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Review Article

An Overview on Essential oil Loaded Nanoparticle Approach for Novel Drug Delivery

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ABSTRACT

Bioactive components are found in essential oils. which show antibacterial, antifungal, antiviral properties etc the volatile secondary metabolites known as essential oils (EOs) are produced by plants and give them their distinct flavor, aroma, or both. skin is affected by a number of conditions, including dryness, aging, eczema, acne, pimples, dullness, wrinkles, and unsightly patches essential oils are used to treat these conditions, there are different types of oil like tea tree, lemongrass, clove, lavender, thyme, and cinnamon etc. which work against various strains of bacteria and fungi. essential oil loaded Nanoparticles are particles that are 100 nm or smaller. The three kinds of nanoparticles—organic, inorganic, and carbon-based—are often distinguished by their composition, nanoparticles are having various advantages and disadvantages, Essential oil loaded nanoparticles are synthesis by various methods High-speed stirring, high-pressure homogenization, and ultra-sonication, and co-precipitation The Stober Antibiotics method, nanoprecipitation, mini-emulsion polymerization, ionic gelation, and spray drying. Essential oil loaded nanoparticles are having various application in various fields. Essential oil loaded nanoparticles are characterized by zeta potential, UV absorption spectroscopy, X-ray diffraction analysis, FTIR, Microscopic techniques, TEM, Physicochemical, Electronic and optical, Magnetic, Mechanical, and Thermal properties and etc., A tremendous amount of work is going on in using nanoparticles as carrier systems for various actives such as essential oils for its obvious advantages.

INTRODUCTION

The EOs are substances that come from plants and have high volatility and intricate aromatic structures. [1] Volatiles are defined as the overall percentage of pungent compounds generated in specific plant cells, such as glands, ducts, or oil cells. [2] These are secondary plant metabolites

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that, by attracting polarizers and providing protection from diseases, are crucial to the dynamics of plants and their environments. [3] By employing various techniques, they can be taken from any part of plants, including the roots and leaves. Numerous environmental, plant nutritional, and stress-related factors affect the existence, yield, and chemotype of EOs. In order to promote particular compositions Breeding and selection strategies are employed for commercial EO production, when yield increases are sought. [4] Gas chromatography and mass spectrometry investigations have previously produced the commercial Essential oil structural characteristics. [5-6] Generally speaking, two or three primary compounds are identified by their chemical structure. that make up over 20% of the entire molecule and are typically in charge of their biological characteristics Their biological features are typically caused by two or three main components that make up more than 20% of the entire molecule, as shown by molecular structure. [7-8]. The bioactive components in EO exhibit antiviral, antifungal, antibacterial, and antiprotozoal effects all at once. Eos and traditional antimicrobials can work in concert to increase antimicrobial activity, which is particularly beneficial for preventative and control initiatives. [9] These plants are also utilized to improve the flavour, colour, and scent of foods and make up a significant portion of the human diet. [10] maybe offering safer substitutes for natural preservatives over synthetic chemical preservatives. [11-12] Furthermore, phytogenic additions are vegetable substances or components added to animal feed that improve animal performance and health and, in turn, the quality of foods obtained from plants and animals. Furthermore, phytogenic additions are vegetable substances or components added to animal feed that improve animal performance and health and, in turn, the quality of foods obtained from plants and animals. [13-14] The volatile secondary metabolites known as essential oils (EOs) are produced by plants and give them their distinct flavour, aroma, or both. Only about 300 of the about 17,500 different plant species that provide essential oils (EOs), notably those in the Rutaceae, Myrtaceae, Zingiberaceae, Asteraceae, and Lamiaceae families, are utilized in commercial settings. [15] The skin is affected by a number of conditions, including dryness, aging, eczema, acne, pimples, dullness, wrinkles, and unsightly patches. Essential oils are used to treat these conditions. Among their biological effects are analgesia, hyperemic, antiseptic, carminative, antibacterial, diuretic, spasmolytic, and stimulatory. [16] Thyme, clove, and oregano essential oils include phenolic components including thymol, eugenol, and carvacrol, respectively., has been linked to the antibacterial action of numerous EOs. An appealing technique for preserving the physical and chemical characteristics of crucial oils to prevent unintended alterations and enhancing food processing is encapsulation. One or more substances, including starch, hydroxypropyl methyl cellulose, phthalate gelatine, gum Arabic, chitosan, and maltodextrin, among others, can create the encapsulating materials. These substances can be utilized alone or in combination. [17] The range of microbiological targets that EOs can affect determines their antibacterial potential. Strong antibacterial action was shown by Essential oils derived from thyme, pimento, clove, cinnamon, oregano, and rosemary in opposition to Salmonella typhi, Staphylococcus and Pseudomonas aeruginosa, aureus. The variety of microbiological targets that essential oils (EOs) can influence determines their antibacterial value. The EOs of thyme, clove, pimento, oregano, cinnamon, and Strong antibacterial properties were shown by rosemary. against Pseudomonas aeruginosa and Salmonella typhi, and Staphylococcus aureus.[18]

Characteristics of essential oils [19]

1. Essential oils do not dissolve in water however they do dissolve in fixed oils, alcohol, and ether.

2. These Oils that are volatile are usually colourless and liquid at the standard temperature. They smell, are frequently liquid with a density at room temperature of less than solidarity, with some exceptions (Sassafras, vetiver, and cinnamon).

3. They have a refractive index and a high optical activity.

4. These volatile oils present in herbs are responsible for the different scents that plants emit.

5. They're commonly used in the cosmetics sector, scent, as well as aromatherapy. The latter is meant to as a method of therapy involving baths, massages, and inhalations employing these ephemeral oils. The last key will act as chemical cues that provide the plant the ability to regulate or control its environment (ecological function): attracting insects that pollinate, deterring predators, preventing germination of seeds, or promoting Plant-to-plant communication (indications of emission that are chemically indicate when herbivores are present, for instance).

6. Essential oils also have deterring and insecticidal or antifungal qualities.

7. Essential oils are present in very component various fragrant plants, such as the following:

- Naturally, flowers such as lavender, pink, orange, and the bud of a clover.
- Usually, leaves like savory, sage, bay leaf, mint, thyme, and eucalyptus, and pine needle.
- The tree's underground organs, including the roots (vetiver), rhizomes (sweet flag, ginger)
- Carvi and coriander seeds
- Citrus epicarps and other fruits, anise, fennel,
- Bark and wood, such as rosewood, sandalwood, and cinnamon.

Types of Oils

Clove oil [20-21]

At a level of Essential oil of cloves, 0.304 mg/mL displayed bactericidal and suppressive activity in opposition to Salmonella typhimurium, S. aureus, Listeria monocytogenes and Escherichia coli. in vitro Clove essential oil's main ingredient, eugenol, was tested in vitro for its antiviral properties against the viruses that cause HSV-1 and HSV-2 are herpes simplex vaccines. The IC50 values weighed 25.6 g/mL for HSV-1 and 16.2 g/mL for HSV-2., which hindered the multiplication of both viruses. Clove oil's MIC value reached 0.5 mg/mL against L. monocytogenes.

Fig no 01: Clove Plant

Lavender Essential oil [22]

Lavender essential oil's when applied to strains that are resistant to antibiotics, such as Staphylococcus aureus resistant to methicillin that or Enterococcus species that are resistant to vancomycin (VRE), lavender essential oil (EO) derived from L. angustifolia Mill. exhibits a potent antibacterial action. Lavender essential oil's antibacterial properties were assessed against Salmonella enterica (10 food strains) and L. monocytogenes (24 strains). Salmonella was inhibited by MIC 10.0 L/mL, while L. monocytogenes was inhibited by MIC 0.3 L/mL, indicating significant action, particularly on clinical strains. The composition of EOs seems to be connected to this activity. Particular components like 1,8-cineole (6.89 and 8.11%, respectively), and camphor (8.97 and 10.30%), and linalool (38.17 and 61.98%).showed the strongest antibacterial activity. It was shown That oil of thyme vital exhibited antiviral properties against the Herpes simplex virus, sometimes known as the DNA virus or HSV1, having IC50 values of 11 g/mL.

Fig no 02: Lavender Plant

Thyme Essential oil [23]

Thyme essential oil's capacity to combat strains that cause acute throat and pharyngitis caused by microorganisms discomfort was also investigated. This illnesses brought on by haemolytic strains of streptococci, such as S. pyogenes. It was discovered that T. vulgaris essential oil worked well against isolates of S. pyogenes that were taken from patients' throats. Thyme EO, which was abundant in p-thymol (24.721%) and terpinene (68.415%), fully stopped Fusarium graminearum from growing at a concentration of 0.06%.

Fig no 03: Thyme Plant

Cinnamon Essential oil [24-25]

The essential oil from Zeylanicum cinnamon mum showed a Completely inhibiting effect against H1N1, or Denver/1/57 influenza virus A1/ after Exposure for 30 minutes at 3.1 L/mL concentration. Cinnamomum zeylanicum EO's primary constituent, eugenol, demonstrated The strongest anti-infectious effects in liquid as well as vapor stages. Recently, cinnamon essential oil was employed to enhance food packaging zein film, which now has an additional 4% chitosan nanoparticle (CNP) concentration. In addition to preventing the expansion of the expansion of antibiotics The bacteria Escherichia coli and Staphylococcus aureus combined antibacterial properties of EO and nanoparticles also enhanced the composite zein film's tensile strength and reduced its elongation.

Fig no 04: Cinnamon Plant

Tea tree Essential oil [26-27-28]

Tea tree essential oil has been utilized in dental and oral hygiene products because of its antibacterial properties, which inhibit the halitosis-causing bacteria The MBC and MIC of Porphyromonas gingivalis and Porphyromonas endodontalis are 0.5% and 0.007%, in that order. The bactericidal properties of Tea trees that are sold commercially Investigations were conducted on essential oils (EOs). Five among the ten essential oils were active. The components found in the essential oil decreased the Pseudomonas aeruginosa biofilm bacterial survival and induced Candida glabrata to oxidatively deteriorate. Melaleuca alternifolia, however, essential oil only showed weak Aspergillus niger antifungal activity (MIC = 625 g/mL), This was clarified by the active components, terpineol and terpinen-4-ol.

Fig No 05: Tea Tree Plant

Lemongrass Essential oil [29]

There are roughly 55 species of Cymbopogon citratus, or lemongrass, is a tall perennial plant that thrives within tropical and subtropical regions. The main active ingredients that give lemongrass oil (LGO) its unique scent are geraniol, neral, and citral (65-86%). Antidepressant, antiseptic, sedative, nervine, fungicidal, bactericidal, and antioxidant qualities have been found in lemongrass oil. Aeromonas veronii, Escherichia coli, Enterococcus faecalis, and Acinetobacter baumanii were among the numerous bacterial species that the LGO was found to be effective against as a bactericidal agent. The MIC for the strains of Salmonella enterica, Proteus mirabilis, Citrobacter freundii, and Aeromonas caviar was 0.125 percent.

Fig No 06: Lemongrass Plant

Nanoparticles –

Small particles are called nanoparticles with sizes ranging from one to one hundred Nanometers. Nothing within the range of a nanoparticle is visible to the human eye. They may possess a variety of important chemical and physical characteristics. They were all connected to their more substantial material equivalent. Scientists define nanoparticles using a variety of techniques. According to a definition developed by the European Commission, One definition of a nanoparticle is one that is 100 nm in size. Or less, with most of them being composed of several hundred atoms. [30] The two primary families of nanoparticles are nanospheres, which have a uniform structure throughout and nano capsules, which possess a typical core-shell architecture. In essence, the medication is encapsulated, dissolved, trapped, or bonded to the polymer matrix. Physically and evenly, the medication is distributed throughout the polymer matrix structure. Both crystalline and amorphous nanospheres are capable of shielding the medication against chemical and enzymatic deterioration. [31-35] Particulate agents are usually between 10 and 200 nm in size. are little spherical entities wherein medications are either disseminated or wrapped in polymer materials. Vesicles are the tiny medication store house capsules, while nanospheres are the solid skeleton framework. These systems are useful for administering medication because they allow for the ingestion or injection of nanospheres, which may be customized for particular release profiles, site-specific drug delivery, and in certain situations, organ-targeted release. It is separated into two categories based on biodegradability: biodegradable and nonbiodegradable nanospheres. The following are examples of biodegradable nanospheres polypropylene dextran, polylactic acid, gelatine, albumin, modified starch, and others. The only polymer authorized for human usage as a controlled-release agent, according to recent literature studies on nonbiodegradable nanospheres, is polylactic acid. Furthermore, The past few years have seen numerous research on magnetic and immunological nanospheres. Because the polymer nanospheres were coated or adsorbed with the antibody and antigen, immunological nanospheres had immune competence. One special characteristic of magnetic nanospheres is their response to a magnetic force. As magnetic polymer nanoparticles, they are typically covered in protective shells. Two types of nanospheres can be combined to create immuno magnetic nanospheres, which have the potential to significantly their focusing. The many benefits These systems provide delivering Their payload of drugs contribute to their appeal. These delivery systems' range of nanosize methods allows direct injection entering the bloodstream of the body without running the danger of obstructing blood vessels. It has been demonstrated that a significant determinant regarding the nanoparticle's in vivo fate is its size. [36]

Advantages Of Nanoparticles [37]

1. Nanoparticles' small size allows them to get in smaller capillaries and be taken up by cells, which makes it easier for drugs to accumulate where they are supposed to.
2. Extended drug release is made possible by the production of nanoparticles from biodegradable materials. over several days or even weeks within the target region.
3. The energy sector can potentially profit via nanotechnology. with this technique, It is possible to make more efficient devices like solar cells, fuel cells, and batteries smaller..
4. The manufacturing industry, which requires materials such as aerogels, nanotubes, nanoparticles, and other analogous substances to create their products, is another enterprise that stands to gain via nanotechnology. These resources are usually stronger, lighter, and more resilient than those made without the use of nanotechnology.
5. Nanoparticles' small size allows them to get in tiny capillaries as well as be absorbed by cells, allowing for effective drug buildup at the body's intended sites.
6. Both the therapeutic efficacy and bioavailability were enhanced by nanoparticles.
7. The medicine that is being carried by the nanoparticles is not biotoxic.
8. Nanoparticles just avoid organic solvents; they do not exhibit any issues during large-scale manufacture or sterilization.

Disadvantages Of Nanoparticles

1. It is now possible to create more potent and deadly atomic weapons and make them more widely available. Nanotechnology can also make these more accessible.
2. Nanotechnology has also raised health risks. Because of their small size, nanoparticles can cause inhalation problems and a number of deadly diseases. Inhaling nanoparticle-contaminated air for just 60 seconds can easily harm the lungs.
3. Nanotechnology is now quite expensive, and it can be quite expensive to create. Additionally, It is really difficult. to create, which likely explains why goods based on nanotechnology are more expensive.
4. Although nanotechnology has improved living standards, it has also led to a rise in pollutants, including air and water contamination. Pollution of this type is extremely harmful to living things.
5. Polyvinyl alcohol is often used as a detergent in the production of drug delivery nanoparticles, which raises concerns about toxicity.
6. Alveolar inflammation and cytotoxicity are demonstrated by drug delivery using nanoparticles.
7. Nanoparticles' disruption of autonomic homeostasis directly affects cardiac and vascular function.
8. Particle growth, erratic gelation tendencies, unanticipated polymeric transmission dynamics, and occasionally burst release are all characteristics of nanoparticles.

Classification Of Nanoparticles

The nanoparticles are typically classified into the organic, inorganic and carbon based.

1. Organic nanoparticles

Commonly recognized polymers or Ferritin is one type of organic nanoparticle, liposomes, dendrimers, and micelles Ferritin. Certain nanoparticles, including Micelles and liposomes, possess a empty center known as a nano capsule and are susceptible to heat, light, and other forms of electromagnetic and thermal radiation. Additionally, these particles are biodegradable and non-toxic. The most common application for organic nanoparticles is in the biomedical sector, such as in medication systems for delivery, since They are efficient and may be injected into certain bodily areas, a method called targeted medication delivery. Micelles, dendrimers, and liposomes are a few types of natural nanoparticles. Ferritin, dendrimers, liposomes, and micelles are common examples of organic nanoparticles or polymers. These nanoparticles are biodegradable and hazardous-free. A few of them, including Micelles and liposomes both have void cores referred to as nano capsules that make them sensitivity to heat and light, among other forms of electromagnetic and thermal radiation. Due to its effectiveness and ability to be administered into specific body parts, the most common application for organic nanoparticles is in the biomedical sector. This type of delivery is referred to as targeted medication delivery. Among the several kinds of Micelles, liposomes, and dendrimers are examples of organic nanoparticles. [38]

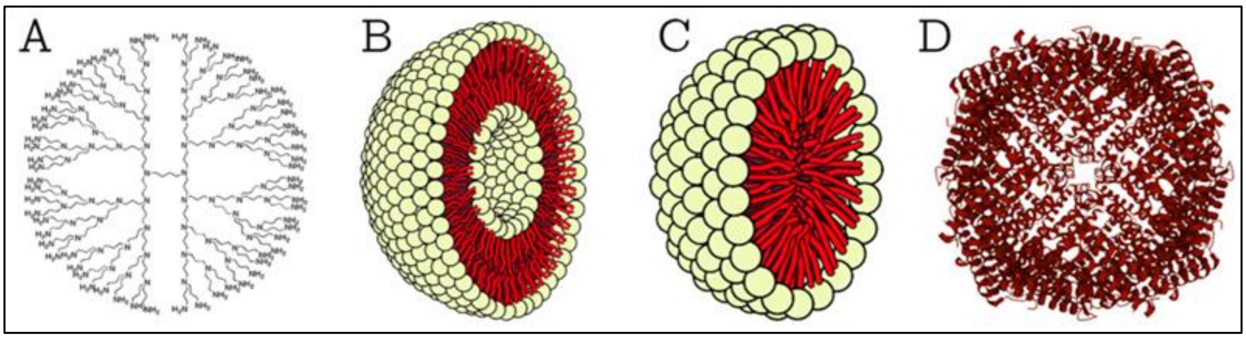

Fig no 07 Types of organic nanoparticle – A) Dendrimer B) Liposomes C) Micelles D) Ferritin

1. Inorganic nanoparticles

Nanoparticles that are inorganic are particles that aren't composed of carbon. Nanoparticles that are not organic usually characterized as based on metal as well as metal oxide.

a) Metal Nanoparticles

The components of metal nanoparticles include entirely of the predecessors of the metals. Since these NPs have renowned localized Plasmon resonance at the surface(LSPR) Features, they have distinct Optoelectrical qualities. Nanoparticles of noble and alkali metals (NPs) of Cu, In the visible spectrum, Ag and Au show a band of absorption. Portion inside the electromagnetic spectrum. The use of metal nanoparticles regulated production in terms of size of the facet and form is crucial for the most advanced materials of today. Metal NPs find application in numerous scientific domains due to its sophisticated optical properties. When sampling SEM, the application of gold nanoparticle coating is common to enhance the electronic stream and generate superior SEM pictures. [39]

b) Ceramics Nanoparticles

By heating and chilling, inorganic non-metallic solids known as ceramic nanoparticles (NPs) are produced. They can be thick, hollow, porous, amorphous, or polycrystalline. Researchers' attention is being drawn to these NPs due to their usage in procedures such photodegradation of dyes, imaging, photocatalysis, as well as catalysis. [40]

c) Semiconductor Nanoparticles

The literature has employed semiconductor materials in a number of ways because of their properties that fell in between metal and nonmetal ones. The enormous bandgaps of semiconductor nanoparticles, bandgap tuning significantly changed their attributes. This leads to, they are important elements for photocatalysis, electrical devices, and photooptics (Sun, 2000). A variety of semiconductor nanoparticles, example, are shown to be very efficient in applications involving water splitting because its appropriate bandage and hand positions of gaps. [41]

d) Polymeric Nanoparticles

These are typically Nanoparticle derived from organic, and they are collectively known as nanoparticles of polymers (PNPs) in the books. The majority of them are either nanospheres or nano capsular formed. The outside the spherical surface's edge is where the remaining molecules have been adsorbed, while the former are particles in a matrix that typically possess a robust bulk overall. In the latter instance, The particle completely contains the solid mass. Polymeric nanoparticles have a wide range of uses in the literature since they are simple to functionalization. [42]

e) Lipid-based Nanoparticles

Nanoparticles like things are helpful in a variety of applications in biomedicine and contain lipid components. Lipid nanoparticles usually possess a spherical shape and a diameter between 10- and 1000-mm. Lipids make up the solid core of lipid nanoparticles with soluble lipophilic compounds in the matrix. Surfactant or Emulsifiers stabilized these NPs' exterior core. The field of lipid nanotechnology is unique which concentrate on lipid nanoparticle synthesis and creation for a range of uses, includes the release of RNA in cancer treatment and medication delivery and transporters.[43]

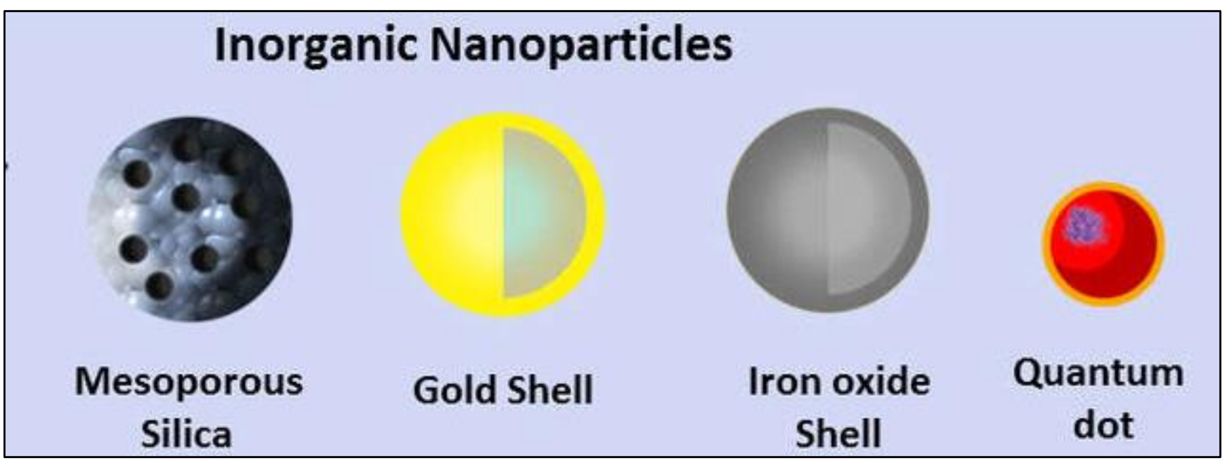

Fig No 8. Inorganic Nanoparticles

Carbon-based Nanoparticles

Two significant forms of carbon-based nanoparticles are fullerenes and carbon nanotubes

(CNTs. Allotropic forms of carbon and other nanomaterials composed of globular hollow cages are seen in fullerenes. Because of their high electron affinity, power, and structure, Conductivity of electricity, and flexibility, they possess attracted significant commercial interest. [44] Carbon units that are hexagonal and pentagonal are arranged in these materials, and each the sp2 hybridization of carbon. CNTs have a long, tubular shape and range in diameter from 1 to 2 nm. [45] Considering their telicity and diameter these can be predicted to be either semiconducting or metallic.[46] From a structural standpoint, these look like sheets of graphite rolling over each other. Depending on whether the rolled sheets contain one, two, or more walls, they are referred to as multi-walled carbon nanotubes (MWNTs), double-walled carbon nanotubes (DWNTs), or single-walled carbon nanotubes (SWNTs). They are frequently produced via use of carbon precursor deposition, especially atomic carbons, onto metal particles by vaporizing them from graphite using an laser or electric arc. They were made recently with the chemical vapor CVD technique of deposition. [47] The unique properties of these materials' mechanical, their physical and chemical characteristics enable them to be utilized as nanocomposites for a range of commercial purposes, containing fillers, in addition to their pure form. [48-49] efficient gas adsorbents to protect the environment cleanup and as a means of supporting several kinds of inorganic and organic catalysts. [50]

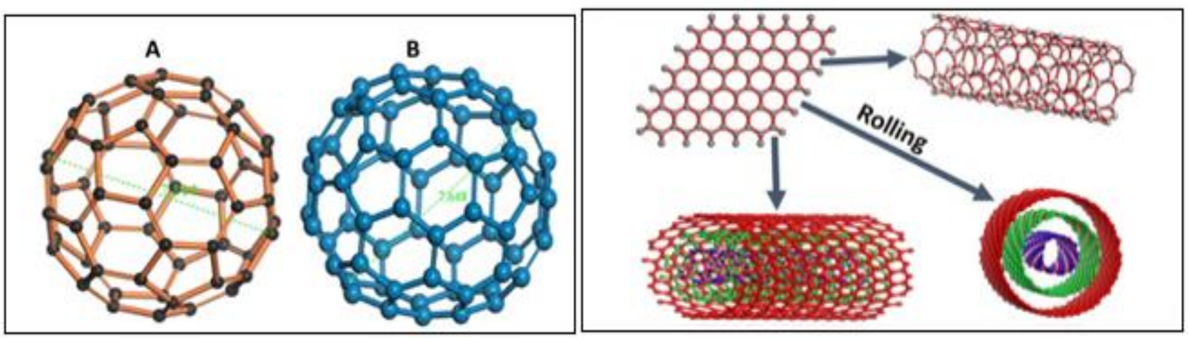

Fig no 09 Different form of Fullerenes/buck Balls (A)C60 B) C70 and Nanotube

Synthesis Of Essential Oil-Loaded Nanoparticles:

The Stober Antibiotics process, co-precipitation, high-pressure homogenization, high-speed stirring, ultra-sonication, ionic gelation, mini-emulsion polymerization, nanoprecipitation, and spray drying are some of the methods that have been created in The final many decades for the production of essential oil-loaded nanoparticles. Since the NPs' dimensions, form, and surface chemical loaded with EOs have a major impact on their behaviour, any changes made to the preparation procedure could have a substantial impact on the end product.

Co-Precipitation Method

Among the most popular techniques for creating Inorganic, metal, and magnetite nanoparticles is co-precipitation because of its moderate reaction conditions, low cost, and non-toxicity. This method uses Hydroxide of In a solvent, sodium, potassium, or ammonium, Metal precipitated from a processor of salt as hydroxide, and Perchlorates, nitrates, sulphates, and chlorides made with a base's assistance to produce nanoparticles through nucleation and grain formation. Along with temperature, ionic strength, pH, and rate of mixing, salt kinds and quantities also affect the dimensions, form, and magnetic properties of both inorganic and metal nanoparticles. By co-precipitating an precursor between iron and an alkaline patchouli oil solution, a bioactive coating consisting of Magnetite nanoparticles infused with patchouli oil was created. Hydroxyapatite nanoparticles loaded with peppermint, lavender, and basil oils, as well as menthol, patchouli, limonene-encapsulated magnetite nanoparticles, clove, rosemary, eugenol, black cumin, cinnamon, ylang-ylang, clove, nutmeg, and limonene, were created utilizing the method of co-precipitation.[51]

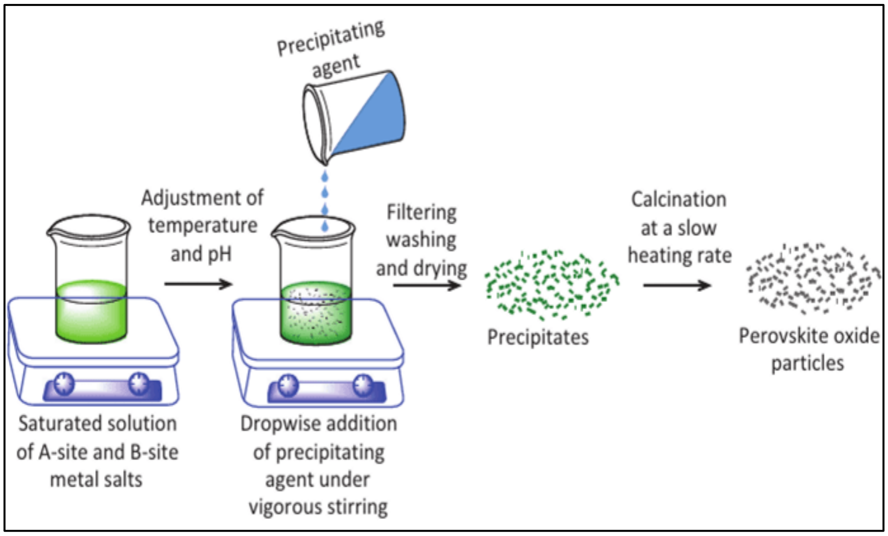

Fig no 10: Coprecipitation Method

High-Pressure Homogenization Method

Solid lipid nanoparticles (SLN) and nanostructured lipid carriers (NLC) are frequently prepared using high-pressure homogenization (HPH) in both cold and hot environments. This method reduces The size of particles and droplets under high pressure. (a) Melted lipids and essential oils are used in the hot HPH process mixed between 5 and 10 C above the solid lipids' point of melting and either dissolved or evenly distributed within the molten lipids. Melted lipid and a heated aqueous phase containing surfactants are combined while being constantly stirred to create a pre-emulsion, which is then utilizing a piston-gap homogenizer to homogenize. After three to five rounds of homogenization at 500–1500 pressure bars, SLNs and NLCs are produced. Lipid The formation of SLNs and NLCs through crystallization result from cooling the nanoemulsions after homogenization. NLCs with a PDI of 0.2 and particles with diameters between 102.10 and 115.6 nm were created using this method and encapsulated with menthol and Punica granatum seed oil. (b) Method of HPH in the cold: Essential oils are distributed or mixed in melted lipids and quickly cool with dry ice or liquid nitrogen. In order to create lipid microparticles, lipid-EO combinations are ground down to a range of 50–100 particle sizes nm in a ball mill or mortar . These are then aqueously suspended in surfactant-containing cold solutions that have been homogenized at 500 bar pressure at 5–10 cycles at 0–4 C to produce NLCs and SLNs. This technique was used to create Oil-loaded melaleuca alternifolia nanoparticles with a PDI of 0.25 and particle sizes smaller than 300 nm. [52]

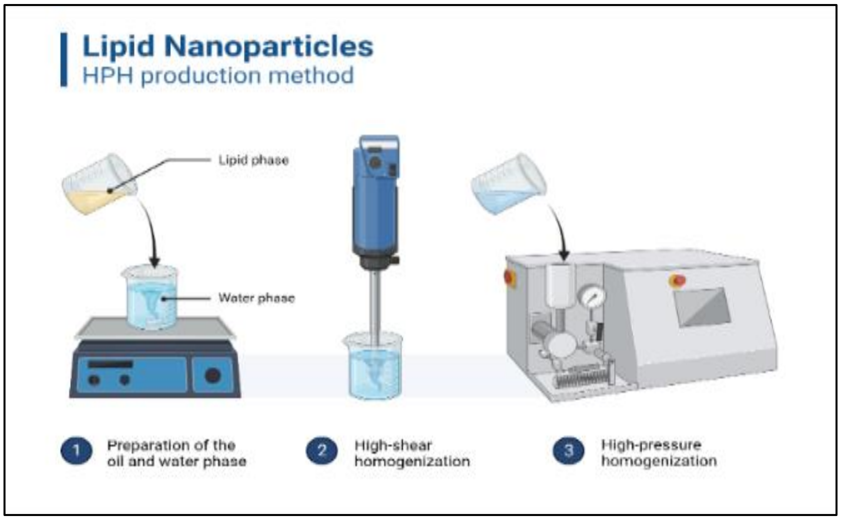

Fig no 11: High-Pressure Homogenization Method

High-Speed Stirring and Ultra-Sonication Methods

Ultrasonication and High-shear homogenization, or high-speed stirring, is linked to reduced use of organic solvents and ease of managing. Easy handling as well as a reduction in the amount of solvents that are organic used are linked to Ultrasonication (high-shear homogenization) with high-speed stirring. This process involves combining EOs with melted lipids at a temperature higher than the melting point of solid lipids . Melted lipid Combining surfactants with a heated aqueous phase are combined at the identical temperature while being constantly stirred to create a hot pre-emulsion. A probe sonicator is used to ultrasonicate the produced emulsion during nine cycles, with 15-second breaks between 30 s of sonication. SLNs and NLCs are obtained by cooling the finished mixtures to room temperature. 300–700 nm particle sizes with a PDI between 0.21 and 0.68 were observed in SLN loaded with essential oils from Eugenia caryophyllata and Melaleuca alternifolia, which were made by ultrasonification after high shear homogenization for five minutes at 20,500 rev/min approximately 6 minutes. [53-54]

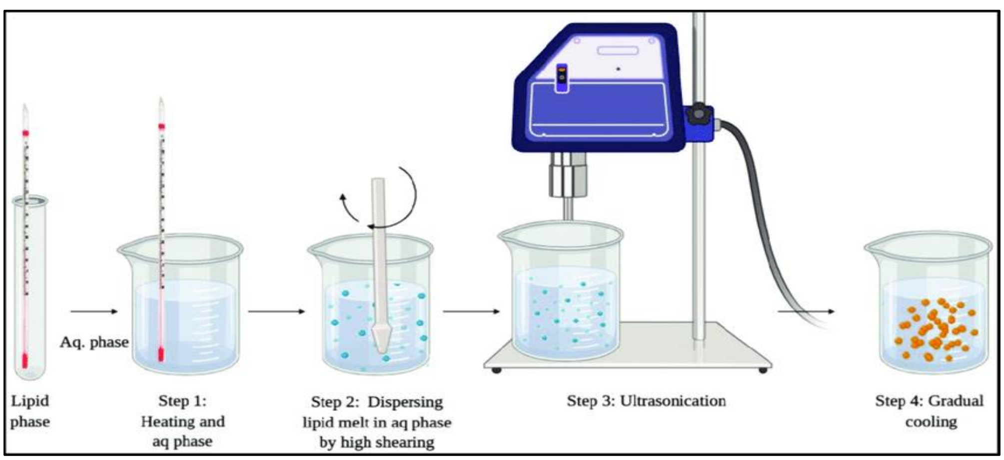

Fig no 12: High-Speed Stirring and Ultra-Sonication Methods

Ionic Gelation Method

The foundation of ionic gelation is polyelectrolytes' capacity to crosslink when counterions are present. [55]. Depending on their solubility, essential oils and a polymer are either mixed in water or a moderately acidic medium, and the final mixture is subsequently gradually mixed to the solution that contains stabilizer and counter ions. The complexation of organisms with opposing charges produces particles with a sphere-like form by precipitation and gelation. The final resolution is sonicated to reduce the particle size within the range of nanometres, and it is then immediately freeze-dried for one hour at 30 C. Particle diameters of chitosan nanoparticles loaded with citrus reticulate smaller than 300 nm, Psidium guajava leaves, Eugenia caryophyllata, Zataria multiflora, Satureja hortensis, Nigella sativa Pineodora Homalomena, Oreganum vulgare, Thymus capitatus, Satureja khuzistanica, Bunium persicum, and Carum copticum vulgare are frequently made using the ionic gelation process. Using ionic gelation, create nanocapsules filled with tea tree, chamomile, and lemongrass oils. [56-57]

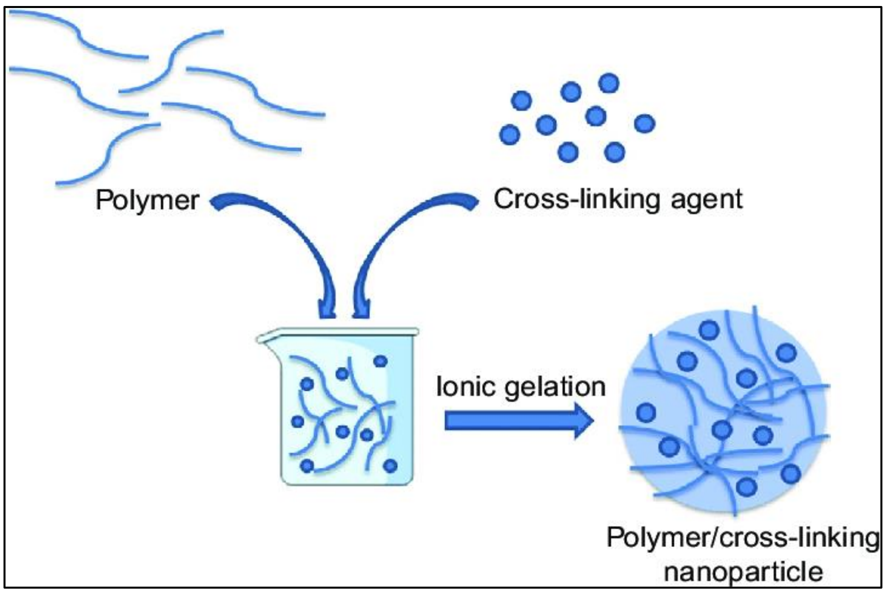

Fig no 13: Ionic Gelation Method

Mini emulsion Polymerization Method

By adding a suitable surfactant and co-stabilizer, cross-linked polymeric nanoparticles are created using Mini emulsion polymerization processes. Aqueous dispersions of closely spaced, closely packed, small monomeric droplets protected against collisional disintegration and Ostwald ripening are created during this method. The sonication period, initiator, co-stabilizer, and surfactant concentrations, among other reaction parameters, determine The particles' size produced by Mini emulsion polymerization. Nanoreactors that are discrete for the creation of polymer nanoparticles are created by high shear mixing, which produces monomer droplets between 50 and 500 nm in size. Because There is no mass movement between monomer droplets by this method, before shear mixing, the organic phase can be supplemented by components occurs Using the Mini emulsion polymerization technique, Polythioether nanoparticles loaded with thymol and carvacrol (NPs) with a 50% w/w loading capacity and more than 95% encapsulation efficiency were created. This technique was used to create Triethylene glycol dimethacrylate with methyl methacrylate loaded with D-limonene-based late Nanoparticles based on co-polymers. [58]

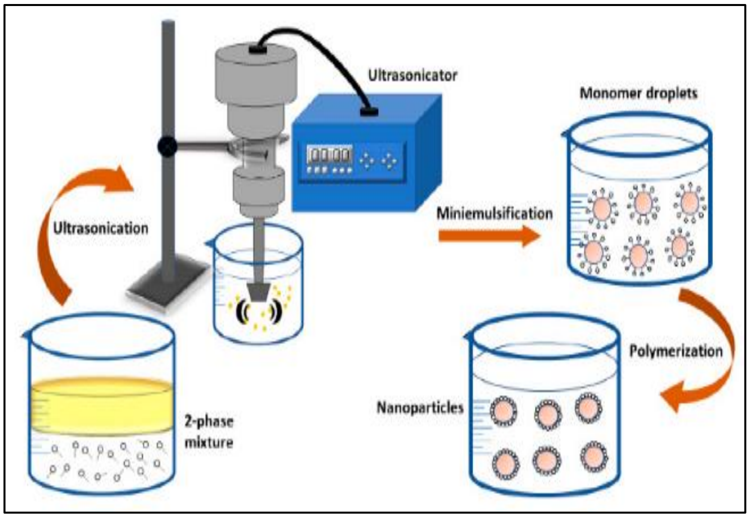

Fig no 14: Mini emulsion Polymerization Method

Nanoprecipitation Method

By dislodging Semi-polar solvents that dissolve in water from a lipophilic solution, a process known as nanoprecipitation creates particles that precipitate and then solidify polymers by covering the polymer interface in the nanoprecipitation process, an aqueous stage as well as an as a non-solvent, the organic phase and a solvent (polymer and EO), respectively. The Before being combined, the organic solvent dissolves the polymer and essential oil with a phase of water that contains stabilizer. This facilitates the organic solvent's penetration Enter the phase of water by lowering the strain that exists between the organic and aqueous phases. Tiny, sparsely distributed NP droplets are immediately created during the aqueous-organic solvent phase interface during surface tension, diffusion, and solvent flow. As a cryoprotectant, the resultant 5% mannitol is used to freeze-dry the nanosuspension to create a finely ground nanoparticle powder. The benefits of using the nanoprecipitation technique to encapsulate vital oils include shorter processing time, ease of use, and decent repeatability, scalability as well as manufacturing of submicron nanoparticles with narrow size ranges and superior encapsulation efficiencies. This technique generated sweet orange and bergamot essential oils starch nanoparticles A PDI with particle diameters under 150 nm of roughly 0.2, as well as a container efficacy of over 80%. Menthone, thymol, and lemongrass were loaded via the nanoprecipitation method into polymeric nanoparticles process. [59]

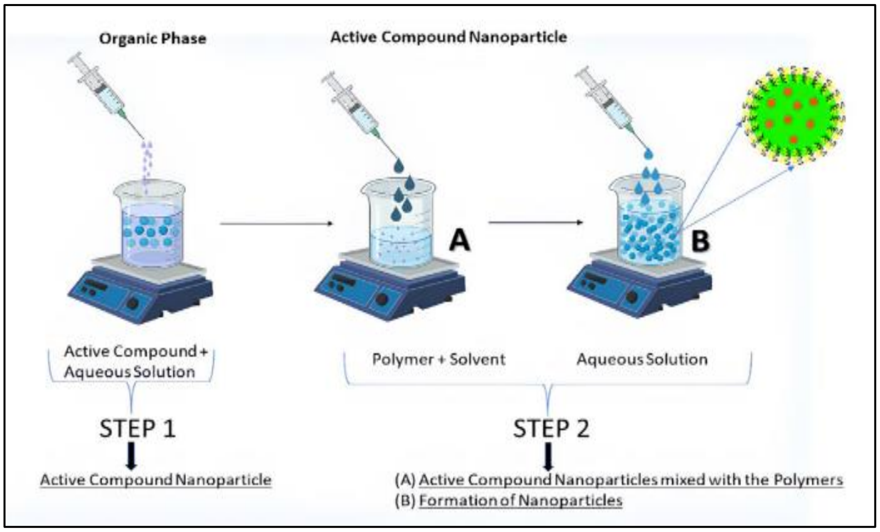

Fig no 15: Nanoprecipitation Method

Spray Drying Technique

Menthone, thymol, and lemongrass were loaded into polymeric nanoparticles using the nanoprecipitation process. Menthone, thymol, and lemongrass were loaded into polymeric nanoparticles using the nanoprecipitation process. By employing a peristaltic pump to introduce polymer solutions, this procedure produces polymeric complexes. At varying ratios of polymer matrix to oil, an Surfactant and oil emulsion is created separately were introduced to the polymer complexes gradually. Among the factors affecting the end result in this process are the pump feed flow, air flow, input temperature, and output temperature. Cashew gum with chitosan nanogels with a PDI of 0.3–0.6 and particle sizes between 300 and 900 nanometres were mixed with Lippia sidoides oil using a spray-drying technique. This method was also used to add aromatic oils to nanogel, including lemongrass, clove, cinnamon, and rosemary.[60]

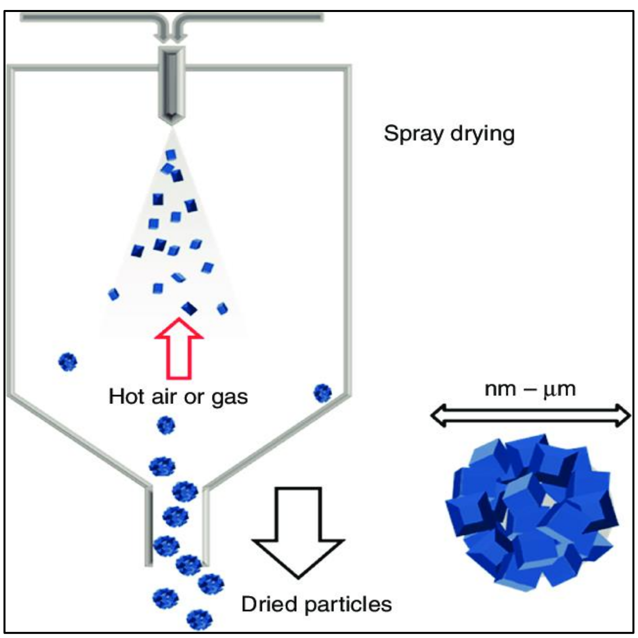

Fig no 16: Spray Drying Technique

Stober Process

The Stober procedure can be utilized to create silica nanoparticles chemically. By hydrolysing and condensing a mixture of tetraethyl orthosilicate and other alkoxysi lanes in a mildly basic water solution that contains alcoholic solvent combinations, water, and ammonia, the Stober process produces particles made of silica. A modified Stober's approach, the sol–gel procedure is utilized to manufacture mesoporous silica nanoparticles (MSNs). The creation of a network that resembles an organized gel of polymers or distinct particles is preceded by Alkoxide monomers are hydrolyzed and condensed into a colloidal solution with a basic or acid catalyst present. This procedure can also be altered by adding including adding a cationic surfactant to the mixture of reactions, which results in submicrometers that are spherical-sized particles that are monodisperse. The essential oils of peppermint, lemongrass, clove, chamomile, and Artemisia annua, and Pistacia atlantica were loaded into silica nanoparticles using this approach, which produced particles with diameters between 20 nm and 500 nm. [61]

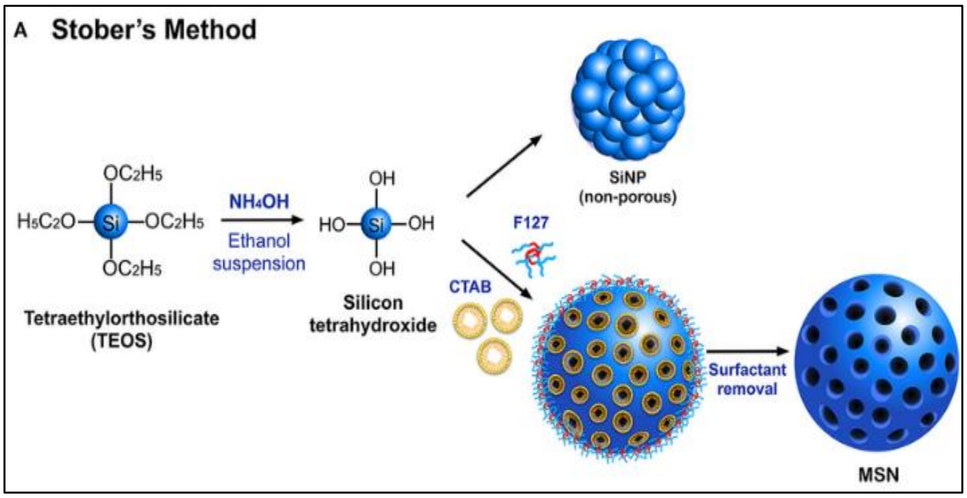

Fig no 17: Stober Process

Thin Film Hydration, Adsorption and Vacuum Pulling Methods

Using the technique of thin film hydration, to produce a thin layer, an organic solvent is evaporated of lipids in a flask with a circular bottom. In a round-bottom flask, Essential oil and lipids are dissolved in 100% ethanol. A rotary evaporator is used to dissolve the resulting mixture at lower pressure in order to create a thin layer. Next, water is utilized to moisten the thin film. To create liposomes containing essential oils containing eugenol, laurel, artemisia, and oregano, the thin film hydration technique was employed. Nanoparticles are adsorbed with essential oils using the adsorption method. TiO2 nanoparticles loaded with rosemary oil, ZnO nanoparticles loaded with fennel oil, eugenol, and carvacrol, and Nigella sativa, Thymus vulgaris, and linalool-loaded metal nanoparticles essential oil were all made using the adsorption approach. EO and Halloysite nanotubes are combined and sonicated in the vacuum pulling process. To remove air from HNTs' inside surfaces After being vacuum-filtered, the mixture was maintained in a vacuum for Half an hour. Using capillary action load essential oil into the HNTs' interior until the air pressure was achieved. Filtration and centrifugation were then performed. Using vacuum pulling, thyme-loaded halloysite nanotubes were created. The literature describes nine distinct techniques for creating Nanoparticles impregnated with essential oils that could effectively produce nanoparticles with the required size, shape, physical stability and surface chemistry The most popular technique for creating SLNs and NLCs is high-pressure homogenization because of its quick turnaround times, simplicity in manufacturing, ability to operate without organic solvents, and potential for scale-up. The cold homogenization method can be used to overcome the drawbacks of the hot homogenization method, which is typically used to prepare SLNs and NLCs filled with essential oils. These drawbacks include product deterioration, aqueous phase loss of essential oils, and erratic lipid transitions. Because it's simple to prepare and modify, and the fact that it only less harmful solvents, the process of ionic gelation is commonly employed to create polymeric nanoparticles. [62] A simpler, quicker, more economical, and more scalable procedure, the co-precipitation approach is widely utilized to manufacture EO-loaded magnetite/metal nanoparticles. [63] The Stober approach is mostly utilized to produce silica nanoparticles loaded with EOs because it produces monodisperse, ordered, nanosized silica particles that are easily modifiable. [64]

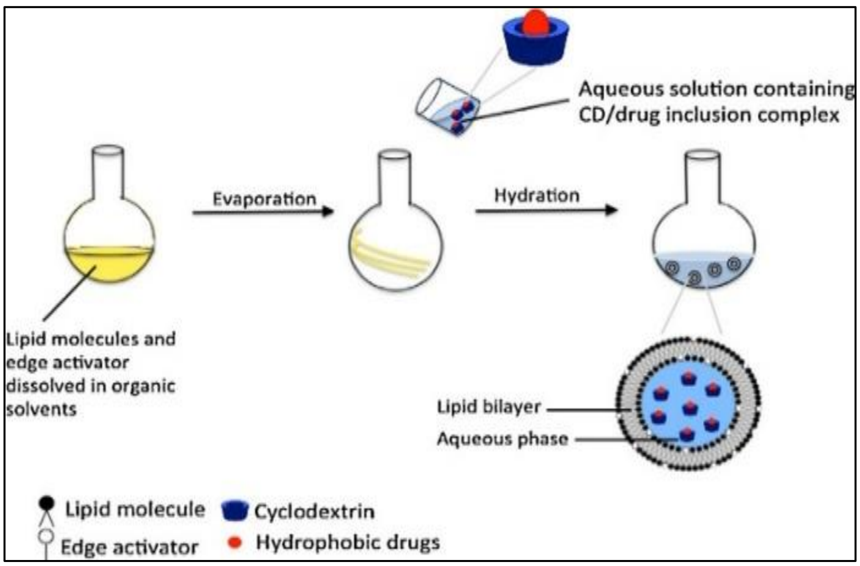

Fig no 18: Thin Film Hydration, Adsorption and Vacuum Pulling Methods

Applications Of Essential Oil Loaded Nanoparticle:

1. Pharmaceutical Application –

There are significant potential applications for nanoencapsulated essential oils in the treatment of different cancers. Using EOs from Cynometra cauliflora, recent research has created nano capsules through a variety of techniques (High-speed homogenization, nanoprecipitation, and ionic gelidification–emulsion).[75] Nanoencapsulated essential oils shown anticancer activity against HepG2 (human hepatocellular cancer), lung tumor cells A549, Melanoma A-375, human breast cancer cells MCF-7 and MDA-MB-231, and breast cancer cells MDA-MB-468. Antimicrobial efficacy of EOs nanoencapsulated. [65]

2. Cosmetic Applications-

Microbial contamination is one of the most significant issues facing the cosmetics industry since it has a detrimental impact on formulations and is challenging to manage. [66] Cosmetic preservatives, which are chemicals of the most diverse classes and help prolong the shelf life of products by preventing the growth of microorganisms in their formulations, are employed to get around such circumstances. [67] For compositions that seek to preserve the antioxidant and antibacterial activity of encapsulated essential oils for use in the cosmetics sector, the nanoencapsulation technique employing nanoprecipitation appears beneficial. For compositions that seek to preserve the antioxidant and antibacterial activity of encapsulated essential oils for use in the cosmetics sector, the nanoencapsulation technique employing nanoprecipitation appears beneficial.[68] By employing alfalfa protein as a wall material, the nanoprecipitation method was also helpful for nanoencapsulating Cannabis sativa essential oil (EO) and demonstrated efficacy in enhancing the EO's stability and usefulness. Following nanoencapsulation, the EO's antioxidant activity was shown to have increased. [69]

3. Food Applications-

EOs that have been nanoencapsulated can be employed in a variety of food applications, namely in foods that are susceptible to oxidation or degradation under specific circumstances, which lowers the product's ultimate quality. [70] Since it can directly affect food preservation, the EO's antioxidant, antifungal, and anti-aflatoxigenic properties are highly coveted for uses in the food sector. [71] Using ionic gelidification–emulsion, nanoencapsulated essential oils are also strongly advised for direct fruit coating to extend their sensory qualities. [72] Controlling mycotoxin generation can also be achieved by encapsulating essential oils. The ability of EO nanoemulsions of cloves (E. caryophyllata), peppermint (M. piperita), cinnamon (Cinnamomum spp.), lemongrass (C. citratus), and thyme (T. vulgaris) to suppress mycotoxins. [73]

4. Environmental Applications-

It is well known that research has been confronted with significant obstacles in the environmental context. In addition to contaminating the environment (soil and water courses), the use of synthetic agricultural pesticides, such as those to combat fungi, insects, and other pests, also contaminates the food that is produced. The chitosan-loaded nanocapsules created using the ionic gelidification approach appear to be the most suitable for this use, and nanoencapsulated EOs have been characterized as promising substitutes for the use of these xenobiotics. [74]

5. Agriculture-

By incorporating bioactive chemicals into environmentally acceptable pest control products, EO nano systems also support sustainable farming practices. Alpha-terpinene and gamma-terpinene from Origanum majorana oil function as fumigants for grain storage by interfering with insect neurological systems, while citronella oil, for example, functions as a mosquito larvicide by targeting the respiratory system of larvae. [75-76] Furthermore, EOs and nanoparticles can be combined to increase a plant's resistance to environmental stress. For example, vetiver oil and titanium dioxide. This method not only reduces damage brought on by stress but also improves plant health and essential oil production. [77]

6. Advanced Packaging

Antimicrobial and antifungal qualities that preserve food safety and quality can be included into packaging by EO-based nano systems. Eugenol, cinnamon aldehyde, and are two compounds that efficiently reduce microbial deterioration in perishable foods like meat products and strawberries by disrupting microbial enzymes and inhibiting cellular respiration. In addition to prolonging shelf life and providing long-term protection, these nano systems allow for the sustained release of active ingredients and provide environmentally friendly packaging options. [78-79]

Characterization Of Nanoparticles:

Zeta potential

A popular way to describe a nanoparticle's surface charge attribute is to look at its zeta potential. It represents the electrical potential of particles and is affected by their makeup as well as the environment in which they are dispersed. About Zeta potentials are present in neutral nanoparticles whereas strongly cationic and anionic nanoparticles have zeta potentials between -10 and +10 mV. larger than +30 mV and less than -30 mV, respectively. Additionally, the zeta potential can be utilized to identify if an active charged substance is adsorbed onto the surface or encapsulated in the centre of the nano capsule. Particle stability can be inferred from the Zeta Potential's magnitude larger potentials show greater electrostatic repulsion and, hence, greater stability. [80]

UV-visible absorption spectroscopy

A solution's optical characteristics can be ascertained using absorbance spectroscopy. The amount of light absorbed is measured when a light is passed through the sample solution. After changing the wavelength and measuring the absorbance at each one. Beer-Lambert's Law can be used to determine a solution's concentration based on absorbance. The UV-visible spectrophotometer's optical measurement shows a distinct absorbance peak at 410 nm. [81]

X-ray diffraction (XRD) analysis

A popular technique for determining crystallographic structure and shape is X-ray diffraction. Depending on the amount of ingredient, the intensity can either rise or decrease. This method determines the metallic nature of particles, gives details on the unit cell's dimensions and form through symmetry in translation based on peak positions, and provides details regarding the electron density within the unit cell—that is, the location of the atoms—based on peak intensities. [82]

Fourier Transform Infrared [FTIR] spectroscopy

It is utilized to identify the kinds of functional groups that are related and structural characteristics of biological extracts with nanoparticles by measuring infrared intensity vs light wavelength. The computed spectra unequivocally demonstrate the known dependency of the optical characteristics of nanoparticles Infrared Fourier Transform [FTIR] Using spectroscopy, analyse the green produced silver nanoparticle using different leaf extracts, and the results indicated distinctive peaks.

Microscopic techniques

These methods, specifically SEM and TEM, are mostly employed for studying the morphology of nanoparticles. These methods were employed by numerous researchers to demonstrate that the produced nanoparticles were roughly consistent in size and shape.

Transmission electron microscopy (TEM)

An electron beam is passed through an incredibly thin object in transmission electron microscopy, interacting with the object as it comes through. The interaction of the electrons passing through the specimen creates a picture, which is then focused and enlarged and displayed on a layer of photographic film, a fluorescent screen, or a sensor like a CCD camera. In a variety of scientific domains, including the biological and physical sciences, TEM is a key analytical tool. TEMs are used in materials science, virology, cancer research, pollution, nanotechnology, and semiconductors. [83]

Physicochemical properties of NPs

Because of their many physicochemical characteristics, encompassing their high chemical reactivity, surface area, mechanical strength, and optical activity, NPs are special and appropriate candidates for a variety of purposes. A few of their important properties are discuss in the following section.

Electronic and optical properties

NPs' Electrical and The interdependence of optical characteristics is greater. For example, noble metal nanoparticles exhibit size-dependent optical characteristics as well as a prominent belt of extinction between UV and visible light that is absent from the spectra of the metal in quantity. This band of excitement, which is called surface plasma resonance in a certain location (LSPR) occurs when the level of the While the conduction electrons are stimulated collectively, the incident photon stays constant. LSPR excitation produces enhanced local electromagnetic fields that enhance spectroscopy around the surface of NPs and wavelength resonance and selection absorption Rays of efficient light scattering comparable to 10 fluorophores. The wavelength at which the LSPR spectrum peaks is known to be influenced by the size, form, and spacing between particles of the NPs as well as by their own dielectric characteristics and those of their immediate surroundings, which comprise the substrate, solvents, and adsorbates. [84]

Magnetic properties

Research from many different fields, encompassing environmental cleanup, Magnetic resonance imaging (MRI), biomedicine, data storage, and magnetic fluids such as water purification, heterogeneous and homogenous catalysis, and more, are very curious about magnetic nanoparticles.(NPs). The study indicates that NPs work best when they are between 10 and 20 nm in size. [85] Because of their effective magnetic characteristics at such a low scale, NPs are valuable particles with a variety of applications [86] Magnetic properties result from the unequal distribution of electrons in NPs. These qualities also depend on the artificial methodology, and they can Be ready with an assortment of synthetic techniques, solvothermal co-precipitation among others, microemulsion, thermal degradation and spraying of flames synthesis. [87]

Mechanical properties

Because of NPs' unique mechanical characteristics, researchers can seek for innovative uses in a number of crucial domains, including tribology, To ascertain Surface engineering, nanofabrication, nanomanufacturing, and the exact mechanical nature of NPs can be used to analyze a range of mechanical metrics, such as adhesion, friction, stress and strain, hardness, and elastic modulus. Moreover, surface coating, lubrication, and coagulation reinforce the mechanical characteristics of NPs. The mechanical properties of Nanoparticles are distinct from those of microparticles and their components in bulk. Additionally, with The pressure of contact is so high, the difference in stiffness between the exterior surface that contacts the NPs ascertains whether the NPs are indented into the plan surface or distorted in a lubricated or oily touch. This important information may disclose the NPs' performance in the contact scenario. To improve surface quality and material removal, having effective control is crucial control NPs' mechanical characteristics and their interactions with various yields positive outcomes in these domains typically need an extensive comprehension of the principles of NPs' mechanical properties, including inherent characteristics that vary with size, friction, interfacial adhesion, movement law, and elastic modulus and hardness. [88]

Thermal properties

Many people are aware that when metal nanoparticles are solid, their conductivities of heat are higher than those of liquids. For example, the thermal conductivity of copper at ambient the temperature is almost 700 times higher three thousand times more than that of water and engine oil. The ability of even oxides, as alumina (ALO), to conduct heat, is greater compared to water. Consequently, it is anticipated that fluids with suspended solid particles will have substantially greater thermal conductivities than those of traditional fluids that transmit heat. Dispersing solid nanometric scale Nanofluids are made by incorporating fragments into liquids like oils, ethylene glycol, or water. According to predictions, nanofluids will outperform traditional fluids for heat transfer and fluids with microscopic fragments. Since the particle surface is where heat transfer takes place, particles having a large overall surface area are preferred. Additionally, the stability suspension is increased by the high overall surface area. [89] CuO or Al2O3 It has recently been demonstrated that NPs in ethylene or water show improved heat conductivity in a nanofluid. [90]

Future Scope –

There are several different businesses that use essential oil-loaded nanoparticles, such as pharmaceuticals, cosmetics, food preservation, and agriculture. In pharmaceutical and medical applications, targeted drug delivery, antimicrobial therapy, wound healing, neurological disorders, in cosmetic and skincare innovations, antiaging and skin care, sunscreens and UV protection, hair care, in food preservation and safety, natural food preservatives, edible coating, in agricultural and environmental applications, pesticide alternatives, post-harvest protection, and water purification, here is a summary of the potential advancements and applications. To increase the stability and economical manufacturing of essential oil nanoparticles, more investigation is required. Prior to extensive commercial use, safety, toxicological, and regulatory issues need to be resolved. The effectiveness and safety of essential oil-loaded nanoparticles in pharmaceutical and medical applications need to be confirmed by more research. Essential oil-loaded nanoparticles offer safer, more efficient, and sustainable solutions for a bright future in food, health, cosmetics, and agriculture.

CONCLUSION:

A promising method for enhancing the regulated release, stability, and bioavailability of volatile and sensitive essential oils is the use of nanoparticles infused with essential oils. Essential oils have been encapsulated using a variety of nanocarrier systems, such as lipid-based, polymeric, and inorganic nanoparticles, which provide enhanced therapeutic efficacy, targeted distribution, and decreased toxicity. Notwithstanding notable progress, issues including scalability, regulatory clearance, and long-term stability still need to be resolved for commercial applications to be successful. To confirm their safety and effectiveness, future research should concentrate on developing new biocompatible materials, refining existing formulations, and carrying out comprehensive clinical trials. Essential oil-loaded nanoparticles have enormous Possibility of application in the food preservation, pharmaceutical and cosmetics industries with further development.

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