Food Oils and Fats: Chemistry & Technology
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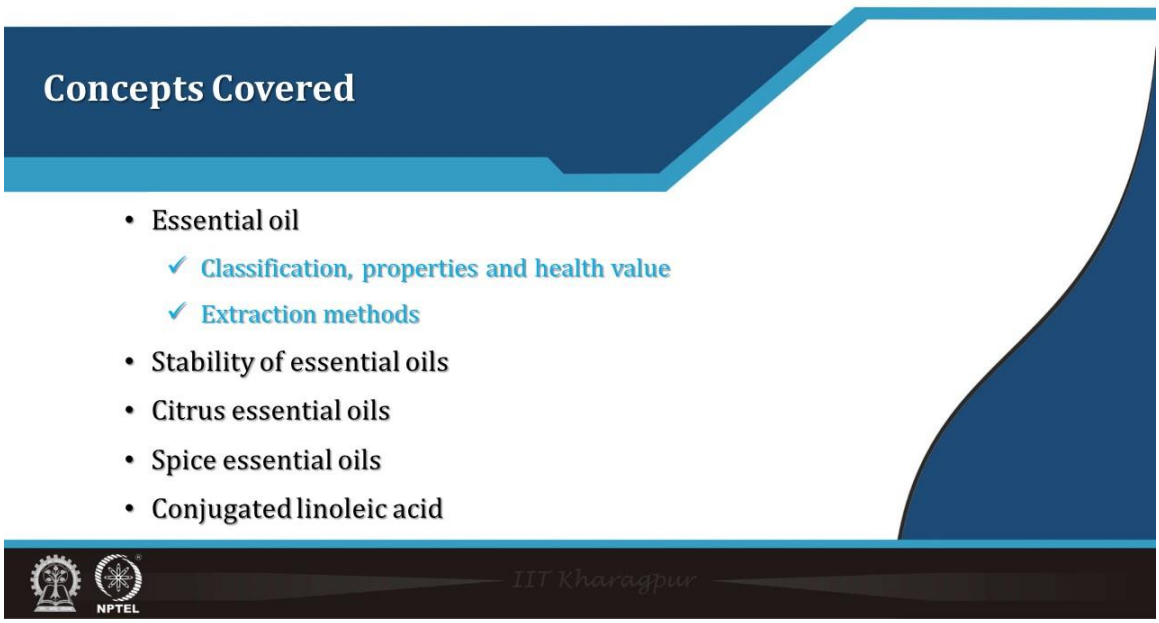
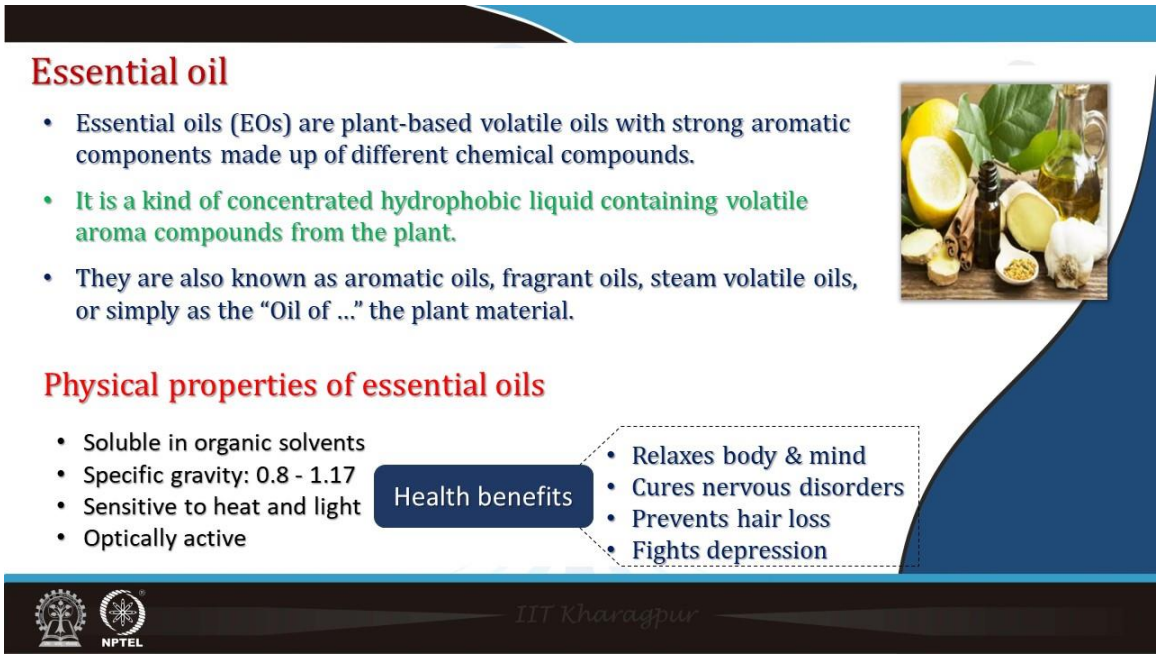
Indian Institute of Technology Kharagpur
Module 10 : Specialty Oils and Fats Products
Lecture 48 : Essential Oils

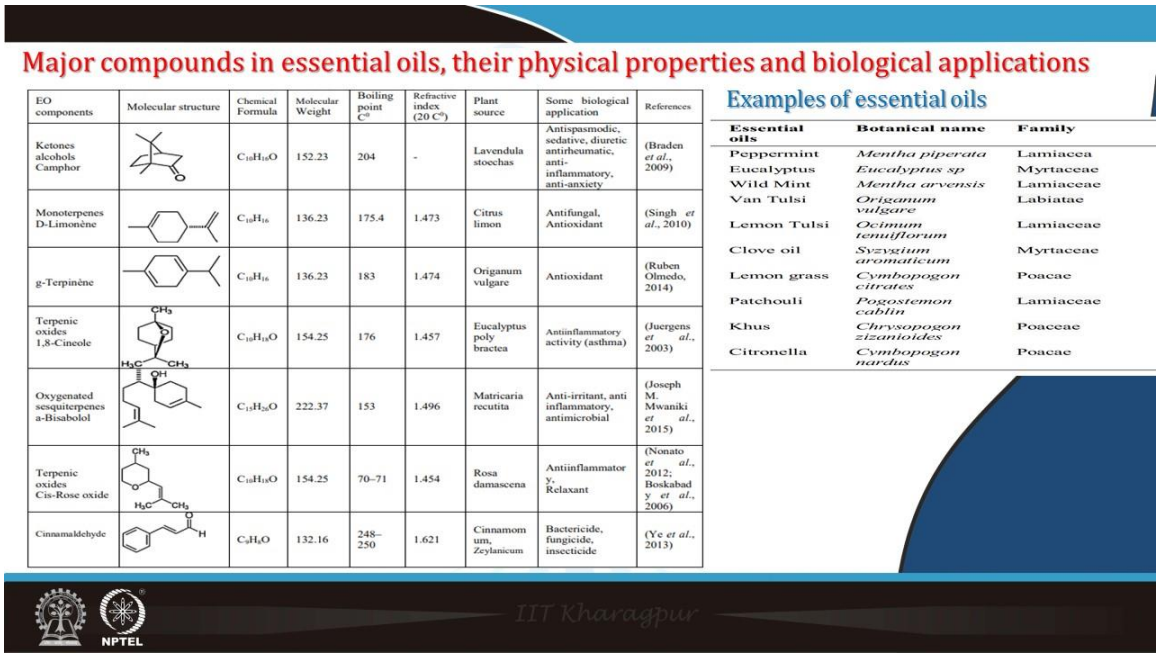


Hello everybody, Namaskar. Now we are in the 48th lecture of this course. Today in the next half an hour or so, in this class we will study essential oils. We will discuss characteristics, properties, classification, health value, and extraction methods for various essential oils. Also, we will discuss the stability of essential oils, then we will take

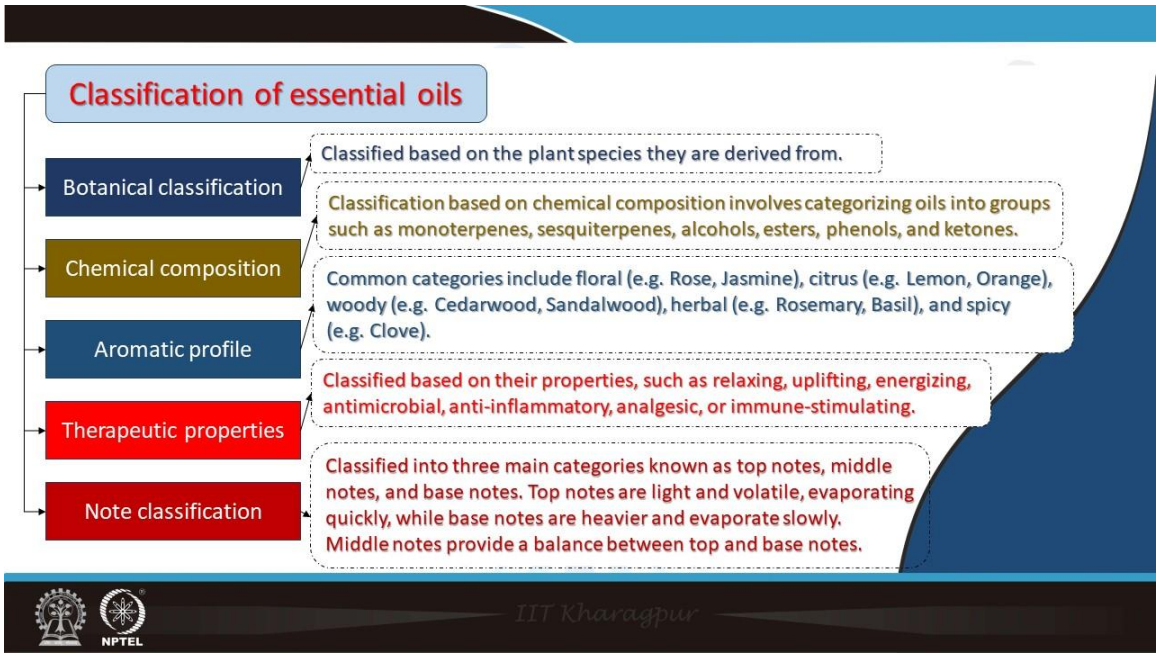
certain case studies and examples. We will talk about citrus essential oils, and spice essential oils, and finally, we will also briefly discuss conjugated linoleic acid which is commonly known as CLA.



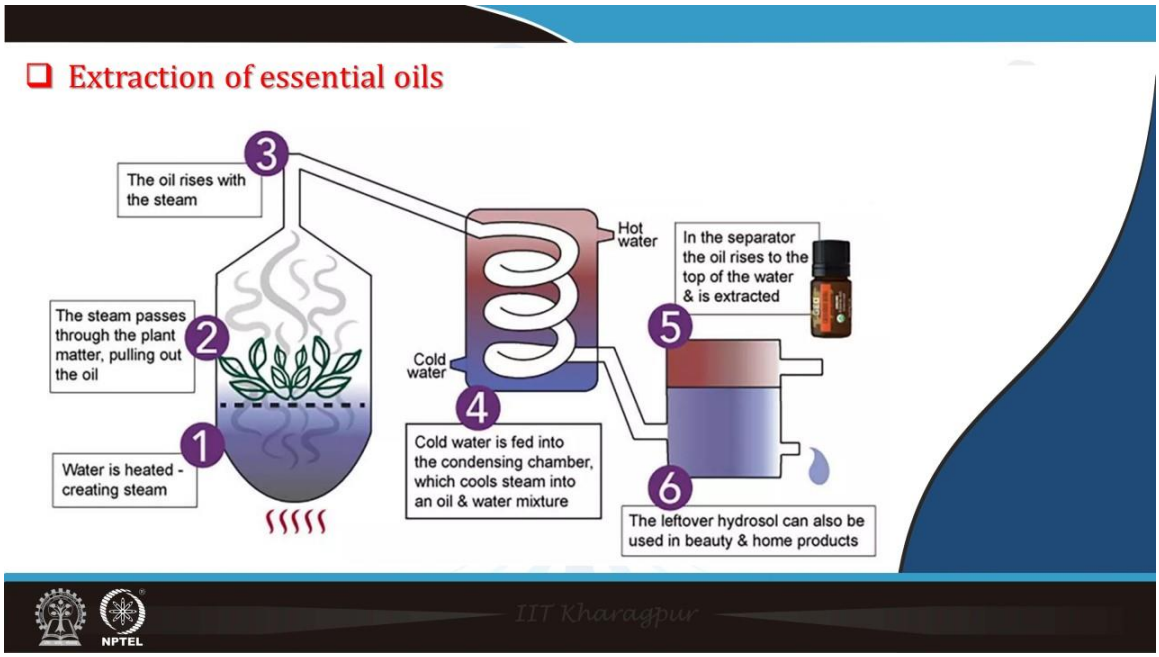
Essential oils (EOs) are plant-based volatile oils with strong aromatic components made up of different chemical compounds. It is a kind of concentrated hydrophobic liquid containing volatile aroma compounds from the plant. They are also known as aromatic oils, fragrant oils, steam volatile oils, or simply as the "Oil of …" the plant material. like oil of clove, ginger, lemon,, and so on. As far as the physical properties of essential oils are concerned, they are soluble inorganic solvents, they have a specific gravity in the range of 0.8 to 1.17, they are sensitive to heat and light and they are optically active compounds. The health benefits include relaxing body and mind, essential oils curing nervous disorders, it prevents hair loss, and fighting depression.



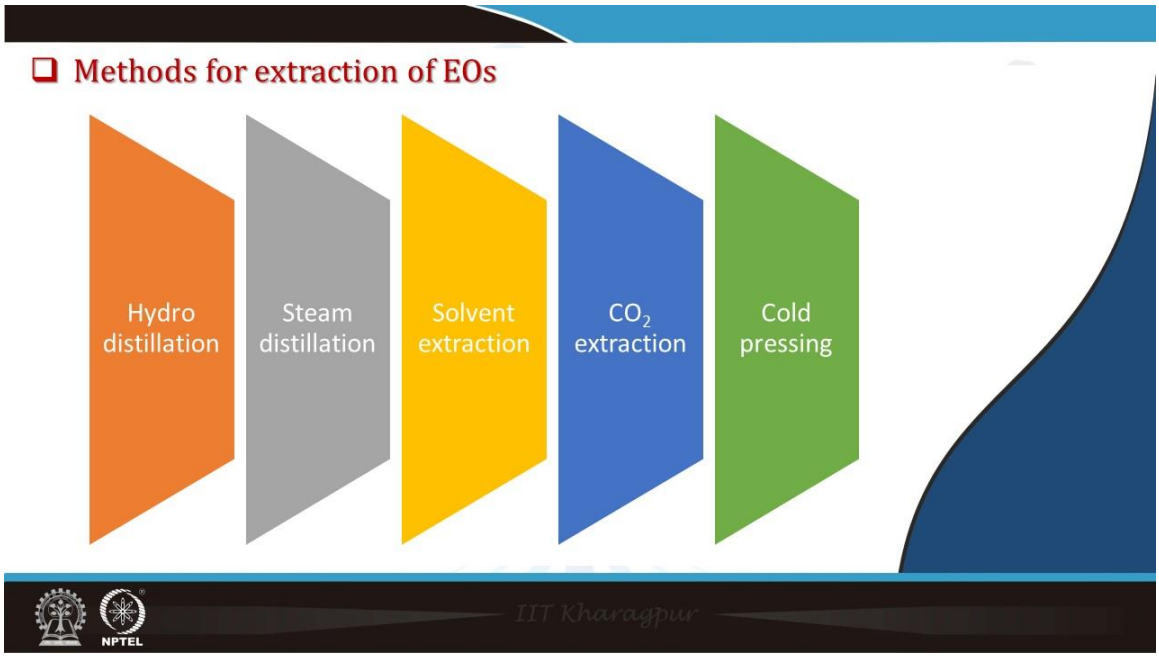
The major examples of essential oil include peppermint, eucalyptus, wild mint, Van tulsi, lemon tulsi, clove oil, lemongrass oil, citronella etcetera. And the major compounds which are present in the essential oils, their physical properties, and biological applications are provided in the table. Compounds like ketones, alcohols, camphors etcetera are available in the essential oil of the plant source lavandola stocchas and they have biological applications like antispasmodic, sedative, anti-inflammatory, anti-anxiety and so on. Similarly that monotrepenes D-Limonene are found in the essential oil of citrus limon. They are well known for their antifungal and antioxidant properties. Similarly oxygenated sesquiterpenes, a-bisabolol are found in the Matricaria recutita and they are known for their anti-irritant, anti-inflammatory and antimicrobial activity. Cinnamaldehyde is a common component of the essential oil in cinnamon, zeylanicum and it is known for its bactericidal activity, fungicidal or insecticidal activities. So, these essential oils contain various organic compounds that have several properties like curative and health promoting activities. They are also responsible for the flavor they introduce in various materials.



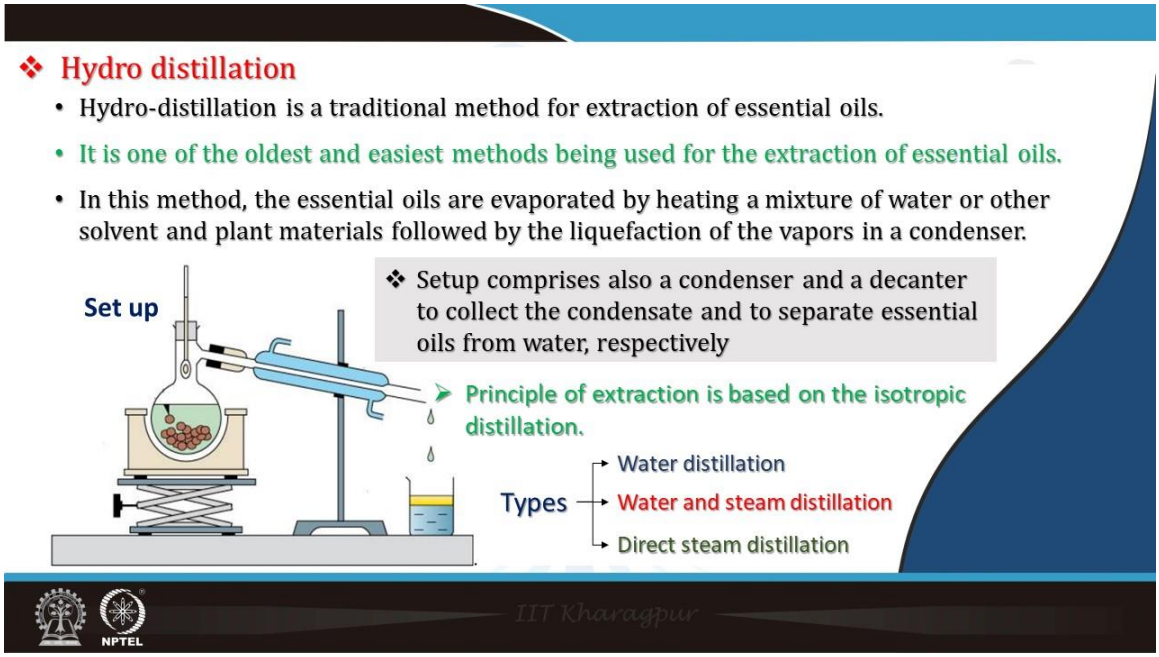
Essential oils are classified in various ways. One way of classification is that botanical classification, that is they are classified based on the plant species they are derived from. Other way of classification may be chemical composition that is it involves the classification based on chemical composition involves categorizing oil into groups such as monoterpenes, sesquiterpenes, alcohols, esters, phenols, and ketones, etcetera. Then they can also be classified on the basis of the aromatic profile and here the Common categories include floral (e.g. Rose, Jasmine), citrus (e.g. Lemon, Orange), woody (e.g. Cedarwood, Sandalwood), herbal (e.g. Rosemary, Basil), and spicy (e.g. Clove). Classification on the basis of therapeutic properties include the properties such as relaxing, uplifting, energizing, antimicrobial, anti-inflammatory, analgesic or immune stimulating. Based on the note, classified into three main categories known as top notes, middle notes, and base notes. Top notes are light and volatile, evaporating quickly, while base notes are heavier and evaporate slowly. Middle notes provide a balance between top and base notes.



Extraction of essential oils include several steps, but the major process is actually the distillation. Here you can see in this figure, that water is first heated in suitable assembly of apparatus and the steam comes in contact with plant material, which contains the essential oils. When steams goes up it carries with it the essential oil contained in the plant material, then the oil rises with the steam above comes into a condenser where it comes in contact with the cold oil and the cold water. There is cold water that is in fact, it is fed into the condenser you can see is coming from bottom and goes out of top. In the condenser chamber, this cold water cools the steam into an oil and water mixture. And then it is separated that is the oil when it is condensed the oil rises to the top of the water and it is extracted. The leftover hydrosol can also be used in beauty or homecare products. So, this is in brief the principle of extraction of essential oil from plant material.

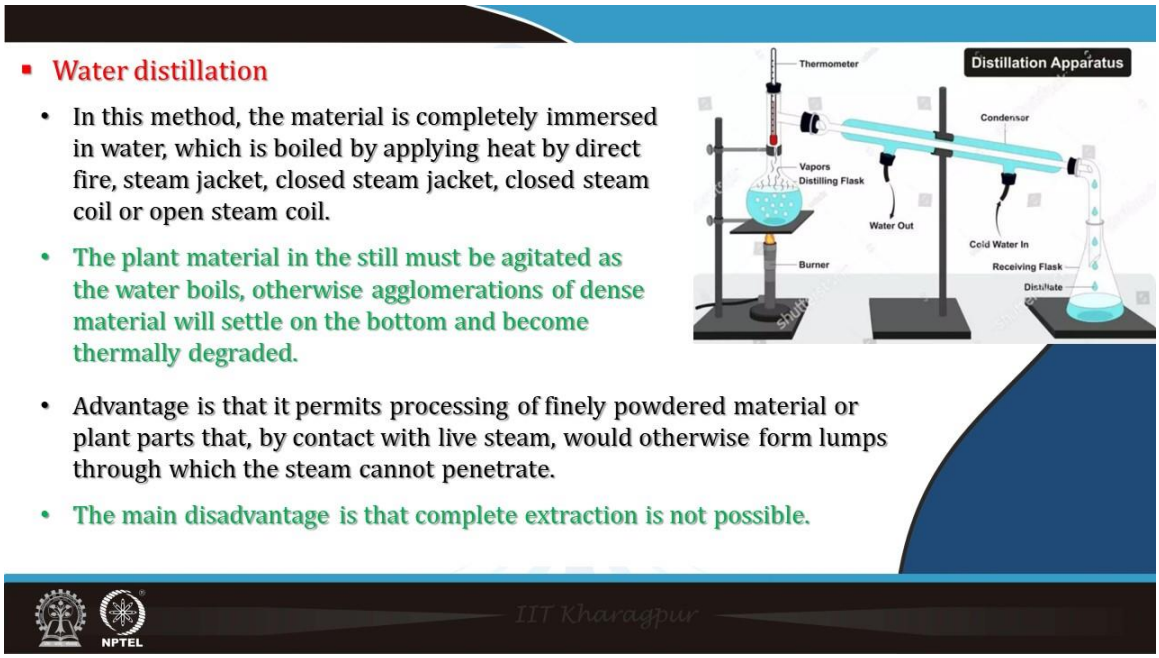


Methods of extraction include hydro distillation, steam distillation, solvent extraction, carbon dioxide extraction or cold pressing.



Hydro-distillation is a traditional method for extraction of essential oils. It is one of the oldest and easiest methods being used in the small scale as well as in the large scale for the extraction of essential oils. In this method, as you can see in the figure the essential oils are evaporated by heating a mixture of water or other solvent and plant materials followed by the liquefaction of the vapors in a condenser. The setup comprises also a condenser and a decanter to collect the condensate and to separate essential oils from

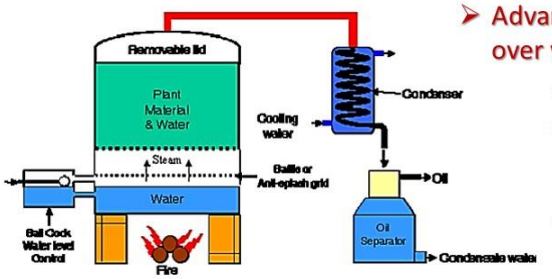
water, respectively. Principle of extraction is based on the isotropic distillation that is water distillation, water and steam distillation or even it may be a direct steam distillation.



In this method, the material is completely immersed in water, which is boiled by applying heat by direct fire, steam jacket, closed steam jacket, closed steam coil or open steam coil as shown here in the figure. The plant material in the still must be agitated as the water boils, otherwise agglomerations of dense material will settle on the bottom and become thermally degraded. Advantage is that it permits processing of finely powdered material or plant parts that, by contact with live steam, would otherwise form lumps through which the steam cannot penetrate. The main disadvantage is that complete extraction is not possible.

Water and steam distillation

- In water and steam distillation, the steam can be generated either in a satellite boiler or within the still, which make plant material separated from the water.
- Like water distillation, water and steam distillation is widely used in rural areas.
- Moreover, it does not require more capital expenditure than water distillation.



➢ Advantages of water and steam distillation over water distillation include

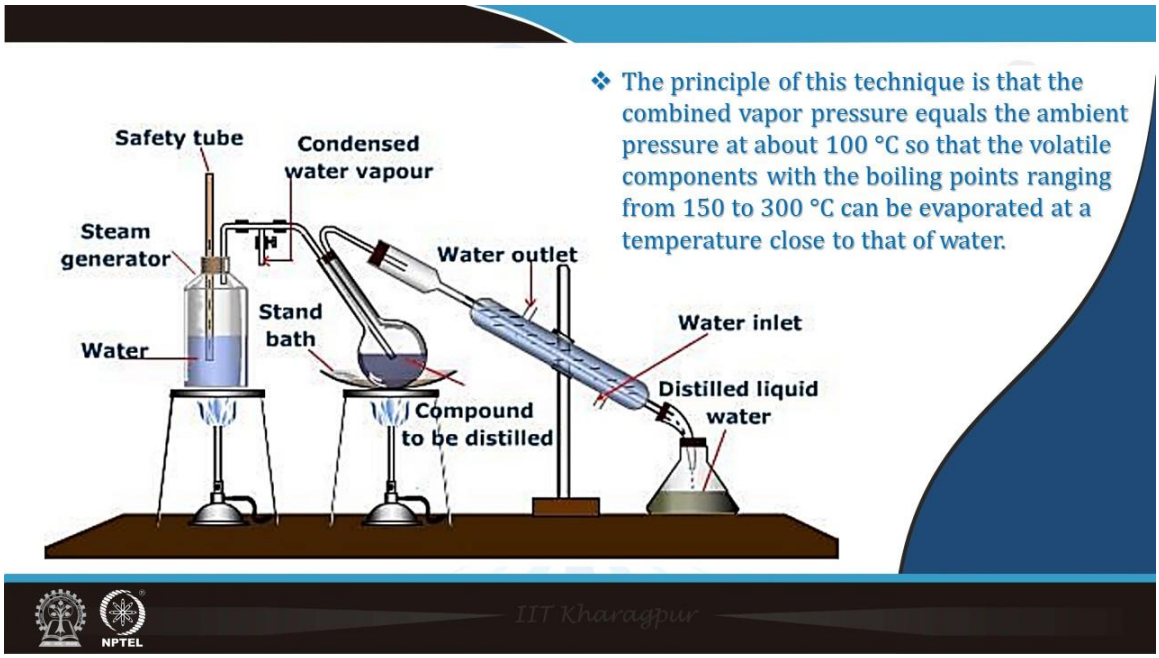
- ✓ Higher oil yield.
- ✓ Components of the volatile oil are less susceptible to hydrolysis and polymerization.
- ✓ Oil quality produced by steam and water distillation is more reproducible.

In water and steam distillation, the steam can be generated either in a satellite boiler or within the still, which make plant material separated from the water. Like water distillation, water and steam distillation is widely used in rural areas. Moreover, it does not require more capital expenditure than water distillation. Advantages of water and steam distillation over water distillation include the higher oil yield, components of the volatile air are less susceptible to hydrolysis and polymerization and oil quality produced by steam and water distillation is more reproducible.

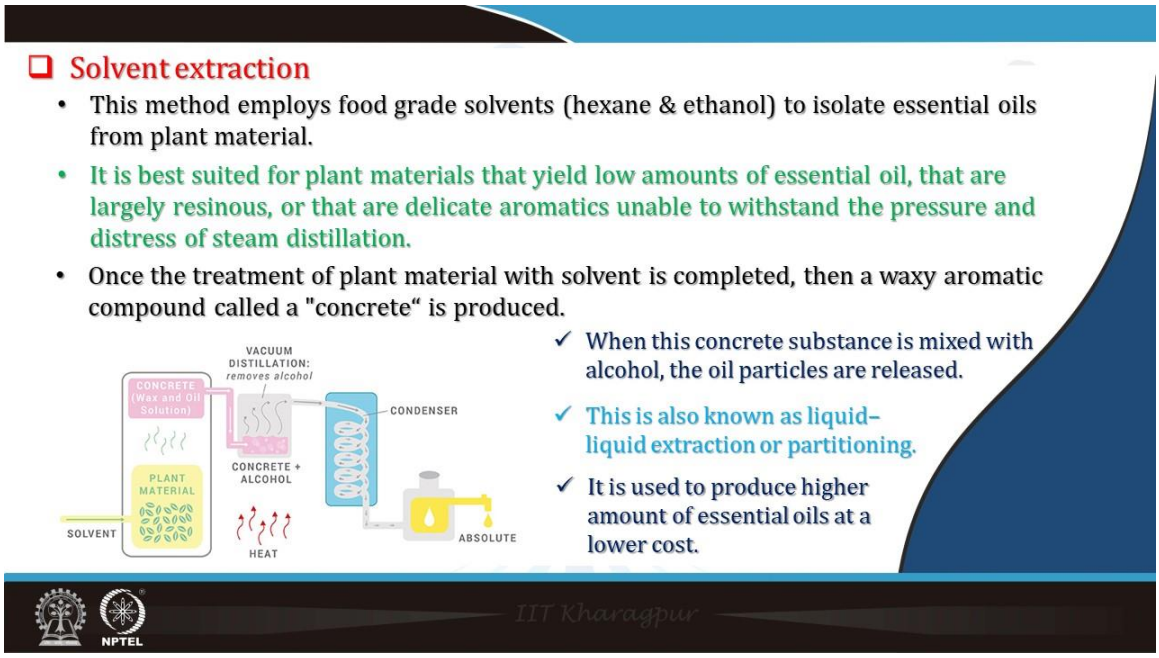
Steam distillation

- Steam distillation is a type of distillation (a separation or extraction process) for a temperature-sensitive plant such as natural aromatic compounds.
- In this method, the plant materials, charged in the alembic, are subjected to the steam without maceration in water. The injected steam passes through plants from the base of the alembic to the top.
- This steam functions as agents that break up the pores of the raw material and release the essential oil from it. The system yields a mixture of a vapour and desired essential oil.
- This vapour is then condensed further and the essential oil is collected.
- It is one of ancient and official approved methods for isolation of essential oils from plant materials.

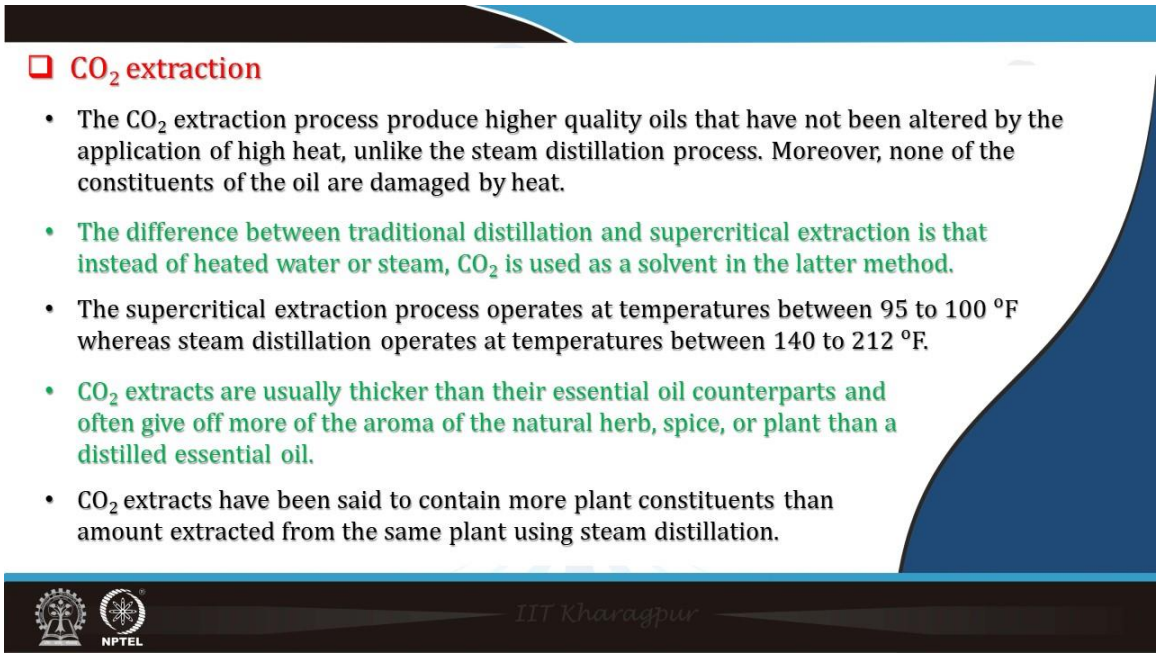
Then let us talk steam distillation. Steam distillation is a type of distillation (a separation or extraction process) for a temperature-sensitive plant such as natural aromatic compounds. In this method, the plant materials, charged in the alembic, are subjected to the steam without maceration in water. The injected steam passes through plants from the base of the alembic to the top. This steam functions as agents that break up the pores of the raw material and release the essential oil from it. The system yields a mixture of a vapour and desired essential oil. This vapour is then condensed further and the essential oil is collected. It is one of ancient and official approved methods for isolation of essential oils from plant materials.



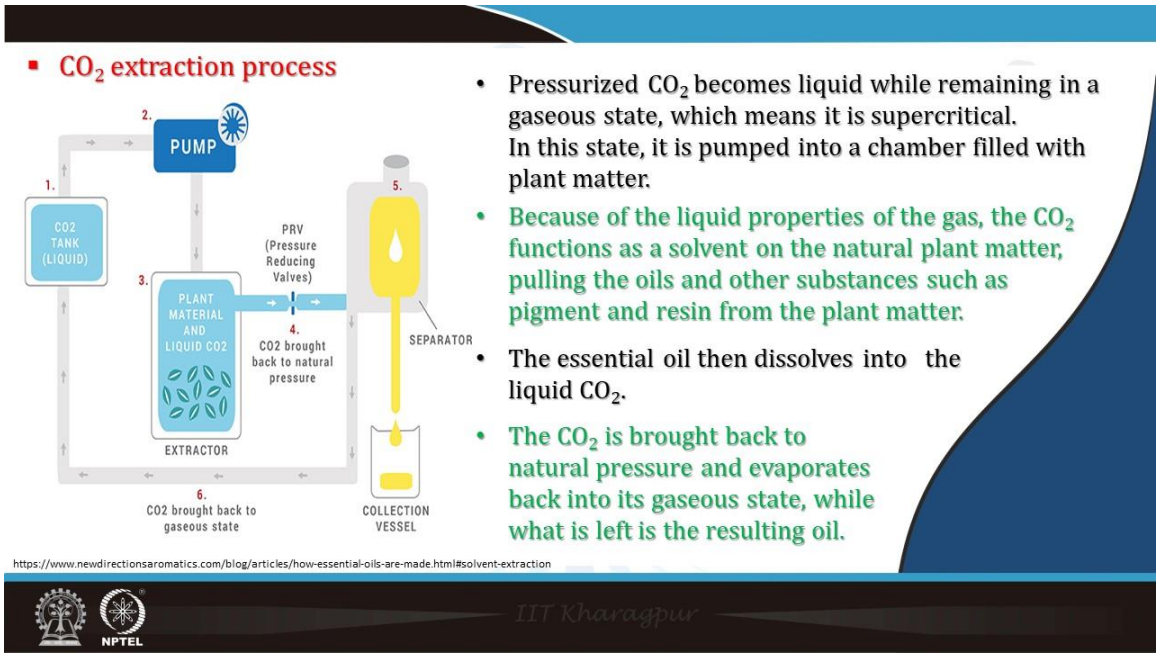
The principle of this technique is that the combined vapor pressure equals the ambient pressure at about 100 °C so that the volatile components with the boiling points ranging from 150 to 300 °C can be evaporated at a temperature close to that of water.



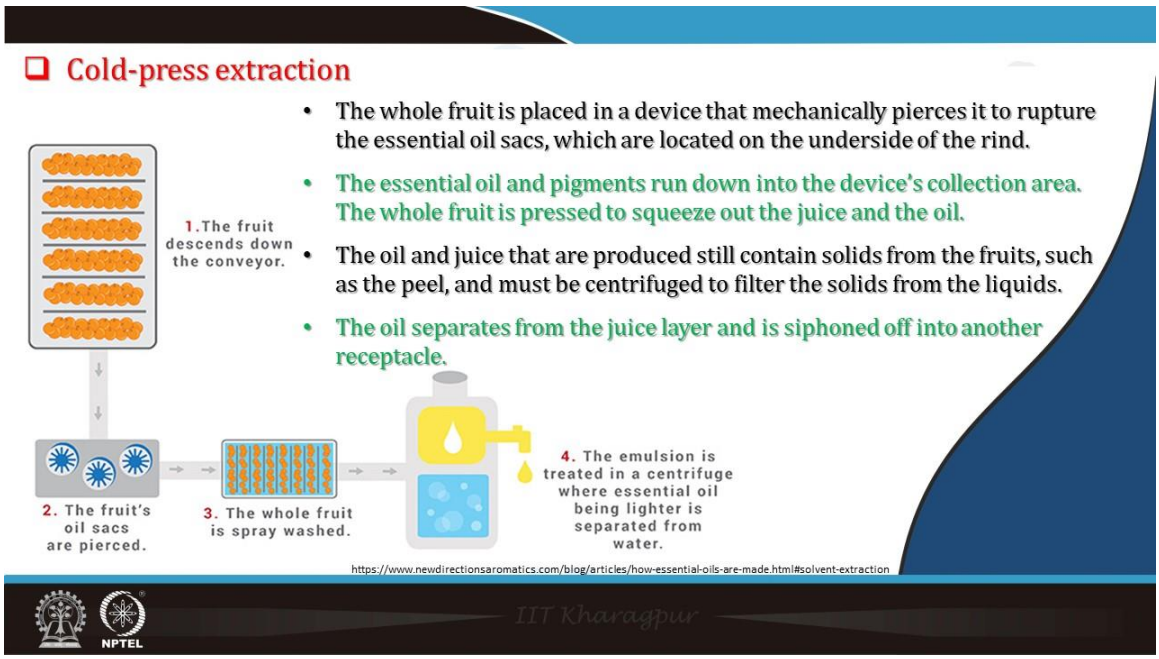
Then next is the solvent extraction method like in the case of earlier oils, here also solvent extraction can be used. This method employs food grade solvents (hexane & ethanol) to isolate essential oils from plant material. It is best suited for plant materials that yield low amounts of essential oil, that are largely resinous, or that are delicate aromatics unable to withstand the pressure and distress of steam distillation. Once the treatment of plant material with solvent is completed, then a waxy aromatic compound called a "concrete” is produced. When this concrete substance is mixed with alcohol, the oil particles are released as you can see in the figure, in this solvent water and oil solution is there and this is mixed with alcohol and heated. This is also known as liquid–liquid extraction or partitioning. It is used to produce higher amount of essential oils at a lower cost.



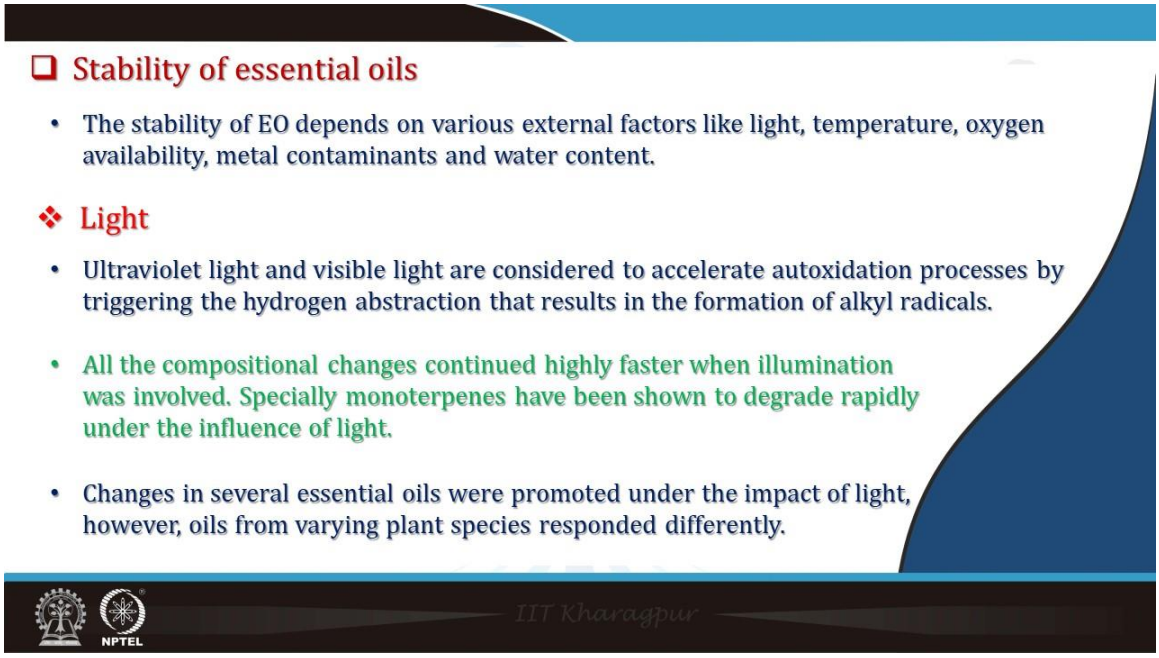
The CO2 extraction process produce higher quality oils that have not been altered by the application of high heat, unlike the steam distillation process. Moreover, none of the constituents of the oil are damaged by heat. The difference between traditional distillation and supercritical extraction is that instead of heated water or steam, CO2 is used as a solvent in the latter method. The supercritical extraction process operates at temperatures between 95 to 100 °F whereas steam distillation operates at temperatures between 140 to 212 °F. CO2 extracts are usually thicker than their essential oil counterparts and often give off more of the aroma of the natural herb, spice, or plant than a distilled essential oil. CO2 extracts have been said to contain more plant constituents than amount extracted from the same plant using steam distillation.



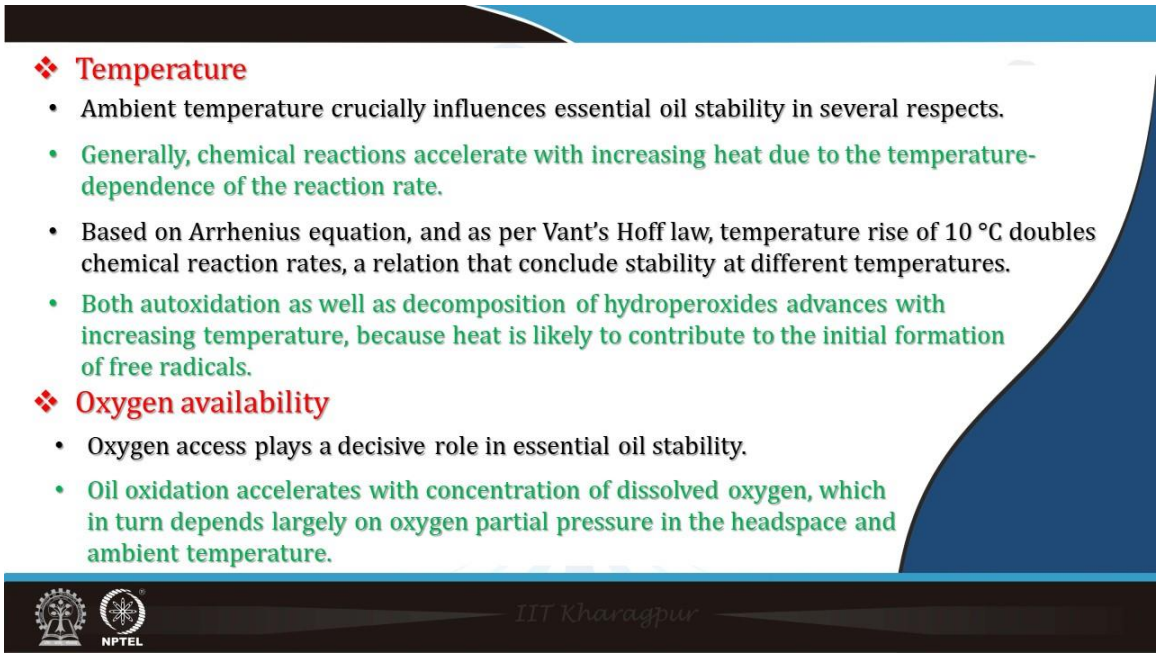
So, the carbon dioxide extraction process in the earlier classes also we have discussed and this is about the extraction setup. So, here in this case also Pressurized CO2 becomes liquid while remaining in a gaseous state, which means it is supercritical. In this state, it is pumped into a chamber filled with plant matter. Because of the liquid properties of the gas, the CO2 functions as a solvent on the natural plant matter, pulling the oils and other substances such as pigment and resin from the plant matter. The essential oil then dissolves into the liquid CO2. The CO2 is brought back to natural pressure and evaporates back into its gaseous state, while what is left is the resulting oil.



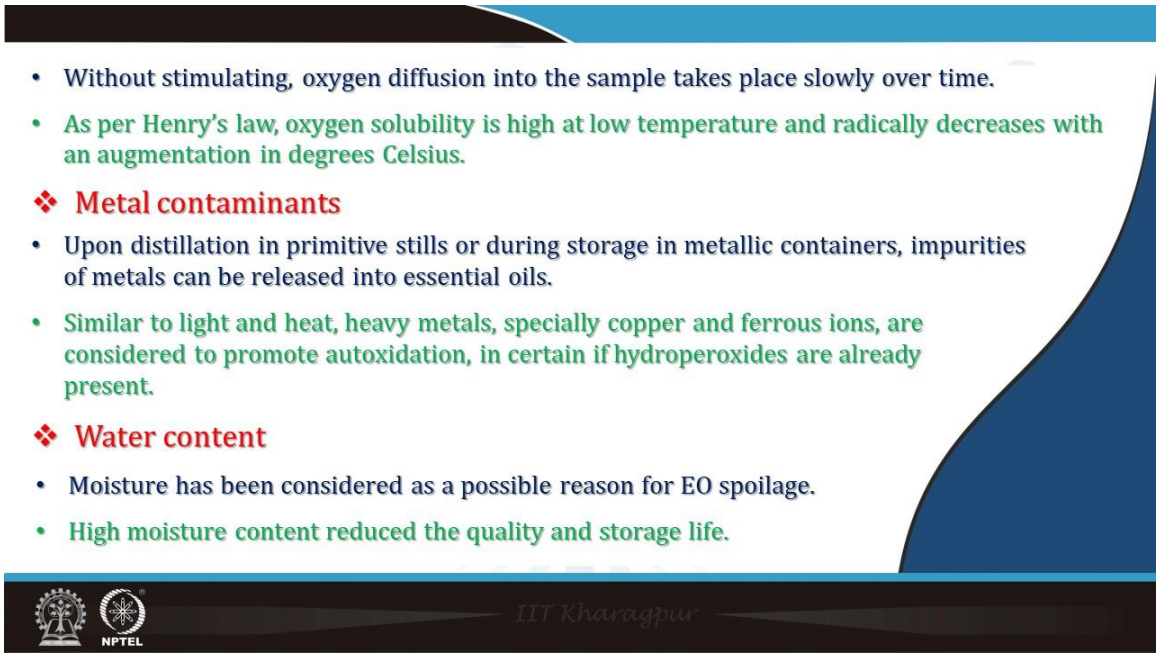
Then another process is the cold press extraction. In the cold press extraction that is the plant material soft tissue, which is containing the essential oils is placed in a device that mechanically pierces it to rupture the essential oil sacs, which are located on the underside of the rind. The essential oil and pigments run down into the device's collection area. The whole fruit is pressed to squeeze out the juice and the oil. The oil and juice that are produced still contain solids from the fruits, such as the peel, and must be centrifuged to filter the solids from the liquids. The oil separates from the juice layer and is siphoned off into another receptacle. That is this emulsion is centrifuged where essential oils being lighter are separated from the water and this process is normally very popular in the extraction of the citrus essential oils.



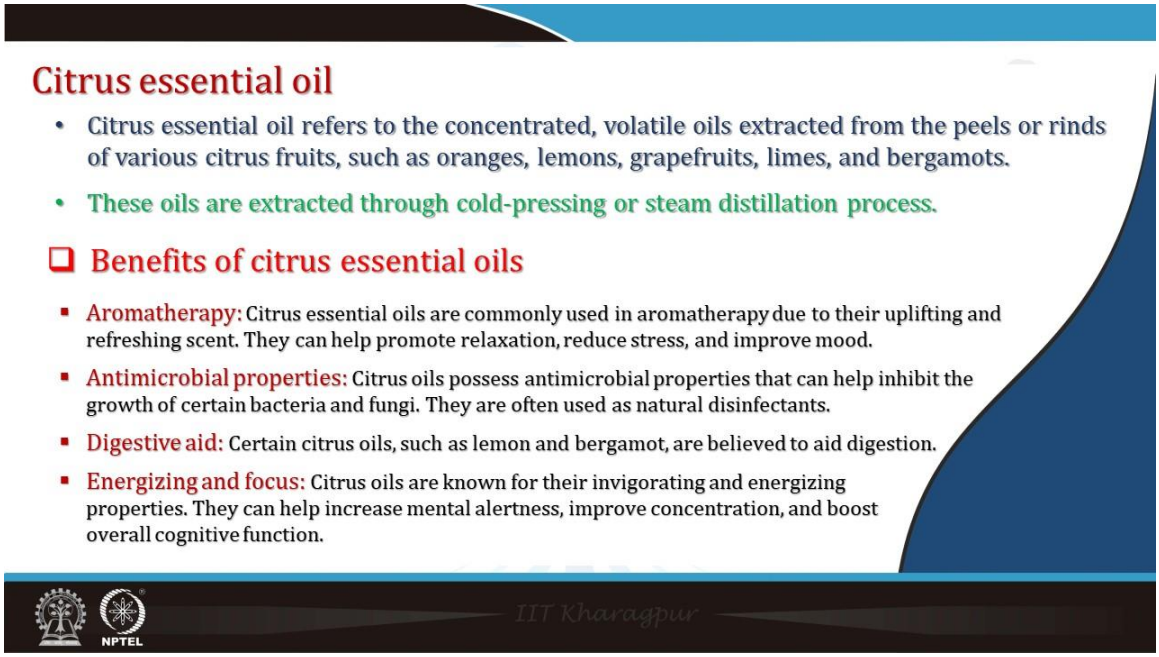
Now, let us talk about stability of the essential oils. Basically, the stability of essential oil depend on various external factors like light, temperature, oxygen availability and metal contaminants and water content. As far as the light is concerned, the ultraviolet light and visible light are considered to accelerate auto oxidation process by triggering the hydrogen abstraction that results in the formation of alkyl radicals. All the compositional changes continued highly faster when illumination was involved. Especially, monoterpenes have been shown to degrade rapidly under the influence of light. Changes in several essential oils were promoted under the impact of light. However, oils from varying plant species respond differently.



Then effect of temperature, ambient temperature crucially influences essential oil stability in several respects. Generally, chemical reactions accelerate with increasing heat due to the temperature-dependence of the reaction rate. Based on Arrhenius equation, and as per Vant's Hoff law, temperature rise of 10 °C doubles chemical reaction rates, a relation that conclude stability at different temperatures. Both autoxidation as well as decomposition of hydroperoxides advances with increasing temperature, because heat is likely to contribute to the initial formation of free radicals. Then availability of oxygen plays a decisive role in essential oil stability. Oil oxidation accelerates with concentration of dissolved oxygen, which in turn depends largely on oxygen partial pressure in the headspace and ambient temperature. Without stimulating, oxygen diffusion into the sample takes place slowly over time. As per Henry's law, oxygen solubility is high at low temperature and radically decreases with an augmentation in degrees Celsius.

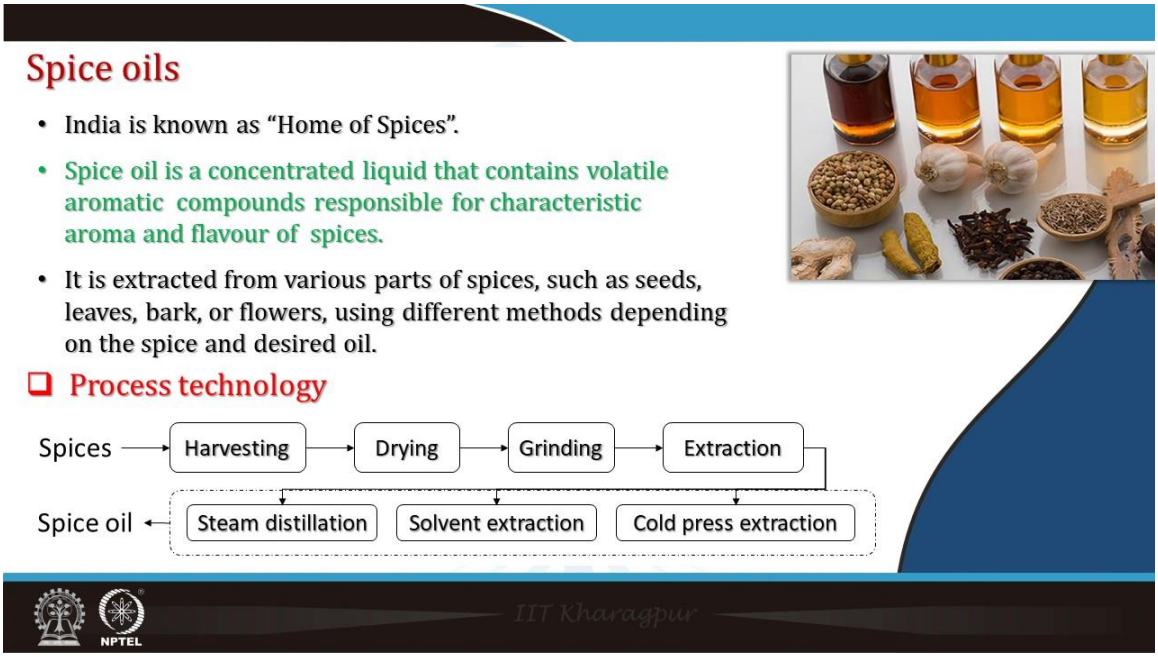


As per metal contaminants, upon distillation in primitive stills or during storage in metallic containers, impurities of metals can be released into essential oils. Similar to light and heat, heavy metals, specially copper and ferrous ions, are considered to promote autoxidation, in certain if hydroperoxides are already present. Another factor is the water content of oil. Moisture has been considered as a possible reason for EO spoilage. High moisture content reduced the quality and storage life.



Now, let us talk about some specific essential oils. We will first talk about citrus essential oils. Citrus essential oil refers to the concentrated, volatile oils extracted from

the peels or rinds of various citrus fruits, such as oranges, lemons, grapefruits, limes, and bergamots. These oils are extracted through cold-pressing or steam distillation process. The citrus essential oils have several benefits like they are known for their aromatherapy. Citrus essential oils are commonly used in aromatherapy due to their uplifting and refreshing scent. They can help promote relaxation, reduce stress, and improve mood. Citrus oils possess antimicrobial properties that can help inhibit the growth of certain bacteria and fungi. They are often used as natural disinfectants. Certain citrus oils, such as lemon and bergamot, are believed to aid digestion Citrus oils are known for their invigorating and energizing properties. They are known particularly during the COVID. They can help increase mental alertness, improve concentration, and boost overall cognitive function.



Then spice oils, as you know India is known as "Home of Spices". Spice oil is a concentrated liquid that contains volatile aromatic compounds responsible for characteristic aroma and flavour of spices. It is extracted from various parts of spices, such as seeds, leaves, bark, or flowers, using different methods depending on the spice and desired oil. So, normally the process for extraction of essential oil is the preparation of these spice plant, like spices they are harvested, dried, ground, and then after grinding the extraction may be depending upon the part of the plant and the type of the species. It may be a cold press extraction, solvent extraction, or steam distillation and by this spice oil is obtained.

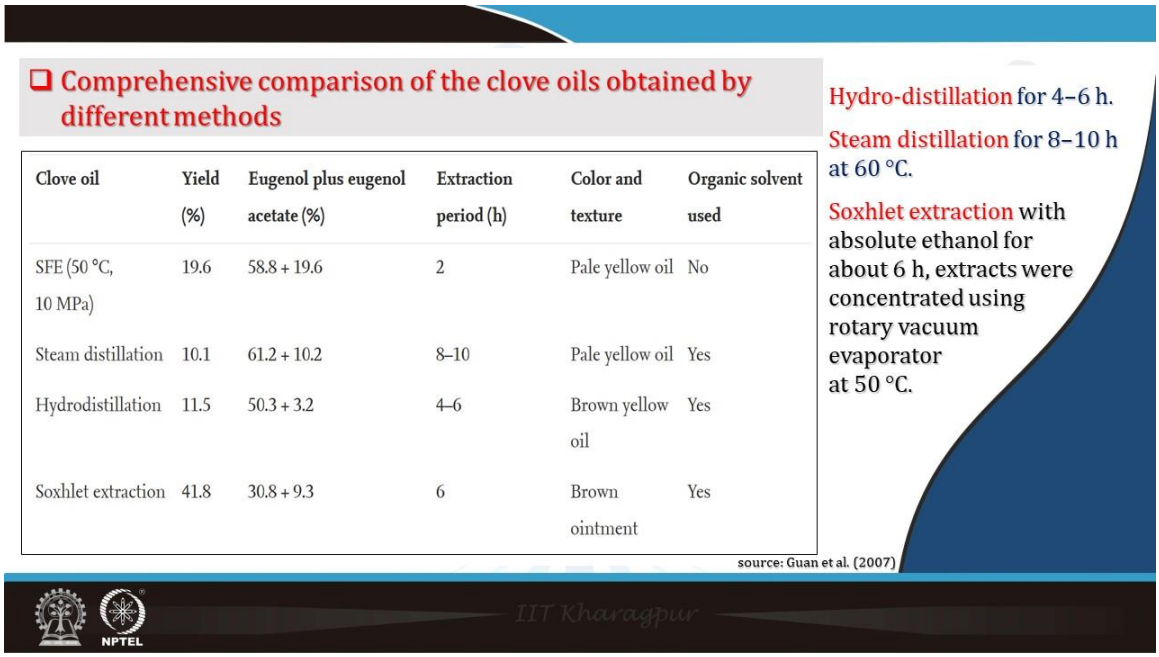
Case Study 1 : Extraction of clove oil

- Characteristic of clove oil extracted from different parts of clove

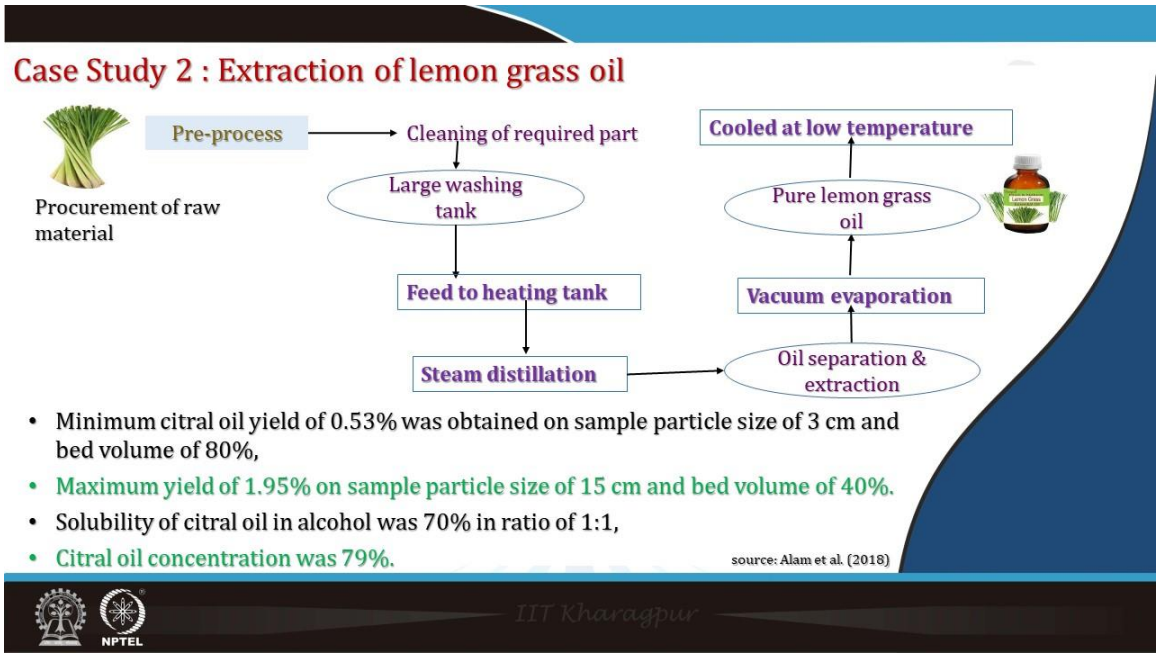
Compound	Bud (%)	Range	Stem (%)	Range	Leaf (%)	Range
Essential oil	18	15–20	6	5–10	3–4	1–4
Specific gravity	10 425	1004–1057	10 495	1048–1056	1030	1030–1060
Refractive index	15 296	1528–1538	15 320	1534–1538	15 295	1520–1540
Optical rotation	– 1.1	0-(– 1.58)	– 1.05	0-(– 1.50)	– 1.58	– 1.58
Total eugenol content	80	85–93	85	89–85	82	78–93
Solubility in ethanol	1:2	1:2	1:2	1:2	1:2	1:2
True eugenol	61.62		80		77.1	
Eugenol acetate	18.72		2.1		trace	
β-Caryophyllene	15.27		12.70		17.02	

source: Nurdjannah & Bermawie (2001)

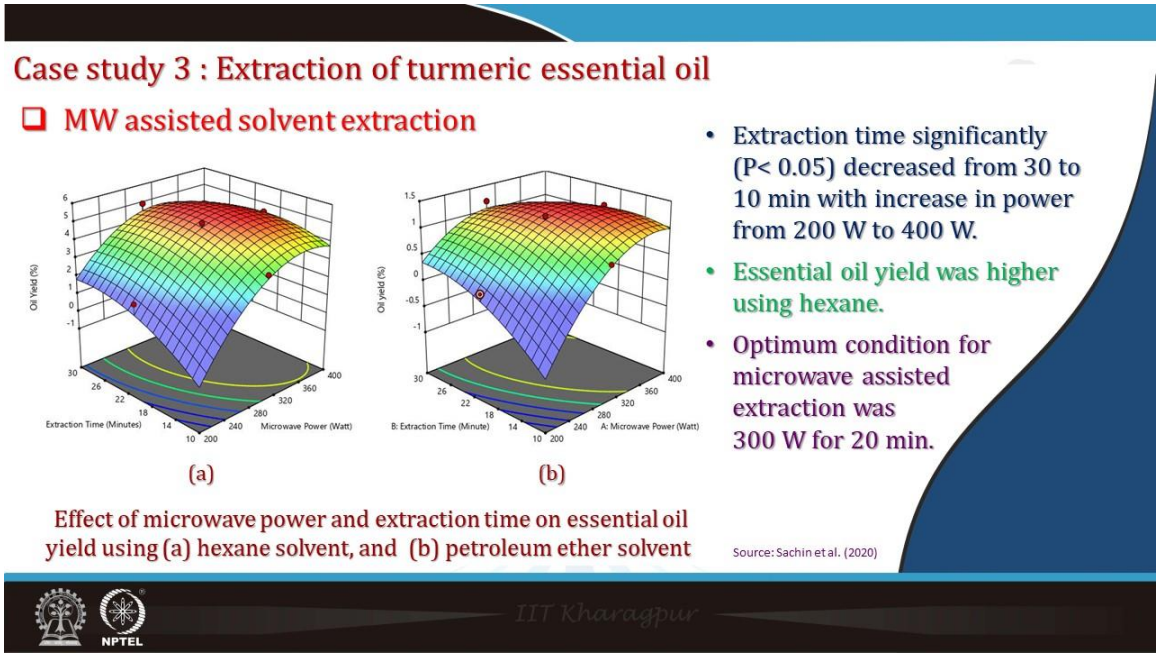
So, let us take one or two case studies like here that is characteristics of clove oil extracted from different parts of the clove that is the bud, stem, or leaf is provided. When bud is used then essential oils obtained is 18 percent whereas, in the stem it is 6 percent and in the leaf of the clove it is 3 to 4 percent. And accordingly the specific gravity of the oil obtained from these different parts fluctuates and there are differences in the refractive index value also with the parts of the plant. Total eugenol content is about 80 percent in the essential oil obtained from bud, around 85 percent in spice oil obtained from the stem and 82 percent in spice oil which is obtained from leaf. Similarly their solubility is ethanol is 1:2 and total eugenol if you see that bud spice oil contains around 62 percent eugenol, in stem essential oils 80 percent, and leaf essential oil 77 percent. Eugenol acetate is 18.72 in spice oil obtained from bud, 2:1 from stem and trace amount in leaf. Beta caryphyllene is about 15 percent in the bud essential oil, 13 percent in stem essential oil and about 17 percent in the leaf essential oil. So, you can see here that is the characteristics of the essential oil, they vary depending upon the part of the plant that is used to extract the essential oil.



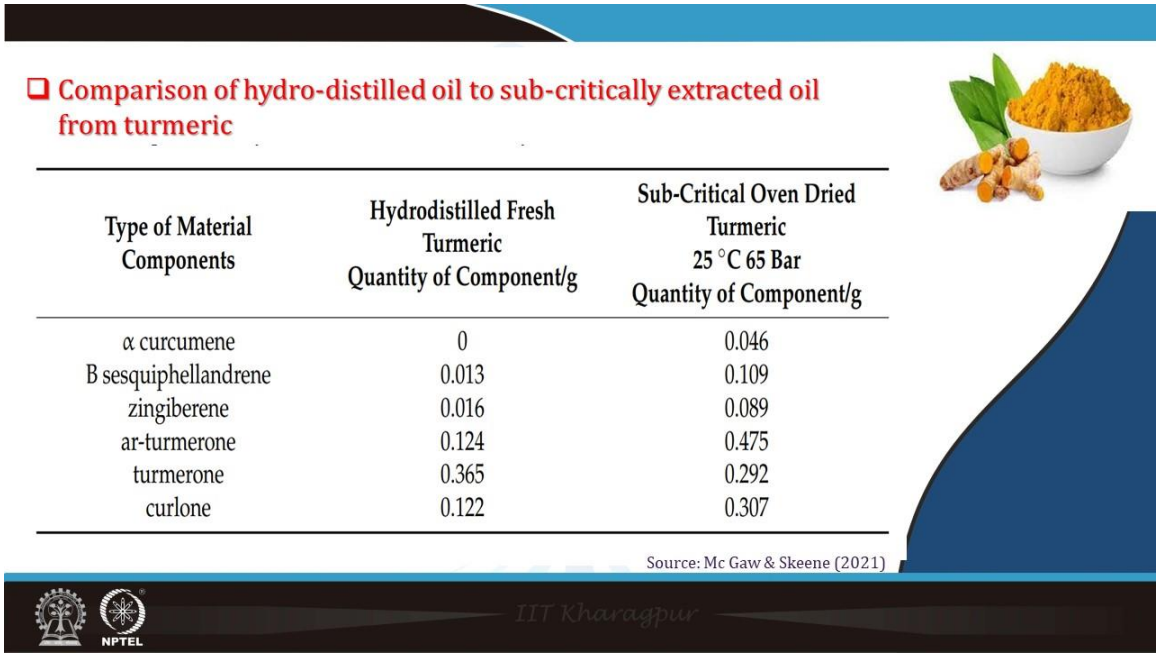
Similarly if you take the a comparison of the clove oil obtained by different methods such as hydro distillation for 4 to 6 hours, steam distillation for 8 to 10 hours at 60 degree Celsius and soxhlet extraction with absolute ethanol for about 6 hours and concentrated using rotary vacuum evaporator at 50 degree Celsius. The comparison is made between supercritical fluid extraction at 50 degree Celsius and 10 mega Pascal steam distillation, hydro distillation and soxhlet extraction. And you can see the yield considerably increases in the soxhlet and it gets a maximum yield of about 42 percent whereas, supercritical fluid extraction gives about 20 percent yield, but the steam distillation and hydro distillation are just half of the supercritical at about 10 percent on an average basis yield. Similarly there is a huge difference in the eugenol plus eugenol acetate percentage. The soxhlet extraction has the lowest that is 30%, while the SFE and steam distillation has double the amount, i.e. 58.8 and 61.2 percent. The hydrodistillation has 50% of eugenol plus eugenol acetate. And the color also varies like the color of the essential oil obtained by supercritical fluid extraction is pale yellow, steam distillation is also pale brown yellow and hydro distillation is the brown yellow. And soxhlet extraction is also brown yellow and the extraction period also varies.



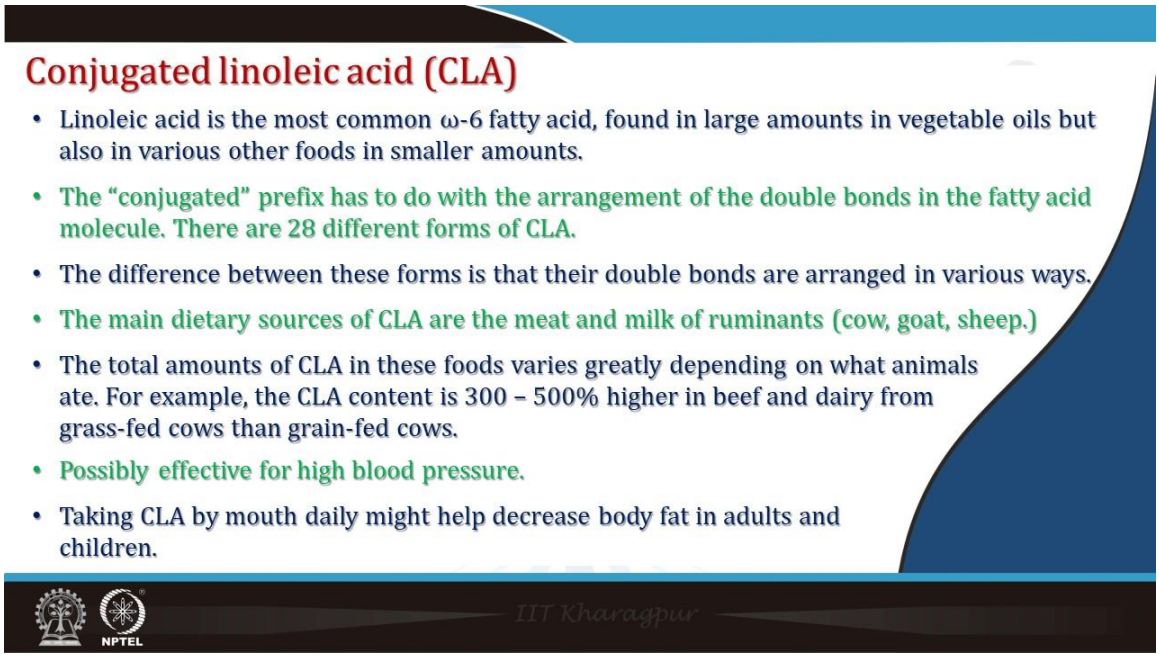
Extraction of lemon grass oil includes procurement of the raw material that is from which the lemon grass oil is processed. Then cleaning of the required part in large washing tank, and fed into the heating tank and then steam distillation. So, oil separation and extraction takes place, followed by vacuum evapouration pure lemon grass oil is obtained and it is cooled at low temperature. Minimum citral oil yield of 0.53% was obtained on sample particle size of 3 cm and bed volume of 80%, Maximum yield of 1.95% on sample particle size of 15 cm and bed volume of 40%. Solubility of citral oil in alcohol was 70% in ratio of 1:1, Citral oil concentration was 79%.



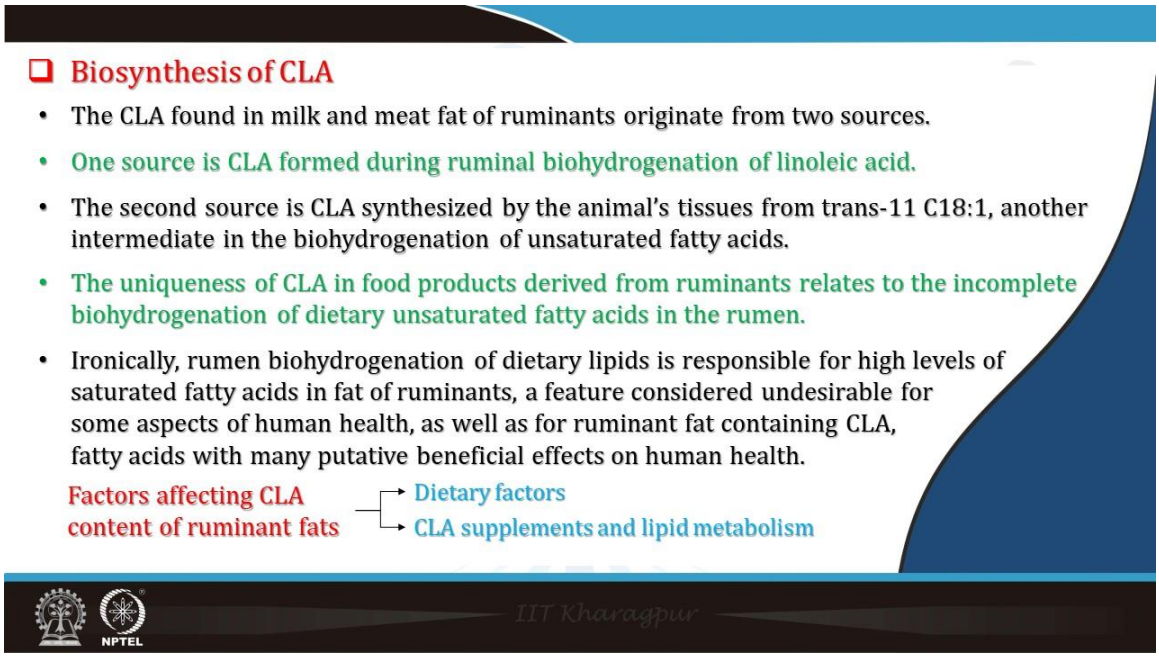
Then it is a extraction of turmeric essential oil by microwave assisted solvent extraction. The picture shows the effect of the microwave power, extraction time on essential oil yield using hexane as a solvent or petroleum ether as solvent. Extraction time significantly ($P < 0.05$) decreased from 30 to 10 min with increase in power from 200 W to 400 W. Essential oil yield was higher using hexane. Optimum condition for microwave assisted extraction was 300 W for 20 min.



The table shows the comparison of the hydro distilled oil to sub critically extracted oil from turmeric. The component alpha curcumin in the hydro distilled turmeric oil is nil while in the sub critical oven dried turmeric is 0.046. There are other compounds like beta sesquiphellandrene, zingiberebe, ar-turmerone, turmerone, and curlone present when the oil is obtained by hydro distillation or by sub critically extracted oil, even though there are certain variations.



Then let us briefly talk about conjugated linoleic acid. Linoleic acid is the most common ω-6 fatty acid, found in large amounts in vegetable oils but also in various other foods in smaller amounts. The "conjugated" prefix has to do with the arrangement of the double bonds in the fatty acid molecule. There are 28 different forms of CLA. The difference between these forms is that their double bonds are arranged in various ways. The main dietary sources of CLA are the meat and milk of ruminants (cow, goat, sheep.). The total amounts of CLA in these foods varies greatly depending on what animals ate. For example, the CLA content is 300 – 500% higher in beef and dairy from grass-fed cows than grain-fed cows. Possibly effective for high blood pressure. Taking CLA by mouth daily might help decrease body fat in adults and children.



The CLA found in milk and meat fat of ruminants originate from two sources. One source is CLA formed during ruminal biohydrogenation of linoleic acid. The second source is CLA synthesized by the animal's tissues from trans-11 C18:1, another intermediate in the biohydrogenation of unsaturated fatty acids. The CLA found in milk and meat fat of ruminant originate from two sources. The uniqueness of CLA in food products derived from ruminants relates to the incomplete biohydrogenation of dietary unsaturated fatty acids in the rumen. Ironically, rumen biohydrogenation of dietary lipids is responsible for high levels of saturated fatty acids in fat of ruminants, a feature considered undesirable for some aspects of human health, as well as for ruminant fat containing CLA, fatty acids with many putative beneficial effects on human health. Factors affecting CLA content of ruminant fats are dietary factors, CLA supplements and lipid metabolism.

Summary

- Essential oils (EOs) are plant-based volatile oils with strong aromatic components made up of different chemical compounds.
- Hydro distillation, steam distillation, solvent extraction, CO_2 extraction and cold pressing are different extraction methods for essential oils.
- Essential oils are classified on the basis of botanical, chemical, aroma, therapeutic and note.
- Temperature, light, oxygen availability, metal contaminants and water content are the different factors affecting the stability of essential oils.
- Linoleic acid is the most common ω-6 fatty acid, found in large amounts in vegetable oils but also in various other foods in smaller amounts.

So, finally, I will summarize this lecture. Essential oils (EOs) are plant-based volatile oils with strong aromatic components made up of different chemical compounds. Hydro distillation, steam distillation, solvent extraction, CO2 extraction and cold pressing are different extraction methods for essential oils. Essential oils are classified on the basis of botanical, chemical, aroma, therapeutic and note. Temperature, light, oxygen availability, metal contaminants and water content are the different factors affecting the stability of essential oils. Linoleic acid is the most common ω-6 fatty acid, found in large amounts in vegetable oils but also in various other foods in smaller amounts.

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So, these are the references that we are used in preparing this lecture. So, this thank you very much for your patience hearing. Thank you.