Isomerisation



(b) Polymerisation

n(cinnamaldehyde) (thin, light fluid mellow, pleasant and desirable flavour notes) --- Polymerisation ---> (Cinnamaldehyde)n Thick viscous liquid with off notes.

(c) Specific chemical reaction involving synthesis of chemical compounds



Besides the chemical reactions suggested, the secretion products in metabolic processes *in vivo* add to the flavour of essential oils and cause complexity to chemical composition of volatile oils. Hence it is difficult to attribute the nature of flavour to a single or a group of chemical compounds. It may be inferred that flavour quality of essential oils is cumulative effect of chemical reactions, metabolic processes and degradative changes with and without oxidation.

The selection of the plant part for extraction of essential oils is based on the location of the cells in which the oil is deposited. Specific staining procedures to differentiate the volatile oil cells from fatty oils is advantageous for the above purpose. Sudan blue and osmic acid stain those cells which are chemically more active than the unsaturated hydrocarbons and alcohols. Phloroglucinol hydrochloride stains phenols and fuchsin indicating the presence of aldehydes. Mostly they are located in between cuticle and rest of the cell wall (Narayanan et al. 1985). In pepper berries the essential oil has been located in the inner portion of the skin (Mangalakumari and Mathew, 1986).

For effective essential oil production the material is packed in a still and brought to boil. Due to the influence of hot water and steam the essential oil is freed from oil glands in the plant tissue. The vapours emerging out of the powdered spice material are condensed by external cooling usually with cold water. In laboratories the volatile oil is extracted by hydro distillation in Clevenger's still. In industrial extraction, the steam is passed through the powdered spice material and the distillate along with water flows into a receiver where oil separates automatically by fixed oil water separator (Govindarajan et al. 1977).

In the present review, a detailed account of essential oils of pepper, ginger, turmeric, cardamom and tree spices is presented which account for bulk of the major spices grown in India

OIL OF BLACK PEPPER (*Piper nigrum* L.)

Black pepper oil is either a colourless or a slightly greenish liquid with characteristic odour of pepper and phellandrene, one of the principal constituents of the oil. The taste of the oil is mild. In the west, pepper oil is a valuable adjunct in the flavouring of sausages, meat, table sauses and bewerages (Guenther, 1972). The oil is also used in perfumery (Pruthi, 1976). Prior to distiliation, the berry is crushed to fine powder, and distilled immediately. The physical and chemical constants and chemical composition are presented in table 3. Among these compounds, the varieties which contain more pinenes have undesirable turpentine like odour and those which have high mono-terpenes like limonene and sesquiterpenes like caryophyllene have pleasing odours (Pangborn and Jennings, 1970 : Richard, Russel and Jennings, 1971). There is wide variation in mono and sesquiterpene hydrocarbons in different cultivars (Table 4). Objective and subjective techniques for describing flavour qualities of black pepper essential oil has been attempted by Pangborn et al. (1970). They have fractionated the aroma of pepper oil into groups of compounds and evaluated the difference from original to reconstituted mixture of selected components. The major components range from piney, lemony, rubbery, woody to peppery, spicy, sweety, musty, unpleasant, medicinal:

acidic and phenolic. For a sensory evaluation, this can form a scale and relative grading of oil can be done on a rather subjective basis. Russel (1968) and Lewis et al. (1969) have shown the presence of a major component of essential oil, the terpenes. While the terpenes contributed to top notes, oxygenated fractions contribute to the characteristic odour of the volatile oil of pepper (Govindarajan, 1977).

The volatile oil levels in popular pepper cultivars are presented in table 5. The volatile oil in popular pepper varieties are reported by Ravindran and Nair (1983) indicated that a cultivar Balankotta exclusively grown in North Kerala has highest oil content of 5.1% and the only hybrid pepper Panniyur-1 has 3.5% oil. In a study on the levels of oil in relation to the maturity, Krishnamurthy et al. (1972) found that the oil content varied from 2-3.5%, the highest content being in the immature pepper berries. However, Sumathikutty et al. (1984) has reported the essential oil composition of pepper at six developmental stages, which shows the immature berries having the least oil (1.75-2.0%) with sesquiterpenes and higher polar compounds as the main components (82-88%) while the later developmental stages yielded 2.5-4.25% oil with 47-64% monoterpenes and 30-47% sesquiterpenes and rest higher polar compounds. The economics of extraction of pepper oil depend on the price of the raw material and yield of products (Lewis et al., 1975). The oil extracting industry should choose a cultivar and appropritate stage of maturity containing high oil content. Pepper oils are blended in different proportions depending upon the chemical composition.

GINGER OIL
(Zingiber officinale Rosc.)

Ginger oil representing characteristic aroma of ginger is generally obtained by steam distillation of the fresh coarsely powdered spice. Unlike pepper and cardamom, ginger takes a longer time for distillation of oil probably because of the presence of larger amounts of high boiling constituents. Even though fresh ginger oil is preferred due to its 'lemony odour', handling of bulk material and slow release of oil are certain technical difficulties. Mathew et al. (1973) reported the presence of high curcumene and lower zingiberene contents in fresh ginger as compared to dry ginger. Salzer et al. (1975) indicated the presence of arcurcumene in fresh ginger oil which is formed on storage due to conversion of zingiberene and β-sesquiphellandrene the main flavour components of freshly prepared oil. Hydrocarbons, alcohols, carbonyls, esters and other analogues are found in ginger oil and are presented in table 6. (Purseglove et al. (1981). The contribution of these compounds individully and in combination to the aroma of ginger oil, is yet to be established. β-sesquiphellandrene, β-sesquiphellandrols and some of the mono sesquiphellandrols and some of the mono sesquiterpene analogues appear to be specific to ginger but their individual role in aroma is yet to be established. Some of the carbonyls and the alcohols are known to contribute to lemony, camphory and flowery notes (Govindarajan, 1982). Salzer (1977) reported the major group of compounds present in ginger oil and suggested citral and citronellyl acetate as important co-determinants of odour.

The age of the oil which can be determined by the ratio of zingiberene + β-sesquiphellandrene to ar-curcumene may probably be the limiting factor of the quality of oil. The significance of individual components in the volatile oil to the total aroma is now established (Govindarajan, 1982). However, the threshold values of these components which contribute to the specific odour is yet to be determined. Badnarezyk and Kramer (1975) have correlated the sensory profile of ginger oil to chemical composition and attributed β-sesquiphellandrene and ar-curcumene to characteristic aroma of ginger, terpeneol, citral-a, citral-b to lemony flavour; Nerolidol to woody or soapy odour.

The physical, chemical constants and chemical components of ginger oil are presented in table 7 (CRC Reviews, 1982). Damayanti **et al.** (1982) attempted to extract oil in fresh ginger instead of dry ginger and reported 0.05-0.13% of essential oil on fresh weight basis. Compensating 90% of moisture in dry ginger, the fresh ginger oleoresin is found to give 30% of oil and is reported economical.

TURMERIC ESSENTIAL OILS

Out of the various turmeric species viz., **Curcuma longa** L., **Curcuma aromatica** Salisb; **Curcuma domestica** Valeton., **Curcuma xanthoriza** Roxb., **Curcuma amada** Roxb., **Curcuma caosia** Roxb., **Curcuma zedoaria** Roscoe., essential oil of **Curcuma longa** L. is economically important. In turmeric, oil is extracted as a by-product in curcumin extraction. As these oils interfere in pigment extraction, rhizomes are depleted of the oil by solvent extraction. Turmerol $C_{14}H_{20}O$ which is the main constituent of turmeric oil was studied by Jackson **et al.** (1982) and found it as an aromatic alcohol. This can be converted to -curcumone, a ketone by interaction of sodium methoxide and alcohol. Essential oils of other curcuma species are not produced in commercial scale. The physico chemical properties and chemical composition are presented in table 8. Natarajan and Lewis (1982) reported 3.5% of turmeric oil yields containing 60% of turmerones, 25% zingiberene and minute quantities of phellandrene, sabinene, cineol and borneol. As turmeric oil is not valued in the spice industry, the possibility of converting turmerones and zingiberenes into more useful flavouring substances is an economical proposition. However, the report of the antimicrobial property of turmeric oil by Banerjee and Nigam (1978) is significant in this context.

ESSENTIAL OILS OF CARDAMOM

Dried seeds in the cardamom capsules is the source material for essential oil of cardamom. Small cardamom **Elettaria cardamomum** Maton and large cardamom **Amomum subulaturm** Roxb., are the two main species from which the oil can be extracted. Since yield and chemical composition differ in both the species, they are dealt separately (CRC Reviews, 1982).

Small cardamom : Decorticated seeds of small cardamom are crushed and powdered. The powder is steam distilled for 3 hours to give easy flow of oil. The physico- chemical properties of the oil are presented in table 9.

The knowledge about the quality of cardamom oil is scanty. Narayana Pillai et al. (1984) suggested two major components, 1 : 8 cineole α-terpinyl acetate as the important ones. These are interlaced by other minor constituents which are yet to be related with the aroma and flavour (Pravatoroff, 1982). By the use of gas liquid chromatography these two important chemical constituents were monitored by Narayana Pillai **et al.** (1984). Based on the analysis of a number of samples from different geographical regions they found that Gautemalayan cardamom sample is having highest α-terpinyl acetate and lower 1 : 8 cineole. α-terpinyl acetate contribute to desirable flavour of cardamom whereas 1 : 8 cineole imparts harsh camphor like odour. Data on 1:8 cineole and α-terpinyl acetate in different types of cardamom are presented in table 10. Malabar and Alleppey types had higher proportions of α-terpinyl acetate than 1 : 8 cineole. Papua New Guinea cardamom is the most inferior one containing very high proportion of 1 : 8 cineole, and very little α-terpinyl acetate.

Optimum condition for the economic recovery of good quality oil, development of commercial still and the time required for complete distillation were worked out by Nambudri and Lewis (1968).

Large cardamom (AMOMUM SUBULATUM Roxb.) : Large cardamom oil obtained by distilling decorticated seeds by steam distillation for about 8 hours yielding 2.5% pale yellow oils (Lawrence, 1970). The physical properties and chemical composition of the oil are presented in table 11.

Composition-wise large cardamom oils differ from small cardamom oil and hence the former can not be equated to latter. Large cardamom oils have a limited use due to flat cineolic odour, very harsh aroma and inferior flavour (CRC Reviews, 1982).

ESSENTIAL OILS OF TREE SPICES

Nutmeg, clove and cinnamon are the major sources of essential oils among tree spices. Nut and the mace (the seed and aril) of nutmeg, flower buds of cloves and leaf and bark of cinnamon are sources of essential oil of the tree spices. Information on these oils is scanty.

Oil of nutmeg and oil of mace : The extraction of volatile oil from nutmeg and mace is done by steam distillation. The yield of oil varies according to the geographical distribution. Wormy nutmegs in commercial distillation give much better yield of oil than sound nutmegs for in the former the fixed oil has been derived by worming without affecting the strong aromatic principles. Sound nutmegs on the other hand retain the fixed oil and portion of volatile oil lowering its yield (Guenther, 1972). In the odour, flavour and physico-chemical properties the volatile oils of nutmeg and mace are so similar that trade rarely distinguishes them. Since mace is costlier than the nut, the essential oil is produced from nut and not from the mace.

Prior to distillation, nutmegs are powdered & the fixed oil is removed by hot pressing. This process is not economical as the fixed oil tends to lower the yields of oil. Incidentally, the broken and worm eaten nuts are economical due to their low price and depleted fixed oil. Gildemiester and Hoffmann (1972) observed that the yields of nutmeg and mace vary from 7% to 16% and 4% to 15% respectively (Guenther, 1972). The physico chemical properties of the oil are presented in table 12. Pinene and camphene account for 80% of the total oil whereas linalool, borneol, terpineol account for about 6% only. An aldehyde with citral odour is reported in traces by Power and Sahay (1907). Myristicin and elemene the known hallucinogenic principles in nutmeg are 4% and 8% respectively.

CLOVE OIL

The yield and the physico chemical properties of clove oil depend upon the distribution, quality of cloves and their condition prior to distillation and the type of distillation employed viz., water distillation, water and steam distillation or direct steam distillation. If whole cloves are employed, the forces of hydrodiffusion play a vital role and the first fraction of oil contains high eugenol levels. Water distillation gives clove oil with 81% eugenol, suitable for perfumery whereas dry distillation yields strong oils containing even 95% eugenol. The yields of oil from clove buds, clove stems and leaves are 17%, 6% and 3% respectively (Guenther, 1972). The physico chemical properties and chemical composition of oil from clove bud, stem and leaves are presented in table 13. Besides the compounds listed, some steroid glucosides (Narayanan and Natu, 1974) and phenolics (Vosgen et al., 1980) are also reported to be present in clove oil.

Volatile oil obtained at lower maturity stage of clove is found to have more eugenol acetate and less eugenol. In fully mature clove, 4 months after the onset of flowering, the eugenol acetate concentration decreases and eugenol increases. Clove oil from younger buds has mellow odour (Gopalakrishnan et al., 1982).

LEAF AND BARK OIL FROM CINNAMON

The leaves of the cut cinnamon stalks are removed prior to the preparation of the quills. Before being distilled the leaves are dried in shade. Approximately 1 cwt of leaf is loaded into the extractor and distillation is continued for 7 to 24 hours depending upon the region and quantity of leaves charged. A charge of 4 cwt normally yields 37 to 50 oz of leaf oil. Approximately 30 to 35 lbs of leaf oil are obtained from one acre of cinnamon plantation (Guenther, 1972). Florentine flasks separate the light oil from heavy oil. The distillation water is collected and used again to avoid any loss of oil. The method of distillation, condition of the chips, their age, presence or absence of outer bark are of importance not only to the yield of oil but also to the quality (Guenther, 1972). Usually Ceylon cinnamon bark contains 55% cinnamaldehyde and 18% eugenol.

The physico chemical properties and chemical composition of Ceylon cinnamon leaf and bark oils are presented in table 14. Leaf oil and bark oil in 189 Indian cinnamon and 102 Ceylon cinnamon accessions were evaluated (Anon. 1985). The leaf oil levels in Indian and Ceylon cinnamon are on par with each other; bark oil in indigenous collection is more than Ceylon accessions.

An attempt has been made to review current status of the researches on essential oils of spices. Although the essential oil industry established routes in our country over half a century back, the present review indicates two important aspects of the same viz., (i) although the technology of extraction of essential oils is not complicated the indigenous industry on the same is yet to make any marked contribution on the economy of our country, (ii) even though researches on extraction procedures have progressed well the fundamental information on the flavour characteristics and the components of the oil that contribute the same are yet to be investigated in detail in many spices crops.

Table 1 : Terpenoid compounds, organic nomenclature, plant origin and number of isoprene units in essential oil bearing plants.

Class of compound	Name of the compound	Plant origin	No. of isoprene units
Monoterpenes			
Acyclic	Myrsene	Oil of bay	2
Monocyclic	Citral	Lemongrass	2
	Lemonene	Lemon, orange peel	2
	β-phellandrene	Fennel	2
	Terpineol	Camphor	2
Bicyclic	Thujene	Turpentine	2
	α-and β-pinene	Turpentine	2
	Sentene	Sandalwood	2
	Camphene	Camphor	2
	Fenchone	Fennel	2
Sesquiterpenes			
Acyclic	Farnessol	Orange peel	3
Monocyclic	β-bisabolene	Cardamom	3
	Zingiberene	Ginger	3
	Curcumene	Turmeric	3
	Cadinene	Oil of cubes	3
	Selinene	Pepper	3
	Vetivone	Vetiver	3
Tricyclic			
Sesquiterpenes	Cedrol	Cedarwood.	3

Table 2 : Major, minor and tree spices with botanical and common names and parts used for essential oil extractions.

Botanical name	English common name	Part used
	MAJOR SPICES	
Piper nigrum L	Pepper	Berry
Elettaria cardamomum Maton.	Cardamom	Fruit & Seed
Zingiber officinale Roscoe	Ginger	Rhizome
Curcuma longa L.	Turmeric	Rhizome
Capsicum annuum & Fruitescens L.	Chillies or Capsicum	Fruit
	TREE SPICES	
Caryophyllus aromaticus L.	Cloves	Unopened Flower Bud
Myristica fragrans Houtt.	Nutmeg	Nut
	Mace	Aril
Cinnamomum zeylanicum	Cinnamon	Bark
Cinnamomum aromaticum	Cassia China or Cassia	Bark
	MINOR SPICES	
Pimpinella anisum	Aniseed	Seed
Carcum copticum	Bishop's weed (Ajwan)	Seed
Carum carvi L.	Caraway	Seed
Apim graveleus L.	Celery	Seed
Cariandrum sativum L.	Coriander	Leaf & Seed
Cuminum cyminum L.	Cumin	Seed
Anethum gravolens L.	Dill	Seed
Foeniculum vulgare Millér	Fennel	Fruit
Trigonella fóenum graecum L.	Fenugreek	Seed
Allium sativum L	Garlic	Bulb
Allium cepa L.	Onion	Bulb
Garcinia indica	Kokum	Peel of fruit
Crocus sativus L.	Saffron	Flower
Vannilla plantifolia Andr.	Vanilla	Pod
Mentha piperita	Mint.	Leaf
Murraya koeniqii	Curry leaf	Leaf
Brassica juncea & nigra	Mustard	Seed

Table 3 : Physical and chemical constants and chemical composition of pepper oil.

Specific gravity	0.864 to 0.884
Refractive index	1.4795 to 1.4880
Optical rotation at 25°C	-1 to -23°
Solubility	1 : 3 in 95% E to OH
Monoterpenes	α-thujene, α-pinene, camphene Sabinene, β-pinene, myrcene α-phellandrene, △3-carene, α-terpinene, p-cymene, β-phellandrene, limonene, 4-terpinene, terpinolene
Sesquiterpenes	α-cubebene, α-copaene, β-elemene, β-caryophyllene, β-salinene, β-farnosene, humelene, β-selinene α-selinene, β-bisabolene.

Table 4 : Per cent variation in mono and sesqui terpene hydrocarbons in pepper cultivars.

Hydrocarbon	Range of variation in percentage
Monoterpene	
Limonene	0-40
β-pinene	5-35
α-Pinene	1-19
α-phellandrene	1-27
β-Phellandrene	0-19
Sabinene	0-20
Carene	0-15
Myrcene	0-10
Sesquiterpene	
β-caryophyllene	9-33

Table : 5 Essential oil composition in black pepper cultivars and the region in which it is grown.

Variety	Region in which it is grown	Essential oil %
Karimunda	Central Kerala	4.0
Narayakodi	Kottanadan, Champakara	4.0
Kalluvally	North Kerala	3.2
Balankotta	North Kerala	5.1
Kottanadan	South Kerala	4.5
Kuthiravally	South Kerala	4.5
Kaniakkadan	Idukki	3.7
Arakulamunda	Central Kerala	4.7
Malligesara	North Karnataka	3.2
Panniyur-1	Hybrid, Whole Kerala	3.5

Table : 7 Physical, chemical constants and chemical composition of ginger oil.

Specific gravity	0.871 to 0.882
Refractive index	1.4880 to 1.4940
Optical rotation	+28° to—45°
B-zingiberene	35.6%
ar-curcumene	17.7%
Farnesene	9.8
Sesquiterpene alcohols	16.7%
Camphene, limoene, Cineole, β-phellandrene Citral-a, Citral-b, linalool and borneol	1%

Table : 6 Composition of essential oil of ginger.

Hydrocarbons	Alcohols	Carbonyls	Esters	Others
n-Heptane	α-terpineol	Acetaldehyde	Bornyl acetate	1,8-Cineole
n-Octane	cis-trans-β-sesquiphellandrol	Propionaldehyde	Methyl acetate	Diethyl sulfide
n-Nonane	Nerolidol	n-Butyraldehyde	Ethyl acetate	Ethyl-Insopropyl sulphide
α-Pinene	n-Propanol	n-iso-Valeraldehyde	Geranyl acetate	Methyl allylsulfide
β-Pinene	Sec-Butanol	Glyoxal		Cis-sesquisabinene hydrate
Sabinene	Nerol	Methylglyoxal		
Myrcene	2-Heptanol	Acetone		
Camphene	2-Nonanol	Methylheptanoae		
Limonene	Linalool	Nonyl aldehyde		
β-Phellandrene	Alcohol A	Decyl aldehyde		
Cumene	Alcohol B	Citral-a		
p-Cymene	Borneol	Citral-b		
Farnesene	Geraniol			
α-Sabinene	Zingiberenol			
β-Elemene				
α-β-Zingiberene				
β-Bisabolene				
ar-Curcumene				
β-Sesquiphellandrene				
Δ^3-Carene				
α-Terpinene				
Zonarene				
10-epizonarene				
Tricyclene				
Sesquithugene				

Table : 8 Physico chemical properties and chemical composition of essential oils of curcuma species.*

	Curcuma longa L.	Curcuma aromatica Salisb.	Curcuma amada Roxb.	Curcuma zedoaria Roscoe
Specific gravity	0.94	0.91	0.90	0.98
Optical rotation	-13 to 2.5°	-12°	-9 to -14°	8 to 17°
Refractive index	1.512	1.500	1.502	
Acid number	0.6 to 3.1	1.9	---	1.3
Ester number	6.5 to 16	2.03	---	1.3
Solubility	Soluble in 80% Alcohol			
	Phellandrene	Camphene		
	Sabinene	Curcumene		
	Cineole	Caprylic acid		
	Borneol		Pinene	Pinene
	Zingiberene		Ocimene	Camphene
	Turmerone		Linalool	Cineole
	Atlantone		Linalyl acetate	Borneol
			Safrole	Zingiberene

Table : 9 Physico chemical properties of the small cardamom Elettaria cardamomum maton.

Specific gravity	0.923 to 0.941
Optical rotation	+24° to 41°
Refractive index	1.452 to 1.461
Acid number	Upto 4.0
Ester number	92 to 150
Solubility	2 to 5 vol. or more of 70% Ethyl alcohol.
	Limonene, sabinene, cineole, α-terpineol, Terpinyl acetate, borneol. (Guenther, 1982)

Table : 10 1 : 8 cineole and α-terpinyl acetate in cardamom oils of different origin.

Origin	% 1 : 8 cineole	% terpinyl acetate
Gautemalayan	23.4	50.7
Mysore	49.5	30.6
Alleppey	34.2	37.7
Ceylon	36.0	30.0
Papua New Guinea	63.0	29.0

Table : 11 Physical constants and chemical composition of large cardamom oil.

Specific gravity	0.920
Optical rotation	—12° to 41°
Solubility	Clearly soluble in 1 and more volume of 80% Ethyl alcohol.
Chemical composition	
Hydrocarbons	α-pinene, β-pinene, myrcene, sabinene, α-terpinene, v-terpinene. Limonene, p-cymene,
Oxygenated compounds	1 : 8 cineole α-terpineolene terpineol, 4-terpineole, nerolidol.

Table : 12 Physico chemical properties of the volatile oil of nut and mace of nutmeg and the chemical composition.

	Nut	Mace
Specific gravity at 15	0.865 to 0.925	0.923 to 0.947
Optical rotation	+8 to +30	+2 to +11
Refractive index at 20°C	1.479 to 1.488	1.486 to 1.494
Acid number	Upto 3.0	2.0 to 3.9
Ester number	2 to 9	1.2 to 7.3
Chemical composition common to nut and aril of nutmeg	α-pinene, camphene, pinene, Dipentene, p-cymene Linalool α-terpineol, Borneol, α-terpinene-4-ol-, Geraniol, Safrole, Myristicin, Eugenol, Formic acid, Acetic acid, Butyric acid, Caprylic acid, A mono carboxylic acid : C_{13} $H_{17}O$ COOH, Myristic acid.	

Table : 13 The physico chemical properties and chemical composition of clove buds, stem and leaf oil.

	Volatile oil Buds	Clove stem Oil	Clove leaf Oil
Yield of oil	17.46%		
Specific gravity	1.051	1.050	1.054
Optical rotation	-0°32'	-0°36'	-1°20'
Refractive index	1.5318	1.5352	1.5379
Total phenol	91%	91%	88.5%
Solubility	1 vol. of 70% alcohol	1 vol. of 70% alcohol	1 vol. of 70% alcohol
	Eugenol Eugenyl acetate Caryophyllene Caryophyllene oxide Mythyl salcylate Methyl n heptyl ketone Valeraladehyde Methyl n amyl carbinol Furfuryl alcohol n-methyl furfural Methyl heptyl carbinol Methyl furfuryl acohol Dimethyl furfural Vanillin	Eugenol Eugenyl acetate β-caryophyllene furfural Mythyl alcohol Methyl amyl Napthalene	Same as stem oil

Table : 14 Physico chemical properties, chemical composition of Ceylon cinnamon leaf and bark oil.

	LEAF	BARK
Specific gravity	1.037	1.023 to 1.040
Optical rotation	-1°96' to -0°40'	Slightly laevorotatory
Refractive index	1.5288	1.581 to 1.591
Aldehyde content	4%	65 to 76%
Eugenol content	77.3 to 90.5%	4 to 10%
Solubility	1.5 volumes of 70% alcohol	2 to 3 volumes of 70% alcohol
	Dipentene	Methyl n amyl Ketone K
	Phellandrene	Furfural
	Pinene	Phellandrene
	Benzaldehyde	p-cymene
	Linalool	Benzaldehyde
	Geraniol	Nonyl aldehyde
	Borneol	Hydro cinnamic aldehyde
	Terpineol	Cinnam aldehyde
	Safrole	Cinnamic aldehyde
	Caryophyllene	Linalool
	Eugenol	Linalyl iso butyrate
	Cinnamyl alcohol	Eugenol
	Cinnamaldehyde	Caryophyllene
	Benzyl benzoate	
	Cinnamanol	
	Foliol	
	Combanol.	

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