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Review Article

Essential Oil Extraction, Method and Approaches, Use in Food Preservation, Trends and Behaviours, Prospects for The Future

Ashwini Pujari*, Avadhut Khot, Akanksha Dalavi, Chaitrali Jagadale, Kumudini Suryawanshi

Dr. Shivajirao Kadam College of Pharmacy, Kasabe Digraj, Sangli (MS), India. 416305

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ABSTRACT

Although studies on Essential oils have been conducted for over sixty years, it wasn't until the urge to rediscovered herbal remedies in the last century that interest in them increased. Due to the fact that therapeutic properties, the use of essential oils has been widely used for many thousands of centuries. Even in prehistoric times, for ritualistic & health benefits. Essential oils are isolated through unprocessed material from plants using a range of techniques that have been Produced throughout the years; the method of extraction selected determines the kind and amount of stereo chemical arrangement of the particles that make up the oil that is essential. Most of the qualities that make essential oils so intriguing to use as pharmaceuticals relate to those constituents; Due to the fact that vital qualities, essential oils are extremely significant in the fields of medicine, food, cosmetics, and agriculture. The most researched ones include wound-healing, antibacterial, anti-inflammatory, and anxiolytic properties. Because of their antibacterial along with antioxidant qualities, which prevent foods from spoiling, In recent years, essential oils have grown in popularity. Although because of their potent flavour, scent, and a hydrophobic nature, incorporating them into low in fat dishes is difficult. The encapsulation is a useful strategy for overcoming these limitations. This analysis discusses methods for encapsulating essential oils that are now being investigated. Several methods for encapsulating essential oils, possible uses in food items, and their post-encapsulation behaviours and trends. The method employed, as well as the sort and Ratio/Concentration of emulsifier/wall ingredient utilized, determine the encapsulation effectiveness, size of particle, and physical strength of essential oils encapsulated in colloid frameworks. Additionally, the advantages of encapsulation are examined, including bioavailability, controlled release, and defence of essential oils from stresses from the environment.

INTRODUCTION

Nature has long been regarded as a great source of medical compounds, and a surprising number of

***Corresponding Author:** Ashwini Pujari
Address: *Dr. Shivajirao Kadam College of Pharmacy, Kasabe Digraj, Sangli (MS), India. 416305*
Email : ashwinispujari01@gmail.com

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contemporary medications have their origins in nature(2) Herbal medicine has recently become the primary attention of scientists worldwide as a supplemental or substitute therapy(3)Indeed, according to estimates from the World Health Organization (WHO), in the range of 70 to 95% of people worldwide get their main kind of medications mostly from natural remedies (4) Among the wide variety of based on plant products, essential oils (EO) are provided special consideration(1) The distinct scent, tastes, and smells of plants are determined by the oils that are essential, which are typically intricate combinations of aromatic organic molecules biosynthesized as secondary substances(5)A broad range of substances, such as Alkaloids, Flavonoids, Isoflavones, Monoterpenes, Phenolic acids, Carotenoids, and Aldehydes, typically makes up these substances. Eos are a broad category of occurring naturally volatile components that are basically extracted through non-woody botanical components using solvent carbon dioxide (CO2) the extraction process, solvent-solvent the extraction process, and a hydro distillation (6) These are distinguished by the presence of primary components in greater proportions as opposed to precise amounts of constituents. For instance, the biological functioning of cloves essential oils is determined by their 85% eugenol & 10-12% eugenic acetyl content. (7, 8, 9) essential oils (Eos) have virucidal, anti-oxidants, fungicides, bactericide, and anticarcinogenic qualities because of these multipurpose chemicals. Essential oils (Eos were previously utilized to reduce contaminated from fungi and bacteria (10) the synergistic action of multiple ingredients gives Eos their effectiveness as anti-oxidants, antimicrobials, and other compounds. These elements are in charge of essential oils (Eos' potential to be incorporated and used in a variety of items, including nourishment, skincare, including nutritional supplements. Due to theirs significant lipophilicity, instability, ease of evaporation, and susceptibility for ecological factors like sunlight, oxygen, along with humidity, essential oils are frequently used in limiting ways. Since an outcome, investigating the possibility of expanding their uses has emerged as a major Investigation concern (11) The purpose of encapsulation is to enhance the potential of Eos. It preserves the bio functional qualities of essential oils, increases their reliability in adverse environments, produces a positive minimizing impact, and permits controlled EO release (12) Customers are calling for more naturally appealing and healthful foodstuffs. As a result, new developments in the food industry are encouraging increased sensible use of food products, lowering the presence of artificial compounds as well as preservation agents, or even substituting them by organic components like oils of essential oils (Eos) (13) But one obstacle to their use was their inability to include oils that are essential into products with reduced fats due to their hydrophobic characteristics. Furthermore, the potent flavour and scent of their usage in large concentration is restricted by Essential oils in certain foods because of potential unfavourable impacts on taste(14) These issues might be settled by encapsulating essential oils, which might enhance the stability and safety, regulate chemical release more effectively, reduce strong smells and aromas, extend shelf life, & enhance the ingredients' its bioavailability and accessibility(15) This technique is being utilized extensively to secure bioactive substances, distribute them to their intended targets, and improve their ability to function biologically(16) Carvacrol-loaded microcapsules were created by Wang and colleagues (2009) with the intention of targeting the intestinal tract for improved antibacterial properties and greater bioavailability. They discovered that the GI tract expelled less than 20% of the oil, while the intestines expelled the remaining amount. Similarly to this, numerous studies have documented essential oils' long-lasting release properties following encapsulate in various matrix (16,17,18) The encapsulation increases the rate of absorption of biologically active ingredients and medications in addition to providing regulated releases. When various EO ingredients (peppermint oil, eugenol, carvacrol, and thymol) were Nano encapsulated, the same pattern was seen, leading to increased antibacterial properties in comparison to conventional oil (19, 20) to realize these advantages. There are numerous ways to encapsulate Eos, however they can be broadly divided into three categories: a) chemical methods, b. physico- mechanical methods, and c. physico-chemical methods. To encapsulate essential oils, numerous studies have employed liposomes, atomic diversity, aggravation and complex aggravation, spray-dried emulsifying ionized gelatine, and emulsion extruded (19,22,23) The encapsulation procedures may use multiple techniques in numerous uses. The variety of coating materials, operating costs, & encapsulating products applicability would all influence the choice of the more practical approach (21) the use of essential oils in food along with the significance of encapsulating this kind of substances. The basic features of emulsifying as an encapsulating approach, an explanation on standard and more current encapsulate technologies, as well the foremost shell components employed in foodstuff processing are discussed. In order to serve as a foundation for future study and possible industrial uses an overview of essential oil encapsulation was also covered (24)

Techniques for Essential Oil Extraction.

A diverse and innovative source of products made from nature, essential oils (Eos) that are made from plant that are aromatic are frequently utilized for bactericides, fungicides, an anti-virus, anti-parasitical, insecticide, therapeutic, or cosmetics uses, particularly in the alimentary, pharmaceuticals, healthy, cosmetics, and farming sectors(25,26) The requirement for essential oils is rising globally these days due to buyers' increased interest in pure substances including their worries regarding possibly hazardous conventional added substances(27) But first, essential oils must be separated from the matrix of plants in order to be utilized or examined. This can be achieved by employing a range of methods, which includes the most popular ones like extraction of solvent by cold pressurization (CP), distillation with steam, hydro-distillation (HD), and simultaneously distilling–extraction techniques, amongst others(28) Despite being employed to several decades to extract essential oils, these methods possess many of drawbacks, including the destruction of certain volatile substances, low effectiveness of extraction, the decomposition of unprocessed or a ester substances via heated or the hydrolytic impacts, along with the potential for hazardous solvents remains in the extracts or essential oils (Eos)(29) As a result of price increases for electricity & the onset of the "Green Era," Essential oil extraction-related sectors concentrated on creating innovative methods for extraction(30) These methods for extraction fall into two groups: traditional procedures and advanced technology. A number of advanced approaches are now accessible to facilitating the extraction of essential oils (Eos) via agriculture would to get over the limitations of traditional approaches for extraction. These include solid-phase micro-extraction, membrane-assisted extraction with solvents, a pressure-sensitive the extraction process, pressurized extraction with heated water, extraction with supercritical fluid (SFE), microwave-assisted extraction, and ultrasound-assisted extraction, among others(31) The use of advanced techniques, like microwave and ultrasonic enhanced procedures, has increased the extracting method's effectiveness with regard to of heat disappearance and the amount of effort needed to isolate an essential oil. It has also increased the yield of manufacturing and produced essential oils of superior quality (32) the information and chemical components of essential oils are greatly impacted by the extraction techniques. It is important to choose the greatest practical and suitable way to concentration the desired biological effective ingredient within the

Essential oil; the greatest typical conventional and emerging techniques for EO extraction are shown in the components that follow (33). process, pressurized extraction with heated water, extraction with supercritical fluid (SFE), microwave-assisted extraction, and ultrasound-assisted extraction, among others (31) The use of advanced techniques, like microwave and ultrasonic enhanced procedures, has increased the extracting method's effectiveness with regard to of heat disappearance and the amount of effort needed to isolate an essential oil. It has also increased the yield of manufacturing and produced essential oils of superior quality (32) the content and chemical components of essential oils are greatly influenced by the extraction techniques. It is important to choose the greatest practical and suitable way to concentration the desired biological effective ingredient within the Essential oil; the greatest typical conventional and emerging techniques for EO extraction are shown in the components that follow (33) Figure 1 shows Essential Oil: From Extraction to encapsulation.

Figure 1: Essential Oil from Extraction to encapsulation.

TRADITIONAL TECHNIQUE FOR EXTRACTION OF ESSENTIAL OIL

The traditional extraction techniques including steam distillation, cold pressing, solvent Extraction, Enfleurage, Maceration, The process of penetration (Percolation), Decoctioning, The Soxhlet Extraction Method, Hydro distillation.

1. Steam distillation

Steam distillation is most significantly popular technique for extracting essential oils from plants (34) the combination of water and steam are employed in the process of steam distillation, however the plant component isn't in immediate vicinity with the water during the process. A heating system generates the steam, which is then forced down via a tube into the container's bottom, wherein the plant substances is placed on a tray with holes in it. Heating is the main factor that determines how well the frameworks of plant substances decompose, rupture, and produce their essential oils or volatile substances (38) The Condensate distilled is made up of a blend of oils and water. A Firenze separator is used for separating oils from the fluid. The container, which divides them according to their dissimilar the densities (35) This technique's common characteristics include the component being put into touch with vapor rather than boiled water, and vapor that is typically completely saturated, soaked & rarely overheated. Similarly to its previous form, water/steam distilling produces vapor at the container's bottom beneath the slotted dish, whereas distillation using steam draws its steam from an outside source. All distilling techniques may be used at pressure in the atmosphere, modest pressure, as well as elevated pressures (36) This method extracts 93% of the essential oils, with the residual 7% being separated through different techniques (37) Figure2 shows A schematic representation of the steam distillation process.

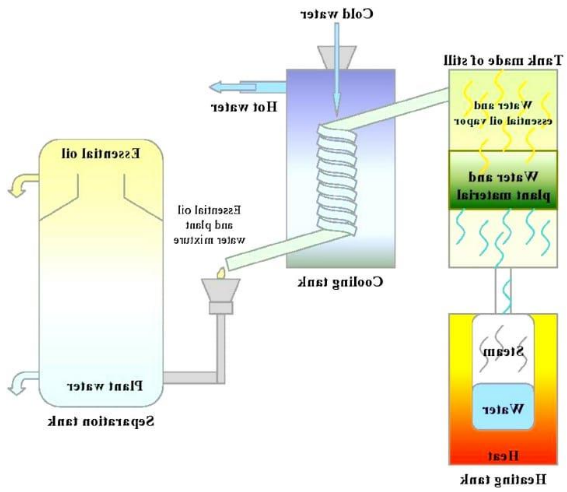

Figure 2: A schematic representation of the steam distillation process.

2. Cold pressing (Expressions)

The oldest method of extracting essential oils (Eos) is by cold pressing or expression, which was used decades prior to anyone developed distilling. Although this approach produces modest yields, it has the benefit of producing minimal or no heat through the entire procedure(39)Because of the significant thermal instabilities of the aromatic compounds they contain, it is mainly used to isolate the outer peel oils of fruits such as citrus(40) In order to obtain essential oils from orange peels, the mechanical cold- pressing process uses force or abrasive to rupture the oily pores, causing the oil to be expelled and rinsed along via a solution of water spraying. There are many readily accessible pieces of machines for CP oil extraction, with the most often used becoming the consistent separator made by FMC (Food Machinery Corporation, Chicago, Illinois)(41) The EOs that CP produces include coumarins, or pigments from plants, and other substances in addition to volatility ones(40) It is therefore important to utilize distilled over neutralized sodium hydroxide or a carbonyl-adduct agent when an authentic oil of essential oil is needed(42) Given the drawbacks of this technique's inadequate yield extracting as well as poor pureness, prior treatments via enzymatic are being studied to enhance both the quantity and the quality of essential oils obtained(43) Soto and associates utilized CP in conjunction and hydrolysis via enzymes to extract borage (Borago vulgaris) seeds oil, yielding higher results than the untreated group that did not receive an enzyme prior treatment; By employing an enzyme-assisted extraction method with CP, Callao et al. increased the amount obtained in the extraction of oil from primrose (Oenothera biennis)(44) Anwar et al. evaluated the impact of several enzymes preparing on the production of pressed cold oil from flaxseed, getting a notably greater yield from processed cold linseed treated with enzymes (38%), as opposed to the controls (32%)(45) Organics essential oils, which are usually sold as unique items & fetch higher rates in market, are produced using CP these days(42) Figure3 Shows diagrammatic representation of cold pressing (Expression)

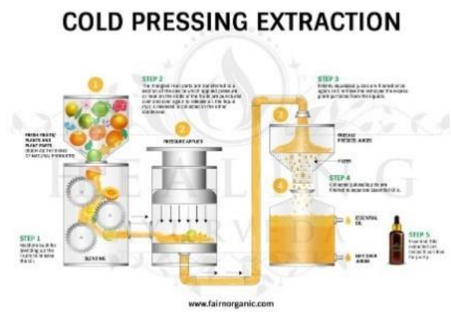

Figure3: Diagrammatic representation of cold pressing (Expression)

3. Solvent extraction

For precious or weak floral components that is unable to tolerate the distillation heat with steam, traditional extraction with solvent has been in use. For the extraction process, several kinds of the solvents, like acetone, ethanol, hydrocarbon ether, alcohol, or ethanol, a can be employed (46) In standard procedure, the plants matter is combined with the solvent, boiled for extracting the essential oil, and then filtered. Afterward, the Evaporation of the solvents concentrates the filtrate that remains. Concentrated is Resins (resinous) or concrete (a blend of essential oil, waxy substance, and aroma) after extracting the oil from the concentrate, it is combined with pure ethanol and boiled below a lower temperature. The smell is absorbed by the alcohol, which leaves behind its floral absolute oils after the ethanol evaporates. But because this procedure takes a while, the oils are more costly than with other approaches (47) Phenolic substances (48.0%) predominated in the oil, with thymol (3.4%) and carvacrol (44.6%) being the principal constituents. Ozen & colleagues investigated the chemical makeup and antioxidant capacity of essential oils obtained through multiple solvents species Figure 4 show an illustration of solvent Extraction.

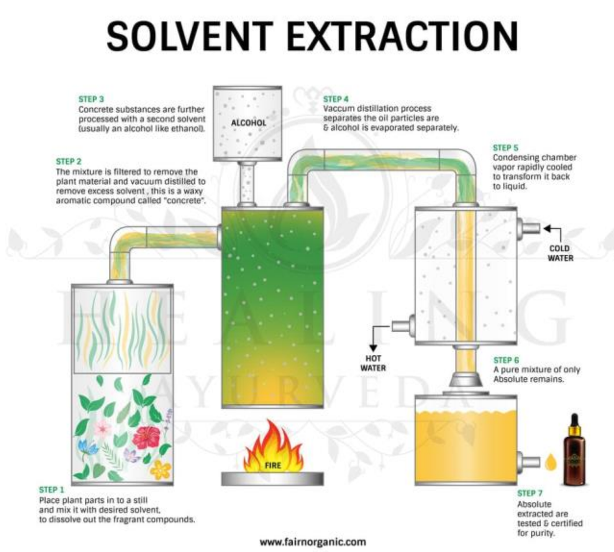

Figure 4: An illustration of solvent Extraction.

4. Enfleurage

A classic and rigorous method of floral oil extraction. Fats is layered on top of the petals of the flower during the procedure. Ethanol is utilized for the reason behind the separation the essential oils from fats once the fats is absorbing them. After the ethanol has evaporated, the essential oil is gathered (48) Enfleurage is a method for capturing aromatic substances released by plants using without smell fats that are a semi-solid at ambient temperature. Another name for it is the cold Fat Extraction. Either “cold” or “hot” enfleurage can be used.

a) Cold enfleurage:

A coating of animal fats, typically two parts grease and one piece grease (from pork and beef, accordingly), is applied to a huge framing piece of glassware known as an undercarriage and left to harden. After that, biological material—typically entire blossoms or petals—is applied to the fat, then over a span of one to three days, the aroma is allowed to penetrate the fat. Once fats reaches the required level of aroma exhaustion, the procedure continues using fresh medicinal plants in place of the expended materials. In the 18th century, this process was created in southern France to produce high-grade extracts. In Europe, the method is still widely employed to produce large quantities of some flowers (49)

b) Hot enfleurage:

Plant material is mixed into solid fats while they are cooked. Once fats is saturated with scent, old botanicals are continuously squeezed out and refilled with fresh substance. This process is thought to be the earliest known way to preserve the compounds that give plants their scent. “Enfleurage Pomade,” which is used in both cases, is extracted individually when the fat has become soaked with aroma (Defleuraged). To extract the aromatic compounds, the enfleurage pomade could be soaked in ethyl alcohol or further cleaned before being sold. After being extracted from the fat, the alcohol is allowed to evaporate in a device known as a “batteuses,” which uses a vacuum to facilitate evaporation and leaves behind the plant matter. Since the spent fat is still somewhat aromatic, it is typically utilized to manufacture soap (49) Figure 5 shows an illustration of enfleurage method

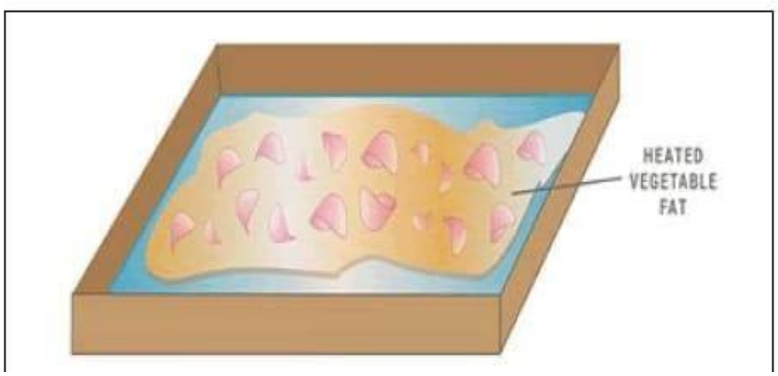

Figure 5: an illustration of enfleurage method.

5. Maceration

It is an ancient technique for making medicines. It is regarded as a popular and affordable method of producing organic goods from plant matter. One technique for extraction of solids from liquids is maceration. This procedure involves adding a solvent to a covered container containing the powder solids components. It is permitted to get for an extended period duration (hours to days) with sporadic agitation. The required period is given for the solvent to permeate the cell wall and dissolve the plant's ingredient. The only way this procedure occurs is by molecule dispersion. The solution is separated off during the allotted amount of period, and the most solvents is recovered as feasible by pressing the solid remnant. To stop bacterial development, a tiny amount of ethanol might be applied when the solvent is waters and the maceration time is lengthy (49) Three phases are involved in maceration. Initially, plant components are ground into a powder. This enables the components and solvent to have good interaction. A selected solvents is introduced in a closed tank following crushing. After that, the liquid is squeezed out, but a significant proportion of obstructed solution are recovered by pressing the solid particles left behind from the separation technique. Periodically agitating the sample throughout the procedure of maceration promotes extracting by boosting dispersion and removing the concentrated mixture from the surface of the sample, introducing fresh solvent into the menstruum for a higher extracting efficiency (50) Figure 6 Shows Digrammatic representation of Maceration Method

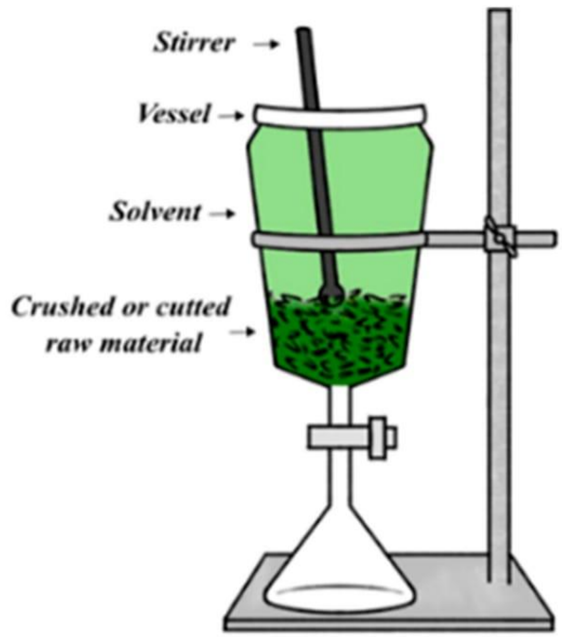

Figure 6 Digrammatic representation of Maceration Method

8. The process of penetration (Percolation)

The most prevalent form for removing active components from tincture forms and extracts of fluids is this one. Typically, a percolator—a thin, a cone-like tube with openings at its two ends—is employed (Figure 6). When moistening the solid components with a suitable quantity of the solvents and letting them remain in a tightly sealed container for about four hours, the mixture is stuffed and the percolator's the top is sealed. After adding more solvent to create a thin film over the bulk, the resulting mixture is left to macerate for twenty-four hours in the sealed percolator. After then, the percolator's exit opens, allowing the fluid inside to trickle gradually. As needed, more solvent is incorporated while the percolating equals approximately three quarters of the final an item's volumes (49) after pressing the substance, the solution is put to the percolating. After adding enough solvent to create the necessary quantities, the combined solution is cleared either by filtering or by sitting and then the decanting process. The procedure is carried out untill there is no residual left behind after an amount in the solvents within the percolator evaporates (51) Figure 7 Shows Digrammatic representation of the process of Penetration

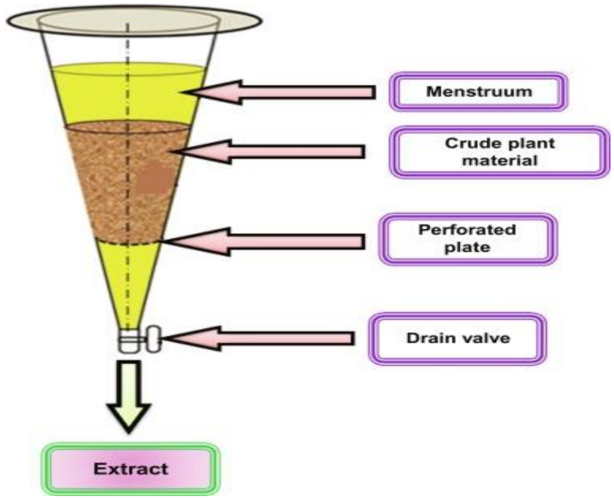

Figure7 Digrammatic representation of the process of Penetration

3. Decoctioning

It is an appropriate technique for removing substances that are accessible in water and resistant to heat destruction (52) A composed of water method for removing active ingredients using botanical products is called a decoction The vegetative matter is boiled using water in this procedure to create a fluid formulation (Fig. 6) While dealing with stiff, woody trees, their shouts, origins, or species that contain compounds that dissolve in fluid, decoction is the preferred technique. Usually, the plant's substance is crushed or split into small fragments. Various techniques for making decoctions are being documented. The crude medication, known as yavakuta (little morsels), is put in ceramic pots or galvanised copper containers having clay on the exterior as part of the Ayurveda technique, which is historically called kwatha. The pot gets warm on a fire and water is introduced. It is advised to employ four times the quantity of water for every one portion of mild stuff, eight times for extremely strong substances, and sixteen times for extremely hard drugs. After that, the combination is heated over low heat till it has been decreased to one-fourth of its initial capacity for gentle medications and one-eighth for moderate or extremely harsh substances. After cooling and straining the resulting extract, the filtrate is gathered in sterile tubes (49) Figure 8 shows Digrammatic representation Decoctioning

Figure 8: Digrammatic representation Decoctioning

4. The Soxhlet Extraction Method

It's the most efficient method for the ongoing extraction of solids by a heated solvent and is referred to by the German agriculture scientist "Franz's Friedrich von Soxhlet apparatus (53) the mainstay of fundamental approaches for removing fats & oily substances from seeds materials is solvents choosing, which includes agitating and heating. With the exception of a few particular uses areas, like the extraction of thermolabile chemicals, Soxhlet apparatus extraction—the ancient extraction technique—is an extremely often used approach to assessing the effectiveness of different solid-liquid extraction techniques (54) the conventional Soxhlet system is depicted in Figure 7. After filling the thimble-holder with condense new solvents from a decanting container, the seeding ingredients (solids) are added (55) a suction draws the thimble-holder solutions and releases it from the flask for distillation as the liquid achieves the excess straight, transferring the collected solutes into the solution's mass. The distillation is used in the solution beaker for separating solutes from the solvent. The container retains the solutes while new solvent enters the solid bed. The process is performed repeatedly until full extraction is accomplished (56) Heating reflex separation and the use of Soxhlet are two distinct procedures. Simply boiled the substance in the solvent and using a cooled barrier to compress the expanding solvent molecules during their boiled off will accomplish heated reflex extracting by restoring the substance to a liquids condition in its vessel without boiling it away(57) Later, the resulting extract decreases to flavor after continuing its concentration in the solvent. Conversely, Soxhlet extraction is used to separate components that dissolve in a solvent (58) Figure 9 shows diagrammatic representatin of Soxhlet extraction.

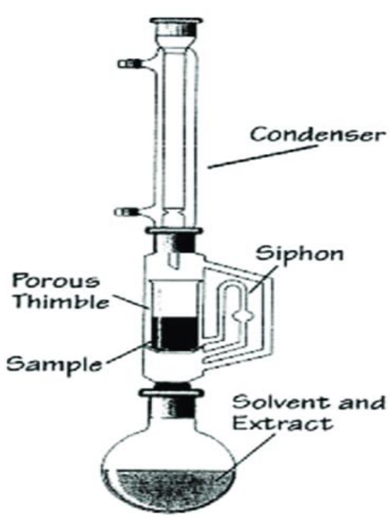

Figure 9: An illustration of Soxhlet extraction

9) Choosing a solvent

When employing the Soxhlet extraction process to extract the desired ingredient, a suitable use of extracting solvent is recommended. Completely various extracts and extracted ratios will result from using varying solvents (59) Hexane is mainly employed as a type of solvent for extracting oils that are edible from plant-based sources. This can be attributed to its modest boiling point, ease of recuperation, and the fact majority of oils dissolve in hexane. One drawback of n-hexane is the dangerously high degree of polluted air it produces Sustainability, longevity, and security concerns have led to a rise in the usage of renewable solvent like isopropanol, alcohol, hydrocarbons, and water. Oil has been extracted from rice bran using d-limonene and hexane (60) in all settings, it was shown that d-limonene extracted a significantly greater amount of essential oil than hexane. The oil produced by rice bran was extracted using water, or H2O, at a pH level of 12. Compared to oil obtained through hexane, the oil extracted utilizing the water-based medium showed less free fatty acid (FFA) and colour-enhancing properties. Minimal free fatty acids provides minimal item degradation and substance colouring initialization. However, since the atomic affinities among the solvent and the solute decreases when various solvents are used, recoveries is frequently reduced. Substitute solvents like acetone & ethanol, while hexane is the expected, might be more expensive. It is usual practice to add an additional solvent to make the phase of liquids more polar. According to reports, a combination of solvents like hexane and isopropanol can improve the extraction's kinetics and yield (61)

5. Hydro distillation

A conventional technique for removing plant parts plant components without the application of organic solvents is water distillation. Hydro distillation involves packing plant substances in a still's storage space, incorporating sufficient water, and then bringing the mixture to a boiling (Figure.8). As a substitute, a plant material is directly injected with heat. The major factor that determine for the discharge of plant matter chemical substances are steam and hot water. Both water and oil condensate composition condense as a result of passive cooling processes through water. One apparently extremely helpful technique for obtaining essential oils from a variety of plant species & their varied sections is water distilling. The amount produced is impacted by several factors, including the raw material's capacity, the amount of water, dimension, and kind (62) three primary physiological chemical reaction are involved in hydro distillation: breakdown, hydro dispersion, and heat-induced breakdown. Certain chemical substances might be removed at elevated separation temps. Its application for the removal of thermolabile compounds is restricted by this flaw (63) to separate essential oils from plant sources, hydro distillation can be done in three different ways:

1. Steam distillation done directly
2. Distilling water
3. Distillation using steam and water

1. Steam distillation done directly

Directly steam distillation, as the name implies, is the method of using steam produced outside the still in a boiler, sometimes known as a steam engine, for distilling material from plants (64) the material from plants stands above its steam the inlets on a slotted system, just like in steam and water distillation. The ability to easily regulate the steam output is a true benefit of satellite steam generating. The material used in plants shouldn't deteriorate thermally since steam is produced in a satellite's burner, which heats it to no more than 100 degrees Celsius(65) The vast majority extensively employed technique to produce essential oils on a big basis is the use of steam distillation(66)

2. Distilling water:

This procedure involves submerging the component entirely in water that has been heated by a straight flames, steam coat, sealed steam coat, closed steam coiling or opened steam coiled. The primary feature of this technique is that the plant component and hot water come into direct touch (67).

3. Distillation using steam and water:

Steam might be produced in a press or in a satellite boilers during steam and water distillation, but it must be isolated from the plant materials. Similar to water the process of distillation rural regions make substantial utilization of steam and water distilling. Furthermore, compared to water distillation, it doesn't need a significant increase in capital cost (67) additionally, the apparatus is largely the same as that utilized in water distilling; however, a perforating grids supports the plant materials over the hot water. Actually, it's not unusual for people who start with water distilling to later move on to steam and water distillation (68)

ADVANCED techniques for Extraction of essential oil

The Advanced methods of extraction such as Supercritical fluid extraction (SFE), Microwave-Assisted Extraction (MAE), Extracting Liquids Sub critically, Pressurized Liquid Extraction (PSE), Hydro diffusion, cold -Finger Distillation, Enzyme -Assisted Extraction

1. Supercritical fluid extraction (SFE)

Distillation using steam and extraction of solvent are examples in traditional methods of extraction that require much organic solvent and require more time to finish(69) Furthermore, one must deal with the drawbacks of these methods, such as the destruction of different volatile elements, inefficient extraction of oils, deterioration of unbalanced substances, and hazardous leftovers from the method of extraction(70,71) The liquid's threshold temperature (Tc) and crucial pressure (Pc) are both fundamental determinants of the supercritical fluids state. These essential factors cause fluids to have extremely intriguing characteristics including large diffusion, moderate viscosity and density that is closer to that of liquids(72) Because of its many desirable qualities, the gas CO is utilized as a saturated solvents for the removal of essential oils: (i) readily reaches the point of criticality (lower crucial temperatures, Tc: 31.2°C, and crucial the pressure, Pc: 72.9 atm); (ii) non-aggressive for thermolabile particles of the plant vitality; (iii) chemically inactive and hazardous; (iv) inflammable; (v) accessible in high quality at comparatively low expenses; (vi) simply eradicated; (vii) comparable to pentane in orientation, making it appropriate to remove compounds that are lipophilic(73,74) Utilizing and reusing fluid in successive compression/decompression stages is a fundamental idea behind the super critical fluid extraction method. This fluid may be heated and compressed to the supercritical condition with carbon dioxide (CO2). After that, it loads flammable substance and extracts from plants by passing by the raw plant substance. Following the procedure, the combination of carbon dioxide (CO2) and plant materials is sent to two dividers for a progressive deformation of the fluid, which separates the extracted material from the carbon dioxide (CO2). Although CO2 readily turns back into a gas at ambient pressure and temperature, little or no solvent residual is left in the finished product after it emerges from the subsequent separate and returned into the tank for storage(75) Some studies have identified the chemical contents of a number of different plant substances, including cloves sprouts, marchantia obscure, roses geraniums, and Eugenia’s caryophyllata, that have been extracted via the supercritical carbon dioxide extraction method(76) An essential oil was effectively obtained and recognized as an advanced volatile oil with outstanding properties and therapeutic properties utilizing the supercritical fluid methodology in a study comparing supercritical fluid extractions with the hydro distillation technique(77) Apart from that, it was discovered that a carrot essential oil produced using the supercritical fluid extraction method had superior antibacterial and antifungal qualities against Bacillus cereus when in contrast to an oil produced by hydrodistillation(78) Figure10 Shows supercritical fluid extraction.

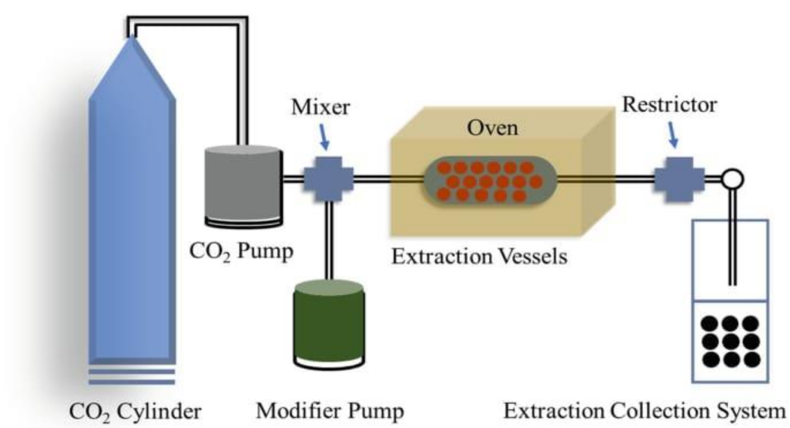

Figure10: Supercritical fluid extraction.

2. Extracting Liquids Subcritically

Many investigators have documented the usage of water in an a subcritical condition and found it to be more efficient and potent substitute for the extraction method of essential oils (79) When a liquid approaches a pressure greater than the point of critical pressure, or PC, and below the critical temperature, or Tc, or vice versa, it is said to be in the a subcritical state. The liquid and carbon dioxide (CO_2) are the liquids utilized in this process to isolate essential oils. Numerous enhanced properties, including decreased viscosity, decreased density, and enhanced diffusivity between gases and liquids, are provided by the subcritical condition of a fluid. Due to its ability to facilitate a quick essential oil separation process at a low operating temperatures, as well as its affordability, ease of use, and friendly to the environment, this extraction method is regarded as the most beneficial strategy (79) Relative to the three hours needed for extracting essential oils via traditional methods, this procedure only requires fifteen minutes of time for extraction. Considerable energy and plant material money are possible with essential oils that have more useful qualities, such as a higher concentration of oxygenation constituents and no discernible terpenes(80) It took 20 minutes and two hours, accordingly, to isolate the the lactones at the a subcritical extraction of water operation temperatures of 100°C and 175°C. In comparison to the subcritical water approach, the technique of Soxhlet extraction shown a significant difference in extraction time, requiring six hours to extract the oils and yielding 40% to 60% less product (81)

3) MAE, or microwave-assisted extraction

A severals of essential oils have been extracted using microwaves in the past decade by different investigators, who found that the essential oils extracted in 30 minutes or less were similar to those gathered after more than twice the time using specific standard procedures like HD or Soxhlet separation, both qualitatively and quantitatively (82, 83) The radiation from microwaves is used in MAE to heat the solvent-sample combination. Owing to the unique properties of microwaves (including, ions conductivity and dipole rotations), heating with microwaves happens instantly and inside the sample, resulting in extremely quick extractions (84) the breaking of weaker bonds of hydrogen, which is facilitated by the molecule' dipole motion, is one benefit of heating with a microwave. Since electro-magnetic waves alter the cell system, MAE extractive technologies differ from traditional approaches in that the extraction happens as a result. The utilizing of microwaves significantly shortens the duration of extraction and the amount of solvent is required, which consequently lessens the environmental load by releasing less CO_2 into the atmosphere(85) Both transportation phenomena—heat and load inequalities acting in the identical direction—may combine synergistically to provide procedure accelerated as well as elevated extracting yields(86) Because temperature is consistently low the procedure, MAE is especially well-suited for extraction of thermolabile chemicals(87) Although the initial investigations detailing the effectiveness of microwave energy for extraction of organic matter were published in 1986(87) it wasn't until relatively recently that MAE was considered to be especially alluring because it could quickly heat water-based samples(83) Numerous studies have noted that the following variables influence the extraction of organic compounds by MAE: sample viscosity, matrix moisture and composition, exposition duration, pressure, microwave intensity result, and solvents type and quantity(89) The solvent that was chosen typically has an elevated dielectric constant and absorbed microwave radiation extensively, but solvents mixes can be used to adjust the media's extraction selective and microwave interaction capabilities(90) Improvements in microwave extraction have led to the creation of a number of methods, including free of solvents microwave the extraction process, the microwave facilitated distillation using steam, microwave hydro-diffusion and gravity (MHG), microwave-assisted simultaneously distillation-solvent extraction, vacuum microwave HD, microwave HD, and microwave-assisted solvent extraction(91) Figure 11shows Micro wave assisted extraction.

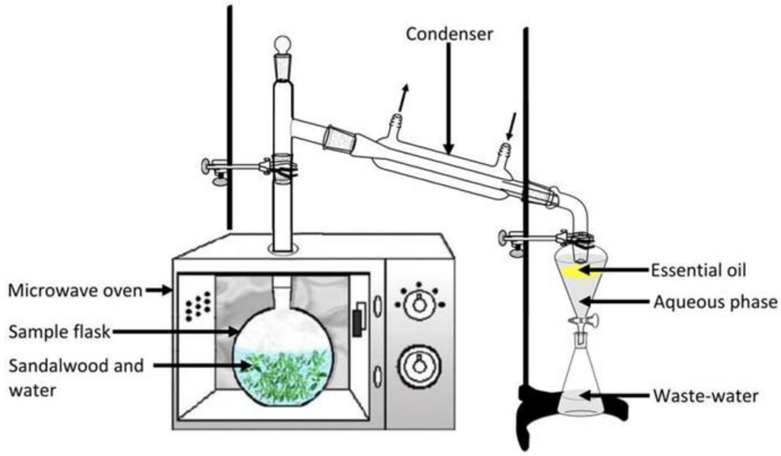

Figure11: Microwave assisted extraction

4) UAE or Ultrasound-Assisted Extraction

The phytopharmaceutical extraction business has acknowledged the capability commercial application of ultrasonic for a variety of botanical extracts(92) In contrast to traditional procedures, UAE is used to isolate volatile chemicals from natural materials at ambient temperature using organic solvents, which reduces the duration of processing, lowers solvent volume, and increases extracts yields(93) At lowest frequencies (18–40 kHz), its impact is significantly more powerful, while at 400–800 kHz, it is essentially insignificant(94) The occurrence of turbulence created in the solvent by the movement of an ultrasonic signal is responsible for the increase in the effectiveness of Ultrasound-assisted organic substance extraction. When ultrasonic is applied, bubbles of cavitation are created and crushed. A "surprise waves" that results from the air bubble collapsing due to the compression's raised pressure and temperature travels through the solvent, improving blending(93) Additionally, it has been demonstrated that when that after treating raw plant tissues, the cells that include essential oils have very thin skins that are readily destroyed by sonication; therefore, using ultrasonic energy promotes the mass transport of the solvent into plant cells from the continuous phase and facilitates the release of extractable compounds(95) Thus, the two main elements enhancing extraction with ultrasonic waves are excellent transfer of mass and effective cell destruction(96) Tools like cleanup bathtubs or examine frameworks are often utilized for the laboratory-scale extraction of essential oils. Since using ultrasound may increase temperatures, it is preferred to utilize an automatic stirrer to stir and cool the extraction combination in disinfecting baths where the extraction can be done by either a direct or Indirect waves(97) When extracting quantities are small, the probing framework may be adequate(98) Many aspects influence how ultrasound energy works to produce a successful and effective ultrasound-assisted the extraction process; a few of these factors are related to the plant's properties (moisture content and particle size), while other factors include the extraction solvent and process variables (frequency, pressure, temperature, and sonication time)(97) There have been reports of increases in extraction yields when Eos were obtained using UAE. According to reports, using ultrasound occasionally does not result in a notable enhancement of the extraction yield. when compared to conventional approaches; however, the deterioration of herb The components of always reduced. Consequently, the UAE is a good method for appropriate compounds (97,99) Sound waves with high frequencies beyond 20 kHz, or above human hearing, are considered to be waves of ultrasound. Both compressive and fluctuations are responsible for the propagation of these vibrations. The liquid experiences a negative force as a result of its expanding. Steam bubbles emerge when the pressure is higher than the liquid's tensile force. Cavitation occurs when these bubbles of vapor undergo implosive breakdown in ultrasonic sectors (100) Macroscopic instability, higher-velocity interparticle impacts, and disturbance of the biomass's microporous granules are produced by the bursting of cavitation bubbles. A fast the flow of solvent is directed via the cavities at the surfaces by cavitation near the water-solid boundaries. These microjets' bombardment causes layer separating, deterioration, and particles disintegration, which makes it easier for biological agents or the desired component to emerge from the ecological framework. As an outcome, the transmission of mass via interior dispersion and turbulent processes increases, improving the effectiveness of extraction. Ultrasound's mechanical characteristics promote the movement of mass by allowing for greater absorption into biological substances. Cellular cell walls are broken down by ultrasonic to allow components to be released more easily (101) Ultrasound's mechanical attributes promote the transfer of mass by allowing for greater absorption into biological substances. Biological cell membranes are broken down by ultrasound to allow materials to be released more easily. Thus, two key elements that improve extraction using ultrasonic energy are cell rupture and efficient transfer of mass. In contrast to conventional extraction procedures, ultrasound enables modifications to the circumstances of processing, such as a drop in pressure and temperature, which enables the separation of thermolabile compounds (102) The extraction output rises with the temperature of extraction for solid-hexane extractor of pyrethrums from pyrethrum flowers without ultrasound, reaching its maximum at 339K. The ideal extraction occurs at temperatures between 313 and 333 K since with ultrasound, temperature has little effect on yield in this range. Consequently, the utilization of UAE Is recommended for two substances, which could be modified Under Soxhlet and thermal reflux extraction working conditions Ations caused by elevated extraction temperature (103) there exist two categories of ultrasound devices that might

An ultrasonic water bath can be utilized for extraction purposes and an ultrasonic probe apparatus equipped with horn transducers an ultrasonic probe is used in a UAE system in Figure. UAE extraction technique has been applied to marketed extraction purposes at both the laboratory and scale of industry (101) Figure12 shows Ultrasound Assisted Extraction (UAE)

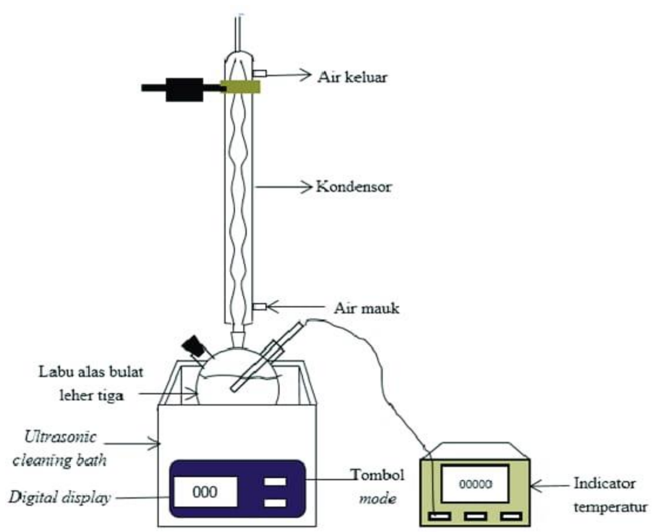

Figure12: Ultrasound Assisted Extraction

4) PLE or pressurized Liquid Extraction

PLE can also be referred to as rapid solvent extraction, solvent extraction under high pressure, or enhanced solvent extraction. The PLE temperature and pressure parameters fall between 323 and 473K and 3.5 and 20 MPa, respectively.The increased pressure results in the solvent temperature tension on the surface of solvents, aiding them in dispersing uniformly Enhance the extraction rate and optimize the biological matrix. In certain instances, Rather than using an organic solvent for extraction, pressurized hot water is utilized. This method is referred to as sub-essential water removal or pressurized hot water extraction (105). IIlustration shows a schematic illustration of a PLE system. The PLE apparatus includes an extraction cell. Where the specimen is presented. The cell contains a heated solvent. Elevated temperature and pressure are then preserved to enable quicker retrieval. It appears that your input was cut off. Please provide the complete text that you would like paraphrased. The system includes a pressure relief valve that protects against excessive pressure. Cell pressurization. Nitrogen is utilized to clear all the Solvents remaining after the extraction process (106) Solvent for extraction, temperature, and pres- Certainly, the count of cycles and duration are noted to affect. Figure 13 shows Pressurized liquid extraction.

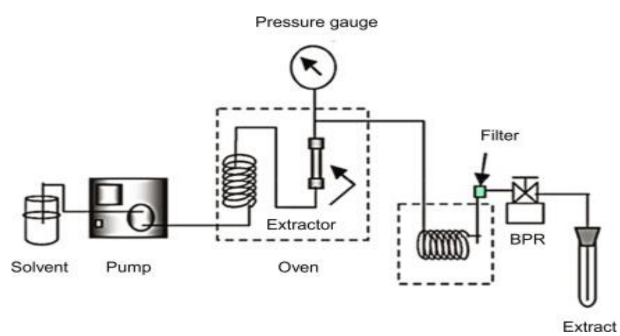

Figure13: Pressurized Liquid Extraction.

5) Hydro-diffusion and Gravity in Microwaves

One of the newest environmentally friendly techniques for removing volatile oils is microwave hydro-diffusion & gravitation (MHG). This method harvests and extracts volatile oils that hydro diffuse from the interior cell regions to the outside of the plant material using microwaves and earth gravitation. Figure 9 displays a schematic illustration of the MHG extraction mechanism. Usually, no solvent is added, and it is done at air pressure. It was intended to be processed and experimenting on an intimate level (107) this method's benefits include being cost-effective, requiring less power, being extremely efficient, and not requiring any water or solvent. In contrast to hydro distillation, which takes hours, the extraction process takes minutes.

6) The Distillation of Ohmic Heated Water

Ohmic hot water distillation (OHWD), which uses ohmic or Joules' heating and uses less energy (per milliliter), is a ground-breaking method for separating essential oils.More precise modeling variables are required for regulating therapeutic uniformity. Fig. displays a schematic illustration of the OHWD extraction mechanism. The rate at which heat is produced is determined by the electric field's intensity squared by the conductance of the medium. Figure 14 shows the distillation of ohmic heated water

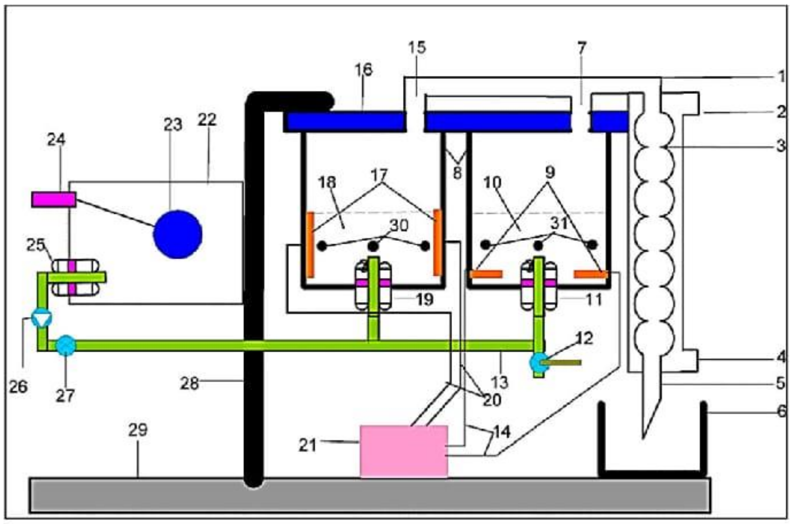

Figure14: Ohmic Hot Water Distillation.

- Encapsulation of essential oils (Eos): Method /Approaches

Eos have been encapsulated using a range of chemical, physicochemical, and mechanical techniques.

A) Chemical techniques

Traditionally, liposomes have been prepared using phospholipids. L-α phosphatidylcholine and cholesterol were combined with thymol and carvacrol egg L-α, the solvent was extracted at 35˚C under a nitrogen stream, and the resulting lipid film was hydrated to create multilamellar vesicles (MLV) from unilamellar vesicles. Liposomes containing 1.07 mg of carvacrol had an encapsulated percentage of 4.16% (0.045 mg). According to a stability research, the liposomes that contained carvacrol and thymol shown improved antibacterial action, and their long-term retention preferred their stability in liposomes(109)

b) Physicochemical technique

Coacervation is a physico-chemical separation process of one or more hydrocolloids from a solution and is often followed by creating a coacervate phase that encapsulates the active ingredient which is suspended in the coacervate, the surrounding reaction medium. A mixture of oils of rosmarinus and thymus was emulsified with a high-shear mixer in a 10% gelatin solution at 40˚C. Then, while stirring for an hour at low temperature (5˚C), sodium sulphate (20% weight/weight) was added to coacervate. In a further step, glutaraldehyde (1 mmol/g gelatin) was introduced at pH 8 at 5°C while stirring at 750 rpm for three hours. The microparticles were then freeze dried after being filtered. After glutaraldehyde (1 mmol/g gelatin) was added at pH 8 while stirring at 750 rpm for three hours at 5˚C, the microparticles were filtered and freeze-dried. The produced microcapsules of 60µm in diameter retained 75% of the oil. As the microcapsules were increased in the feed, a drastic increase in the mortality of the Indian meal moth (P. interpunctella) was noted

C) Mechanical technique

Spray drying is a broadly employed commercial technique, primarily for the encapsulation of essential oils, due to its simplicity and low cost. In spray drying, the core is integrated into a polymer solution and then atomized into warm air. Sanchez and coworkers have employed a spray-drying technique on an OEO emulsion prepared with β cyclodextrin at room temperature and inlet air temperature of 105˚C with a pump flow rate of 1.1 ml/min. Microcapsules were ellipsoidal to spherical in shape. Relative size ranges of the microcapsules were 0.71 - 20 µm, 1.42 - 28.14 µm, and 1.07 - 38 µm. The larger size formulation also had higher encapsulation efficiency (81.03%) compared to smaller capsules (0.71-20 µm), which had an efficiency of 53.90%. The whey protein-maltodextrin conjugate-prepared thymol-loaded emulsion was additionally spray-dried at an inlet air temperature of 150˚C, a compressed air pressure of 600 kpa, an air flow rate of /h, and a feed rate of 6.67/min. At 10% oil volume fraction, the encapsulation efficiency ranged from 73.8% to 82.8%. Phase, but when the oil phase percentage rose to 30%, it dropped to 67.6%. Additionally, they observed that thymol was lost as a result of an inlet temperature equal to its vapor pressure (8.0 kpa) and a corresponding loss of capsule shape, or a burst wall, which occurred during spray drying and was visible in the AFM image (109)

Essential Oils' Primary Uses and Restrictions in the Pharmaceutical Industry

The latter metabolism of aromatic plants gives rise to the production of Eos to be liquid mixtures of perfumed euvolatiles. Over 60 genera of plants can form complex mixtures of secondary metabolites, which usually include terpenes, ethyl alcohol, ethers, ester, ketone, and aldehyde in different proportions.The primary constituents are monoterpenes and sesquiterpenes, with aromatic and aliphatic compounds making up a smaller portion. Concentration fluctuation makes it challenging to compare data and causes notable variety in the products utilized in various investigations (110) Eos typically consist of 20–60 components.up to 100 distinct chemicals in a wide range of concentrations. When compared to other components that are present in trace amounts, two or three key components are typically present at large concentrations (20–70%).Typically, essential oils (Eos) comprise anything from 20 to 60 constituents to over 100 individual compounds, all at varying quantities. In contrast to other constituents that are present in trace amounts, two or three primary ingredients are typically present at considerable concentrations (20–70%). EO use is restricted because of the following issues: oxidative and hydrolysis-induced instability; high volatility; hydrophobic nature (and, thus, insolubility non water); as a result, current research is concentrated on the potential application of novel formulation for EO encapsulation. But as Eos are typically safe, with the exception of some skin sensitivities and UV sensitivity (exposure to sunlight may induce irritation to the skin or pigmentation), their medicinal usage as pure components was investigated, primarily for exterior treatments (mouthwashes or inhalation). It is crucial to avoid applying EO on injured skin and to not exceed the recommended dosage as this could result in considerable systemic absorption and, consequently, severe side effects. The fastest method of administering essential oils is by inhalation, which is followed by topic one. It is not advised to use powerful oils for diffusing or direct inhalation since they may irritate the eyes. Even though it is thought to be safe, oral administration of Eos is uncommon, and they are typically diluted with milk or olive oil.

Anti-Inflammatory Properties

Inflammation is a natural reaction to damaging stimuli, whether they are acute or chronic. Acute inflammation typically subsides within days, characterized by signs such as heat, swelling, redness, pain, and reduced function. Chronic inflammation occurs due to extended or continuous damage, frequently involving immune cells such as monocytes and lymphocytes. Conventional anti-inflammatory medications (NSAIDs and corticosteroids) are frequently utilized, yet they may lead to considerable side effects, including ulcers or a heightened risk of infections. This has resulted in increasing interest in natural substances for managing inflammation, such as essential oils (Eos). For example, rosemary essential oil has a lengthy history of being used to treat ailments such as rheumatism, asthma, and bronchitis. Animal models, like carrageenan-induced pleurisy, are frequently utilized to investigate the anti-inflammatory properties of essential oils. For instance, Ogunwande et al. examined the essential oil of Bougainvillea glabra for its anti-inflammatory effects (112)

Antimicrobial Action and the Healing of Wounds

The management of microbial infections has consistently been among the most critical and Aspirational objectives in the pharmaceutical domain. The capacity of microorganisms to persistently Creating new drug resistance mechanisms renders this an constantly changing area. Certainly! Please provide the text that you would like me to paraphrase. Resistance to antibiotics is a primary barrier to carrying out an adequate Therapy for specific infections. In spite of the existence of numerous types of antibiotics, and thus a significant quantity of molecules, this issue is becoming more pertinent today and various therapies, including Eos, are being explored to address it. Even Hip- Pocrates, over two millennia ago, stated that the use of essential oils in fumigation was Helpful in safeguarding against the plagueThis was demonstrated during the Middle Ages when a few Groups of thieves, based on the belief in tinctures with essential oils, managed to take. From the residences of the plague victims without contracting the disease. Consequently, Eos possess Have been thoroughly researched and regarded as a legitimate alternative treatment for Bacterial diseases. The antibacterial properties of essential oils rely on the existence of specific Elements, particularly mono- and sesquiterpenes, recognized for their effective antimicrobial properties Biological agents. AdditionallyPhenolic groups are thought to have the strongest antibacterial activity, followed by cinnamic aldehydes. Other groups like alcohols, aldehydes, ketones, ethers, and hydrocarbons are also important; in particular, the levels of long-chain alcohols and aldehydes are linked to the antimicrobial efficacy against Gram-positive bacteria because, according to Shojaee-Aliabadi, the antimicrobial efficacy of alcohols is directly proportional to their molecular weight. (113) Eos' antibacterial properties can be used to treat infections caused by skin injuries. In actuality, the presence of the wound results in a decrease in the skin's fundamental barrier function against the outside world and, as the most hazardous side effect, a higher chance of contracting microbial infections. Because of their demonstrated antibacterial action against multidrug-resistant skin pathogens, essential oils (Eos) have been accepted as a legitimate treatment for wounded skin infections. Nevertheless, at certain doses, Eos may be cytotoxic, therefore the risk-benefit ratio for each one should be evaluated beforehand. The capacity of Eos to accelerate wound healing is another characteristic that supports their topical application. "Three stages make up wound healing: the inflammatory phase, which includes stopping hemorrhage is followed by vasodilation and immune system mobilization. The second phase entails the growth of multiple cell lines, such as fibroblasts, which results in tissue granulation and angiogenesis. Lastly, the third phase produces new collagen fibers and fibroblasts that distinct, drawing the wound's two edges closer together (114)

Antifungal Properties of Essential Oils

In humans, fungi are a major cause of deep-seated infections, especially recurrent infections of the mucosa, nails, or skin that can be rather serious in those with low or compromised immune systems. However, several cereals, fruits, and other crops are susceptible to fungal infection in the field or during storage. Fungi can produce a wide range of chemical substances known as mycotoxins as extra metabolites.They can also produce a lot of asexual spores. The food sector worldwide is still dealing with issues including the potential the existence of mycotoxigenic fungus in food and pressure to reduce fungicide residues on fruits, vegetables, legumes, and cereals. Guidelines that restrict unwanted biocide residues and require producers to select treatments that preserve product quality must be followed. However, there is growing worry about the health dangers connected to fungi and their spores in human living environments.Therefore, stopping fungal development is a good method of avoiding the buildup of mycotoxin. It is crucial to remember, though, that if fungal development is somewhat inhibited, such as by lowering the rate of development, the mold may produce more mycotoxin in reaction in stress (115)

Conclusion and future prospective

Since the atmosphere, light, and moisture promote oxidation or volatilization and lower biological activity, encapsulation is a useful method of protecting EOs from these elements. Encapsulation also improves oil's solubility, allows for controlled release, and boosts its bioavailability. Additionally, encapsulation renders oil more accessible, enhances its solubility, and allows for controlled release. The most practical and extensively utilized commercial methods for encapsulating EOs are spray drying and emulsification. The encapsulated essential oils shown improved antiviral, antioxidant, antifungal, antibacterial, and pesticidal properties. Encapsulated essential oils (EOs) in food, cosmetics, and pharmaceuticals can provide economic benefits while also addressing consumer safety concerns. Encapsulated essential oils (EOs) are not widely used in cosmetics or pharmaceuticals. To better understand the processes of oxidation, isomerization, and thermal rearrangements as well as preventative measures, more study is needed to 669 support previous analytical methodologies. Furthermore, identifying the goods produced by these processes seems like a worthwhile goal for the future. Additionally, encapsulated essential oils (EOs) can be employed to enhance their bioactivities in actual food systems, investigate how they affect cell membranes, and give non-lethal medicinal agents to treat a variety of illnesses.

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