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Chemistry of Extracting Essential Oils

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Abstract
Essential oils are a composite mixture of volatile compounds present in a very low concentration in plants. A variety of methods have been invented for extracting these oils from plants such as cc8 including distillation, steam distillation, solvent extraction; However, these methods have their own advantages as well as limitations. In order to overcome the disadvantages and limitations, recently, some new methods which are more efficient have been developed such as supercritical fluid extraction, Microwave Assisted extraction and ultrasounds. Such methods not only enhance the yield but also reduce extraction time. Thus, such methods improve quality of oil. This essay covers the recent trend of extracting the essential oils from plants using various methods
Keywords:- *Microwave, Steam, Distillation*

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I. Literature Survey:-

The extraction of oil from plants have proved to be significant in the fields of medicine. In their quest for good health and longevity, mankind continues to search for various sources of compounds that have health benefits. When the process of extraction of oils was discovered, a large number of medicines were synthesized and were used for their health benefits. Scientists believe that aromatics was known right from the Neolithic period. Paolo Rovesti, a professor of Instituto Derivati Vegetali, Milan University, Italy, pointed out that steam distillation for extraction of essential oils was carried out for 5000 years (Riley, M. Hargreaves; Fletcher; J. Clarissa; Compositions for removal of toxins; Essential Oil Consumption; Issue 2; 2004). Ibn Sina, who was a physician and an Avicenna in Europe, who is considered the father of modern medicine, first extracted scent("attar") from the rose petals through the 'enfleurage' process (V. Rao; D. Pandey; A.Sahu; The Beginnings of Modern Aromatherapy:- Extraction of Essential oil And its applications- Issue 8; 2006-2007). Before his discovery, perfumes or attar used contain crushed herbs and oil. Ibn al-Baitar, an Andalusian Arab physician was known to extract scented syrup from leaves and flowers, by using fats and hot oils and water-cooled with oil extracted from cinnamon, sesame or olives. (N.A.Borhan; N.M. Nor; A. Ruskam; I. Al-Baitar; Ibn Al-Baitar: The Pioneer of Botanist and Pharmacist; Issue 3; 2014). Even in the Holy Bible, it is mentioned that olive oil was used widely to light lamps, anointing and grain offerings.

The most widely used method for oil extraction from plants is steam distillation. It is a separation process for temperature-sensitive substances where different solvents are used in elevated temperatures using a simple apparatus.

Microwave-Assisted Extraction(MAE) is the under-utilized but the most evolved and novel method to date to extract phyto-constituents including the organic compounds from raw plants which increases the kinetics of extraction (K. Ingle; A.Deshmukh; D. Padole; M.Dudhare; M. Moharil; V. Khelurkar; Phytochemicals: Extraction methods, identification and detection of bioactive compounds from plant extracts; Journal of Pharmacognosy and Phytochemistry; 2017). The salient features of this process are: 1. Saving of time, 2. Improved yields, 3. Reduced solvent consumption, 4.Energy saving and 5. better accuracy.

STEAM DISTILLATION

Steam distillation is a separate procedure that involves distilling water along with volatile and non-volatile compounds. It is an action that uses the property of the low boiling point of a non-homogeneous mixture. It is only used when the substance to be distilled is immiscible and also chemically does not do the reaction with water. The action of steam distillation was the first idea of Ibn Sina, who is also known as Avicenna in the west which eventually distinguished himself as the pioneer in the distillation process for extraction of essential oil. (V. Rao; D. Pandey; A. Sahoo; The Beginnings of Modern Aromatherapy; Extraction Of Essential Oil And Its Applications; Issue 8; 2006-2007) This process got invented in the ninth century in Spain. The main motive behind this invention was to produce essential oils. The main intention behind steam distillation is that using steam to put up the pressure that requires be to equal the operating pressure. If it is done perfectly then the advantage is, to keep the temperature of the system less than the temperature which will be

essential even if we do not have steam. If steam is to be used then the constituent should be immiscible with water. So, when the condensation of vapours takes place and if we use such solutions which are immiscible then it becomes much easy to separate them with the help of a decanter. The prime difference between regular distillation and steam distillation is the separation theory. When the constituent in the distilling flask do not mix, such as when water and non-polar organic compounds, the vapour that assembles from these two mixtures is entirely different. The constituents act differently from one another and the partial pressure from each module is not at all fixed by its mole fraction. The partial pressure of each unit is its vapour pressure. (L. Nichols; Steam Distillation; A Complete Organic Chemistry Lab Techniques Textbook; Vol 2; 2017)

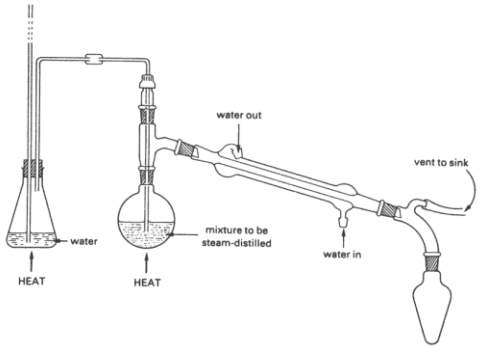
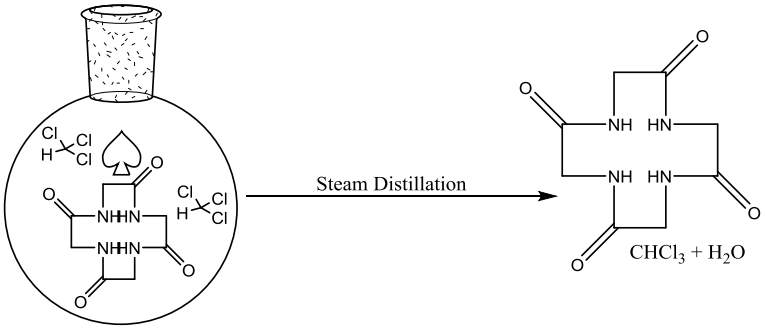


Fig1.1 Steam Distillation apparatus



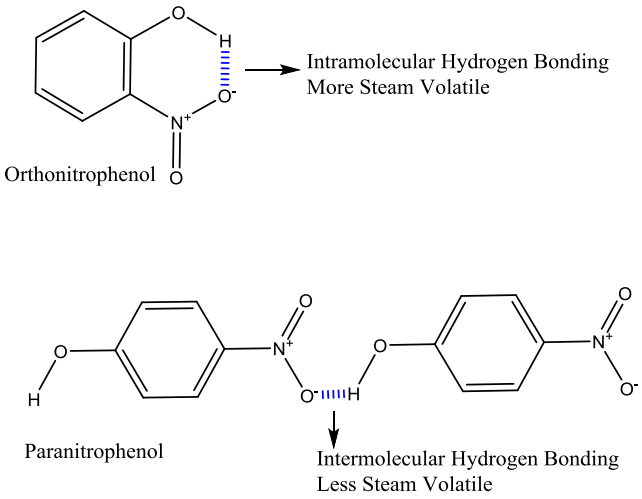
e.g. Aniline is a type of amine

Steam distillation is a process that uses water as one of the immiscible liquids. It's also used to purify liquids that decompose at natural boiling temperatures. for example Glycerol, Organic compounds are separated from plant parts using steam distillation. Lemongrass oil, Eucalyptus oil, and so on.

Intra and Inter Molecular Hydrogen Bonding:

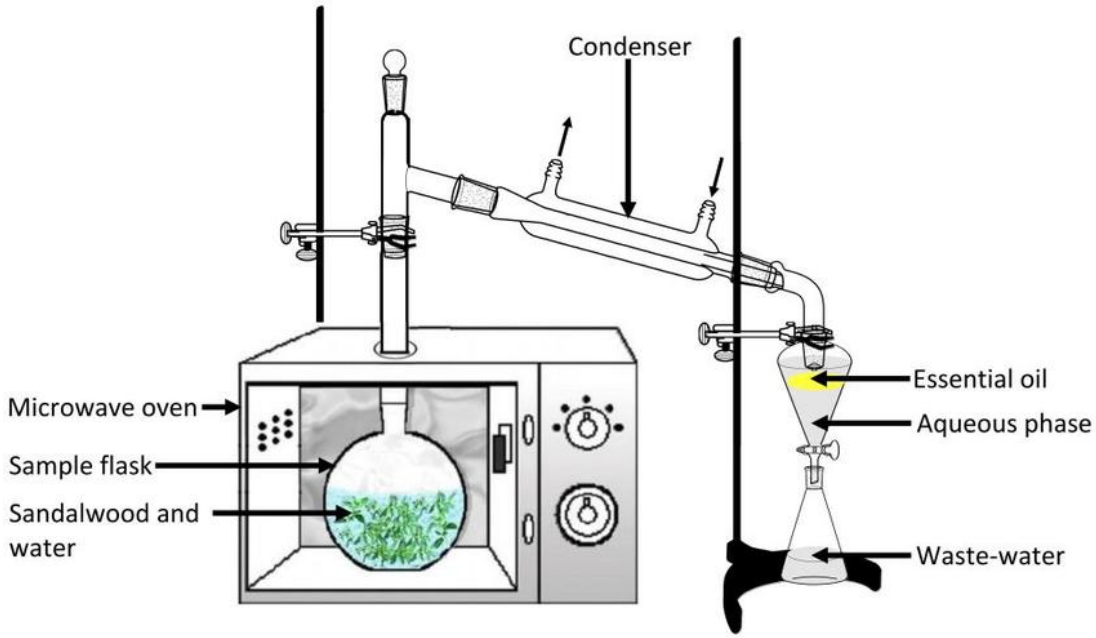
In o-nitrophenol, there is intramolecular hydrogen bonding. The formation of hydrogen bonds within the same molecule is caused by the polar structure of the O-H bonds. Water solubility is reduced and volatility is increased by this intramolecular hydrogen bonding.

Intermolecular hydrogen bonding (between the H and O atoms of two separate para-nitro phenol molecules) is possible in p-nitrophenol. P-nitrophenol undergoes interaction as a result of intermolecular hydrogen bonding, raising the molecular weight and decreasing volatility.As a result, o-nitrophenol can be steam distilled while p-nitrophenol cannot. Para nitrophenol with intermolecular hydrogen bonding:



Microwave-Assisted Extraction

The constituents in plant tissue are heated by ionic conduction and rotation of dipole. The electrophoresis is the reason for the ionic conduction wherein the charged particles in the solvent moves under the electric field, but for this, there must be free ions or ionic species in the solvent. This leads to the generation of heat and the transfer of energy takes place depending upon the temperature of the plant tissue. The molecule of water and the solvents having ions with a difference in electronegativity rotate back and forth to realign dipole with changing electric field resulting in a gain of heat energy and friction, thus leading to dipole rotation. (P. Tatke; Y. Jaiswal; An Overview Of Microwave-Assisted Extraction And Its Applications In Herbal Drug Research; Research Journal of Medicinal Plants; Issue 22; 2010) The primary element of this extraction is microwave, the non-ionizing electromagnetic waves with frequency 300 MHz to 300 GHz positioned between X-ray and infrared rays in the electromagnetic spectrum, which causes heating and agitation by convection. (V. Mandal; Y. Mohan; S. Hemalatha; Microwave Theory; Microwave-Assisted Extraction – An Innovative and Promising Extraction Tool for Medicinal Plant Research; Vol 1; Issue 8; 2007) The process starts with bringing the plant under microwave radiation so that moisture within the plant evaporates. This generates tremendous pressure on the cell wall thereby causing swelling of a plant cell. This ruptures the cell leading to the exudation of active constituents from the cell. The process works, even more, better if we soak plant matrix in solvents that have higher heating efficiency under the microscope. The Pharmacopoeia of the People's Republic of China (PPRC) or the Chinese Pharmacopoeia (ChP) describes the advantage when both MAE and steam distillation works together. (C. Zhi-ling; C. Jian-ping; C. Hui-lin; B. Wei-tao; C. Hai-yan; Li Mo-lin; Introduction; Research on the Extraction of Plant Volatile Oils; Vol 8; Issue 427; 2011) There is a particular frequency above or below which process of heating doesn't occur and that is estimated to be 2450 MHz. (V. Mandal; Y. Mohan; S. Hemalatha; Microwave Theory; Microwave-Assisted Extraction – An Innovative and Promising Extraction Tool for Medicinal Plant Research; Vol 1; Issue 8; 2007) To check the efficiency of the heating by microwave, dissipation factor proves to be very important represented by dissipation factor(tan δ)= $\varepsilon''/\varepsilon$, where ε'' is the efficiency of the microwave energy to get converted to heat and ε is the efficiency of the solvents to absorb microwaves which we term as "dielectric constant". Polar solvents like methanol and ethanol have lower dielectric constant as compared to water hence they have lower ε value. As ε value is lower, the dissipation factor increases which means that the solvent has higher heating efficiency. The principle of Microwave-Assisted Extraction (MAE) is its heating effect that happens due to perpendicularly oscillating electric and magnetic fields, which can be performed in two ways- Pressurized MAE in closed vessels and atmospheric MAE system. Pressurized MAE in closed vessels is done for extraction of solvent with high dielectric constants, and the solvent remains in the liquid state although the vessel is pressurized without actually boiling the solvent. Atmospheric MAE system is done for extraction of solvent with low dielectric constants, and such solvents, having the inability of absorbing more energy, can be extracted from an open vessel. The water and thermolabile analytes, having high dielectric constant increases the temperature of the sample and enhances the process. (J.R. Dean; Extraction Techniques And Applications: Biological/Medical and Environmental/Forensics; Theory of Extraction Techniques; 2012)



For carrying out the process of MAE, appropriate targets in the dried plant material must be selected. The targets are those areas of the plant which has moisture. As it is known that the higher is the tan δ, the more is the dissipation factor, so the solvent has higher heating efficiency, thus increasing the yield of Phyto-constituents. Even an increase in temperature can enhance the extraction of the phytoconstituents from the plant matrix. As now it is known that moisture fastens the process of extraction, this research has led to the fields of hydro-distillation. Microwave-Assisted Hydrodistillation(MAHD), the most recent method of hydrodistillation, is the extraction process in which microwave heat and water both are used for the extraction of water. (B. Liu; J. Fu; Y. Zhu; P. Chen; Introduction; Optimization of Microwave-assisted Extraction of Essential Oil from Lavender Using Response Surface Methodology; Journal of Oleo Science; Issue 2; 2018) Even lavender (Lavandula angustifolia) which comes in the family of Lamiaceae has its oil extracted with the help of the MAHD method. Nowadays, even bamboo shoots have proved significant for the extraction of polyphenols, flavones and other vital compounds that have been proved to be antioxidants and anti-inflammatory, have strengthened the immunity of our body and protected us against chronic and life-threatening diseases. (G. Milani; F. Curci; M. Cavalluzzi; P. Crupi; I. Pisano; G. Lentini; M. Clodoveo; C. Franchini; F. Corbo; Introduction; Optimization of Microwave-Assisted Extraction of Antioxidants from Bamboo Shoots of Phyllostachys pubescent; Issue 1; 2020) Seabuckthorn, coming from the family of Elaeagnaceae, is full of bioactive substances like fatty acids, vitamins, polyphenols and flavonoids. The flavonoids in this deciduous shrub include Rutin(RU), Isorhamnetin(IS), Quercetin(QC), kaempferol(KA) and the oil that is extracted from seabuckthorn has been proved a boon for skin diseases as this oil is used for skin regeneration, enhances blood circulation in our body, prevents wear and tear of the skin by oxygenating it and repairs the damaged cells. The conventional extraction procedures include HDE for Eos, Ethanol ultrasonic-assisted extraction (EUAE) for the main flavonoids, Ionic liquid-based ultrasonic-assisted extraction (ILUAE), Ionic liquid-based microwave-assisted extraction (ILMAE) for the main flavonoids. (Li C; Zhang J; Zhao C; Yang L; Zhao W; Jiang H; Ren X; Su W; Li Y; Guan J.; Introduction; Separation of the main flavonoids and essential oil from seabuckthorn leaves by ultrasonic/microwave-assisted simultaneous distillation extraction; Issue 2; 2018) Oil extracted from black colour jatropha seeds which are used in soaps can be extracted with the help of microwave-assisted extraction (MAE). Matured seeds of jatropha are cut to get oil.

II. Conclusion

To prove Microwave-Assisted Extraction is better than Solvent Extraction for the Extraction of Oils from plants.

Solvent extraction is the distillation of water along with volatile (high vapour pressure at room temperature) compounds and non-volatile (low vapour pressure at room temperature) compounds. It is particularly done with those substances that don't form a homogeneous mixture with water.

Microwave-Assisted Extraction(MAE) is also called "dielectric heating" as in the process of extraction, moisture or solvent of particular dielectric strength(Example: Dielectric constant of water is 80) in Phyto-constituents is involved. It is a really fast heating process (internal superheating) as the electromagnetic energy is converted into thermal energy in a very short period of fewer than 30 minutes. Choosing appropriate

power is necessary for the efficient extraction of oil. If the power chosen is more than the appropriate value, the solvent gets evaporated. Hence, we must choose a maximum power between 600 W and 1000 W for a closed system and 250 W for an open system. The structure of the cell changes very rapidly as the conversion of energy volumetrically inside the cell leads to the ejection of phytoconstituents and recovery of neutraceuticals leading to disruption of the cell. (D. Verma; E. Fortunati; S. Jain; X. Zhang; Microwave-assisted extractions (MAEs); Biomass, Biopolymer-Based Materials, and Bioenergy; 2019) In common conventional processes like conduction, convection and radiation, heat is transferred from outside to inside and the mass is transferred from inside to outside; but the process works differently in the case of Microwave-Assisted Extraction (MAE). In MAE, both heat and mass are transferred from inside to outside. The process that works in MAE is powerful-first electromagnetic energy is converted to thermal energy followed by ionic conduction and dipole rotation. (A. Sadeghi; V. Hakimzadeh; B. Karimifar; Heating Mechanism; Microwave-Assisted Extraction of Bioactive Compounds from Food: A Review; Issue 20; 2017)

In steam distillation, you can decide the temperature and amount of steam you have to use on the plant. Also, it is cheap and requires lesser fuel for steam boiling. But the steam distillation has a higher initial cost, longer extraction time and also you need special training to work with it. Also, the cost of maintenance is high and it is not as powerful as Microwave-Assisted Extraction (MAE). So, it is coupled with other extraction techniques like MAE to accelerate the process. Hence, it can be concluded that Microwave-Assisted Extraction is much better and sought after than steam distillation.

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