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SCENT AND DEFENSE: DUAL FUNCTION ENCAPSULATED OIL, A COMBINED NOVEL APPROACH FOR PERFUME AND MOSQUITO REPELLENT

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Abstract: Mosquito-borne diseases, comprising malaria, dengue, chikungunya virus, and zika virus pose a significant threat to public health. To prevent the transmission of these illness, it is crucial to use effective mosquito repellents. Although traditional repellents, such as DEET, are widely employed, they are derived from chemical synthesis and can have detrimental effects on human health. As a result, there has been an increasing trend towards using natural extracts and oils, such as essential oils, as mosquito repellents. Essential oils are derived from natural sources and possess aromatic properties, bioactive effects and insect repellency. Integrating mosquito repellency into personal care products is a promising strategy for enhancing the use of these oils. However, essentials oils are volatile and tend to degrade, limiting their long-term efficacy. Encapsulation technology offers several advantages, such as increased stability and efficacy, controlled release of active ingredients, and prolonged repellent activity. Additionally, this technique preserves the aromatic properties of essential oils, making it a versatile approach for the development of consumer-friendly products that meet both aesthetic and protective requirements. This study explores a novel approach that combines the dual function of encapsulated essential oils, providing a promising solution for the development of personal care products that offer effective mosquito repellency.

Keywords: Mosquito-borne diseases; Mosquito repellents; DEET; Essential oils; Natural oils; Volatile oils; Encapsulation technology; Controlled release; Aromatic properties; Insect repellency; Long-term efficacy; Consumer-friendly products; Dual-function products

Introduction

Mosquitoes, particularly the Anopheles species, pose significant health risks to humans and animals [2]. There are over 500 species of Anopheles mosquitoes found globally [2]. Preventing bites from these mosquitoes is an effective method of prevention [2]. The World Health Organization has recommended various prevention methods, including pesticidal spraying in homes and insecticide-treated clothes outside the home [3]. Products that are applied topically to the skin, clothes, or other surfaces to prevent biting and landing of mosquitoes or insects are known as mosquito repellents [9]. According to dermatologists, the most common skin reactions are caused by synthetic cosmetics and perfumes [5]. Commonly used synthetic repellents include DEET, allethrin, prallethrin, and dimethyl phthalate [6]. Essential oils are a potential alternative to synthetic repellents because they are target-specific, biodegradable, and environmentally friendly [3]. Essential oils are safer alternatives to synthetic repellents and fragrances and can be used to prevent skin reactions. Essential oils possess therapeutic properties, such as antimicrobial, antioxidant, anti-inflammatory, and neuroprotective effects [1]. Among the various applications of essential oils, aromatherapy and mosquito repellency are the most popular. They need reapplication as they are volatile and evaporate easily which results in short term efficacy [4]. When essential oils are applied directly to the skin, there may be an increase in skin toxicity and negative systemic consequences. Certain factors should be taken into account when looking for the perfect repellent. These include the natural active ingredient, such as extracts or essential oils, spray formulation, lotion, cream, or gel, or new technologies, like patch and cyclodextrins, extended-release systems like micro/nanoparticles lipidic solid, polymeric micro/nanocapsules, nano emulsions, microemulsions, and polymeric micelles [11]. They are highly efficient but degrade easily due to oxidation, heating, and light [7]. Microencapsulation techniques can be used to stabilize essential oils by creating a barrier that prevents degradation and allows for controlled release [7]. Natural fragrances can enhance the attractiveness of personal care products, such as creams, lotions, perfumes, shampoos, and deodorants [8]. Incorporating natural fragrance and repellent properties into a single product could enhance its use in personal care products, offering consumer-friendly products.

Essential oils in fragrances

The most popular natural smells are essential oils. These are intricate mixtures of terpenes and other aliphatic or aromatic compounds that are produced in particular aromatic plant secretory tissues as secondary metabolites [17]. Plants contain essential oils in a variety of places, including glandular hairs, specialized cells, pockets and reservoirs, and even the intercellular spaces [12]. Out of over 3000 plant species, it has been estimated that 300 essential oils are commercially available in the tastes and fragrances industry [18]. Essential oils can be categorized into top, middle, and base notes based on their volatility, diffusion rate in air, and aromatic qualities [19]. To give the blend freshness, the top notes, for example, are the most volatile and the first noticeable smells that are perceived and fade earliest [19]. They are the perfume's selling point since they are in charge of establishing initial impressions with customers. These smells are mild and last for five to ten minutes, or up to thirty minutes [20]. Middle notes are those essential oils that offer body to blends and have a tendency to be spicy or floral; they can also last for up to an hour. On the other hand, a perfume's base notes provide its depth. They are least volatile and long lasting [19][20].

Essential oils as mosquito repellents

Significant antiseptic, antibacterial, antiviral, antioxidant, anti-parasitic, antifungal, and insecticidal properties have been found for essential oils. As a result, essential oils can be an effective technique for lowering bacterial resistance [15]. An increasing number of research projects have demonstrated the effectiveness of plant extractions against mosquitoes at different stages of development [10]. Because of their apparent safety, effectiveness, affordability, biodegradability, and environmental friendliness, natural repellents have become more and more popular in recent years [11]. An active insect repellent formulation should have the following qualities: (i) low toxicity, low penetration, non-irritating to skin, mucous membranes, and eyes; (ii) odourless and disagreeable to mosquitoes; (iii) prolonged repelling activity to prevent the need for frequent reapplications; (iv) wide range of insecticidal activity, particularly against mosquitoes; (v) Outstanding visual and sensory qualities that prevent skin from feeling greasy; (vi) Absorbency of fluids and profuse perspiration; (vii) Excellent chemical stability and inertness when in contact with glass, acrylics, plastics, and synthetic fibres; (viii) Clothes and textiles shouldn't be stained by it; (ix) Cheap; (x) Doesn't harm the environment [11].

Table 1. Repellency of some most common essential oils

Essential oils	Repellency %	Protection time (hrs)	Major constituent	Fragrance
Lemon eucalyptus oil [6][8]	52.4%	8 hrs	citronellal, citronellol	Pleasant, citrusy with a hint of mint
Citronella oil [6][8]	100%	11 hrs	citronellal, geraniol, citronellol, geranylacetate	Strong floral, rose, sweet like
Peppermint oil [6][8]	100%	11 hrs	isomenthol, p-menthone, isomenthyl	Sweet minty, cooling and fresh
Lavender oil [6][8]	80.9%	8 hrs	linalool, linalyl acetate, lavandulyl acetate, α-terpineol, geranyl acetate, terpinen-4-ol, 1,8-cineole	Pleasant, floral and citrus
Rosemary oil [6][8]	100%	8 hrs	verbenone, camphor, borneol, bornyl acetate, α-terpineol, terpinen-4-ol	Strong, warm, woody, balsamic aroma

Repellency mechanism

Since most insect repellents are unpleasant to insects in some way, they work by creating a vapor barrier that keeps insects from coming into touch with human skin [11]. Based on the behaviour of insects that have been observed, repellents are divided into five categories: The three types of repellents are as follows: (a) true repellent, also known as a spatial repellent or expeller, which "pushes" mosquitoes away from odour sources without making direct contact; (b) contact irritants, also known as landing inhibitions, which cause insects to orient themselves away from a source after making direct contact; (c) deterrents, which are substances that inhibit specific behaviours like blood feeding or oviposition; (d) odour masking agents: these inhibit human attraction by making the host less attractive or by causing olfactory signals to interfere with the host's location; (e) visual masking agents: these interfere with visual signals, making it impossible for insects to locate the host [11]. They serve as comparatively short-lived chemical messengers that alert pheromones in insects and other animals. According to published research, the hairs of mosquito antennae are sensitive to moisture and temperature. Thus, the repellent molecules interact with the olfactory receptors of the female mosquito, obstructing her ability to perceive scent and making it more difficult for the mosquitoes to identify their host [21]. According to the most recent research on the mechanism of action of citronellal, Anopheles gambiae detects citronellal molecules through olfactory neurons in the antenna that are driven by the TRPA1 gene and immediately triggered by the highly potent chemical. Similar to humans, mosquitoes can react to DEET directly; DEET-sensitive olfactory neurons have been discovered in Culex quinquefasciatus's antenna and maxillary palpi. Unfortunately, a clear explanation of how these substances work to stop mosquito bites has not yet been established [18].

Comparison with synthetic repellents

The majority of the main components of commercial mosquito repellents, such as dimethyl phthalate, allethrin, and N,N-diethyl-meta toluamide (DEET), are synthetic chemicals [22]. Due to potential negative effects on human health, such as allergies, dermatitis, cardiovascular disease, neurological disorders, etc., mosquito repellents containing the aforementioned ingredients for regular use are strictly limited to medical indications [23]. Furthermore, these artificial substances have a negative impact on the environment, altering the organic ecosystem, leading to medication resistance, negatively impacting insects that are not the intended target, and so on [23][24]. Despite being widely used in the past century, effective mosquito repellents like dimethyl and di-n-butyl phthalates (DMP and DBP, respectively) are no longer often recommended due to their toxicity [26]. Naturally occurring essential oils are safer alternative as a repellent [25]. Duration of essential oils is shorter as they are volatile and evaporate quickly from the surface of skin is the only disadvantage [25]. Essential oils are delicate and unstable volatile compounds, despite their great potential. As such, if they are not shielded from outside influences, they may disintegrate quickly due to oxidation, volatilization, heating, and light. A controlled release might be provided by such protection, increasing their action duration [27]. Microencapsulation is a useful technique to increase the stability of essential oils. Its function is to shield the active ingredient by forming a barrier that prevents chemical reactions and/or permits the controlled release of its contents over an extended period of time or at a specific moment [28].

Need of herbal mosquito repellent

Researchers like Tenenbein and records from poison control centre telephone data have reported and found only a few cases of dermatitis, allergic reactions, and neurologic and cardiovascular toxicities like seizures following the use, ingestion, and high-concentration use of DEET on children and adults, despite the widespread use of DEET-containing products [26][29][30]. Additional adverse health consequences, such as tremor, encephalopathy, slurred speech, aberrant behaviour, coma, and even death, have been reported [26][31][32].

Figure 1. Lavandula angustifolia Mill. (Lamiaceae)

Figure 2. Eucalyptus citriodora Hook. (Myrtaceae)

Figure 3. Mentha × piperita L. (Lamiaceae)

Figure 4. Rosmarinus officinalis L. (Lamiaceae)

Figure 5. Cymbopogon nardus (L.) Rendle (Cardiopteridaceae)

Encapsulation of essential oils

The process of coating or encasing one substance, or a combination of materials, inside another material or system is known as microencapsulation. The coating material is also referred to as shell, wall material, carrier, or encapsulating agent. The coated substance is known as active or core material and can be solid, liquid, or gas. Microparticles have a diameter ranging from 1 to 1000 µm and are composed of many components [33]. Microspheres are frequently referred to as a matrix system, where the active component dissolves or is distributed throughout the carrier matrix [13]. The active ingredient in the microcapsule is shielded and isolated by a layer of an encapsulating agent, preventing insufficient exposure. Microcapsules can be shaped irregularly or regularly, such as spherical, tubular, or oval [34]. In order to shield EOs from the external medium, this approach creates a physical barrier between the wall materials and the core [35]. Microencapsulation has been regarded as one of the best methods for delivering controlled-release substances and enhancing EO management [36][37]. The use and application of microcapsules, the necessary size of the microcapsules, the nature of the shell and core material, the properties of the shell and core material, either chemical or physical, the system required for core release, the cost and scale of manufacturing, and so on, all influence the choice of encapsulation [38]. The primary techniques for encapsulating include spray drying, spray chilling, extrusion, coacervation (simple and complicated), and emulsification, as documented in the literature [3]. Microencapsulation has the capacity to alter an encapsulated substance's colour, shape, volume, apparent density, reactivity, durability, pressure sensitivity, heat sensitivity, and photosensitivity [39]. Furthermore, it can reduce the rate of evaporation or transfer of the active material from the core to the medium, prevent chemical reactions, lessen agglomeration issues of finely divided powders, enhance the handling qualities of sticky materials, control substance release, lower local concentrations, and lessen toxicity or irritation [40]. It can also shield a core substance from the effects of UV rays, moisture, and oxygen [13]. Microencapsulation techniques have been reported using a variety of methods, but they can be broadly categorized into three main categories: (i) chemical processes (such as in situ polymerization and interfacial methods); (ii) physiochemical processes (such as emulsification solvent evaporation/extraction and coacervation (phase separation); and (iii) physical–mechanical processes (such as fluid bed coating, air suspension method, pan coating, spray drying, spray chilling, and spray cooling) [40].

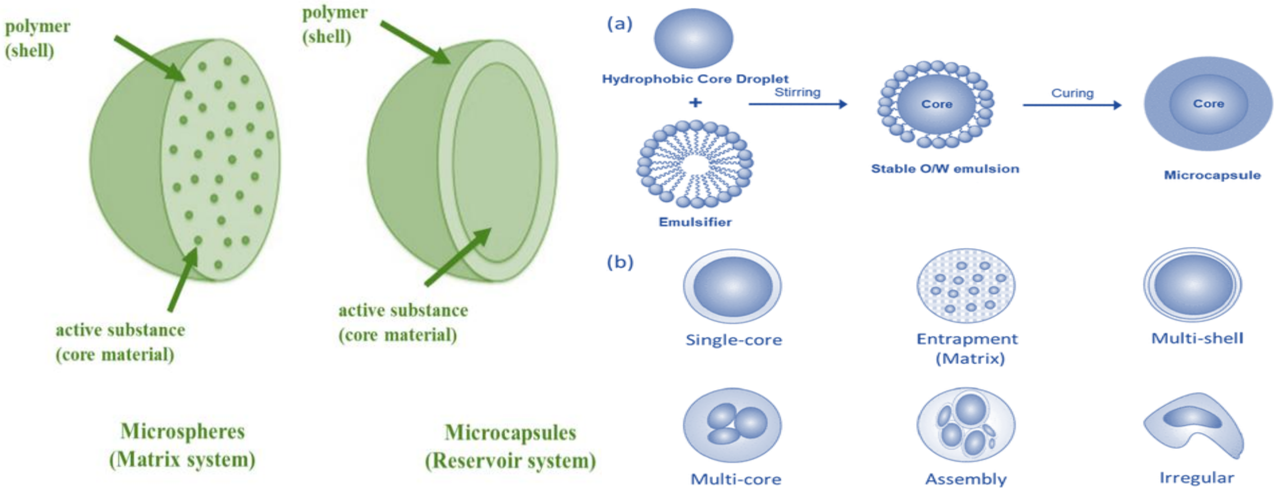

Figure 6. Encapsulation technique

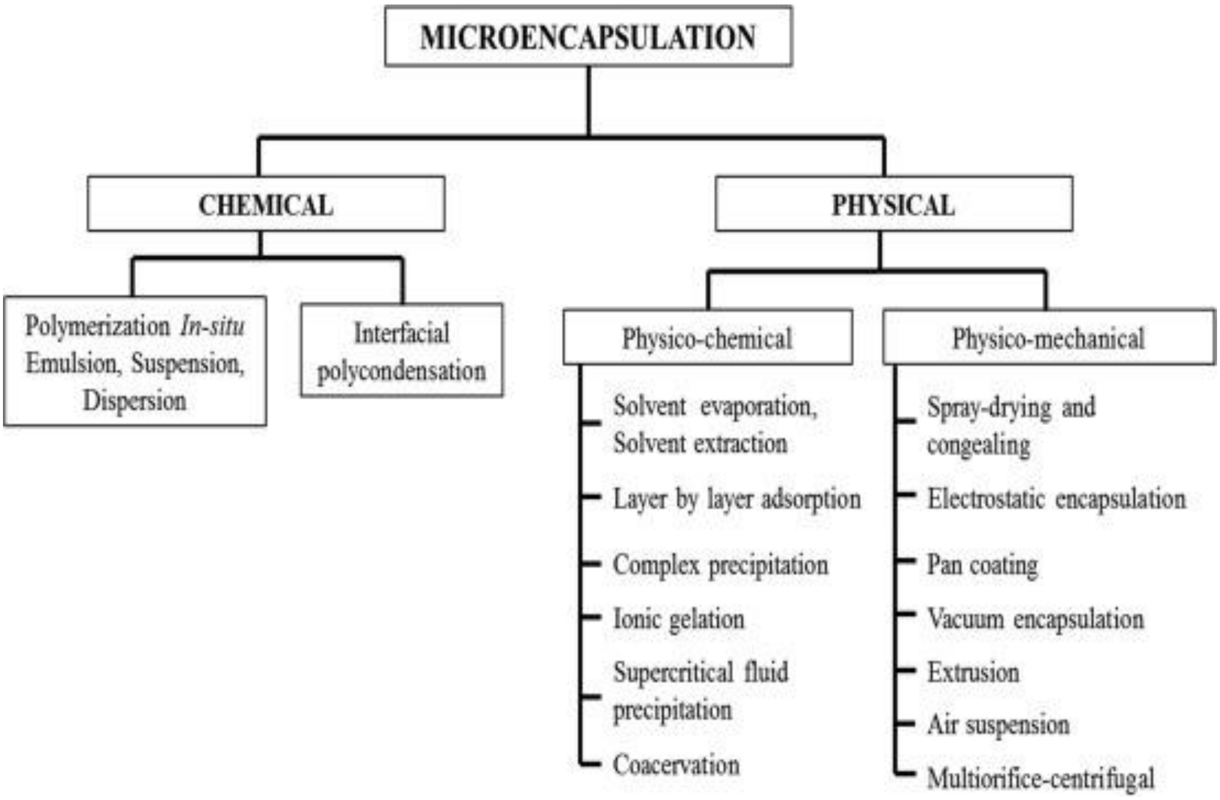

Figure 7. Types of microencapsulation

Table 2. An example list of shell materials used to microencapsulate essential oils significant to cosmetics

Shell material	**Core material: essential oil**	**Microencapsulation technique**
GA (Gum Arabic) and Maltodextrin Alginate [13]	Pterodon emarginatus Lime Clove (Eugenia caryophyllata) Thyme (Thymus vulgaris) Cinnamon (Cinnamomum zeylanicum)	Spray drying Spray drying Emulsion, extrusion
Chitosan Gelatin [13]	Citronella Holy basil	o/w emulsification simple coacervation
Ethylcellulose [13]	Rosemary Lavender	Phase separation o/w emulsification, solvent diffusion
Melamine formaldehyde [13]	Rosemary (Rosmarinus officinalis) Lavender (Lavandula hybrida) Sage (Salvia officinalis)	Modified in situ polymerization
PMMA (Polymethyl methacrylate) [13]	Jasmine	o/w emulsification, solvent evaporation

Table 3. Types of microencapsulation

Types of microencapsulation	**Description**	**Condition**	**Carrier**	**Application**
Complex coacervation [14]	The ionic interaction of two oppositely charged polymers, along with the shared positive charges on protein molecules and anionic macromolecules, forms the capsule.	Three immiscible chemical phases form. coating's deposition. Consolidation of the stratum.	Alginate and polylysine, albumin and gum arabic, gelatin and carboxymethylcellulose, etc.	Bioactive components to be encapsulated by the food and pharmaceutical sectors.
Simple coacervation [14]	Through hydrophobic contact, the polymer competes for the solubility of the gelatin protein in the fluid.	Creation of chemical phases that are immiscible. Depositions of coatings. Solidification of layers.	A polymer that is more water soluble or non-solvent, such as ethylcellulose or gelatin.	Yogurt-like encapsulation of bacterial organisms.
Phase inversion precipitation [14]	A regulated procedure known as de-mixing converts the originally homogenous polymer solution from a liquid to a solid state.	The choice of polymer affects the structure, characteristics, and chemical interactions of the membrane as well as the additives added to the casting solution.	A solvent, a non-solvent, and a polymer (polysulfone).	Creation of Herbal Product Nano emulsions.
Centrifugal extrusion [14]	A liquid coextrusion procedure made use of nozzles with a concentric aperture situated on the outside rim of a spinning cylinder.	The separation of the coating material's core mix. Transfer the blend onto a revolving disc to get an enclosed little fragments. Desiccation.	Gelatin, starches, carrageenan, sodium alginate, and cellulose derivatives.	Food components or microencapsulations of probiotic bacteria.
Interfacial polymerization [14]	At the interface between an organic solution having a second monomer and an aqueous solution containing one, condensation polymerization takes place.	Layer of polyamide generated in situ.	Polyamide membranes made of thin-film composite.	EO encapsulation for the cosmetics and healthcare sectors.
Spray drying [14]	Based on the active ingredient's combination atomization with a melting lipid. The substance is kept in a cold room where droplets that come into touch with the cool air solidify to create solid lipid microparticles, which hold onto and shield the active ingredient.	The process of getting ready, homogenizing, atomizing the dispersion, and dehydrating the atomized particles.	Gum, maltodextrin, and modified starch.	Enclosing an active component, such ascorbic acid.

Coacervation (Phase separation)

Phase separation microencapsulation is the process of separating a solution containing a dispersed macromolecule into two immiscible liquid phases. The liquid or solid to be encapsulated is dispersed in a solution of a macromolecule (wall material). The encapsulating polymer is induced to separate as a viscous liquid phase (coacervate) through various methods; this separation process is known as coacervation. The macromolecule is present at high and low concentrations in the coacervate phase and in the supernatant phase, respectively. Under certain conditions, the coacervate phase forms a continuous layer that coats the material to be encapsulated. The formed microparticles can be collected by centrifugation or filtration, and then cleaned with the appropriate solvent, dried, and hardened by thermal, cross-linking, or desolvation techniques [13]. Coacervation, then, is a three-step process: (i) creating an oil-in-water (o/w) emulsion (polymer is dissolved in the organic phase and the active compound is dispersed in the aqueous phase); (ii) coating the core material with the liquid polymer; and (iii) stabilizing and hardening the coating material to create self-sustaining microcapsules [13]. One might categorize coagulation in the aqueous phase as simple or complicated. A shift in circumstances that results in the wall material's dissolution induces simple coacervation [42]. By generating electrostatic interactions between the macromolecules of shell materials, the complex aggravation is produced. Mutual neutralization of two oppositely charged polymers leads to complex coacervation [43]. Stirring speed, viscosity of the aqueous and organic phases, type and concentration of surfactant (if applied), vessel and agitator arrangement, and temperature profile throughout production are some of the elements that influence the size of the microcapsules [44][45]. High encapsulation efficiency and effective particle size control are made possible by this method. Furthermore, it can inhibit degradative processes, stop volatile aromatic component loss, regulate release, and enhance the stability of the flavour and essential oils [46]. Nonetheless, the most typical issue is microcapsule aggregation [47]. In addition, it is costly and operationally complicated, requiring meticulous control over the experimental setup [48]. There are situations where the microcapsules must be stabilized by high temperatures, extremely low pH levels, or cross-linking agents. This restricts the ability to encapsulate chemically and thermolabile components like proteins and polypeptides. Additional restrictions include the oxidation of the product, the solubility of the active ingredient in the processing solvent, and the evaporation of volatiles (such as flavours and EOs) during processing [42].

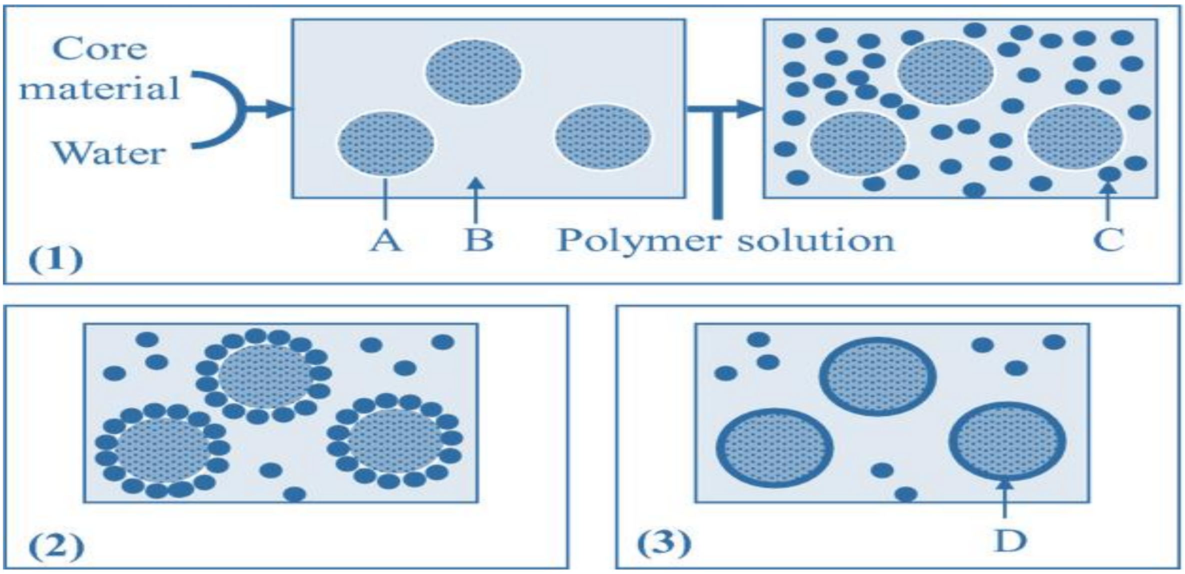

Figure 8. The general process of microencapsulation by coacervation consists of three steps: (1) creating an oil-in-water (o/w) emulsion (polymer (C) is dissolved in the organic phase, and core material (A) is dispersed in water (B); (2) coating the core material with a liquid polymer; and (3) hardening the coating material to form self-sustaining microcapsules (D). **[13]**

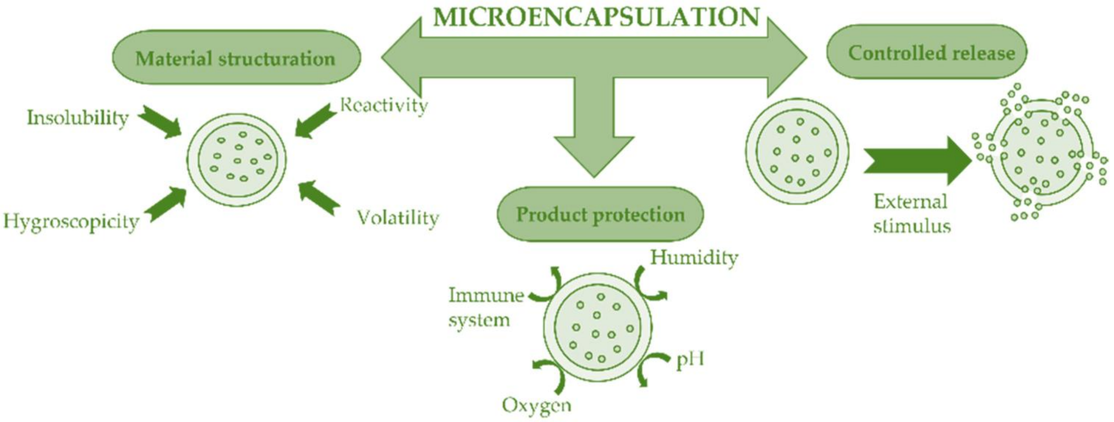

Figure 9. Objectives of microencapsulation

Table 4. Particle size produced by different microencapsulation technologies and their advantages and disadvantages

Microencapsulation technique	**Particle size (μm)**	**Advantages**	**Disadvantages**
Simple coacervation	20–200	Encapsulation efficiency is high.	Costly method.
Complex coacervation [13]	5–200	Effective management of particle size.	Particle aggregation, arduous scaling up volatiles evaporating Potential for the active ingredient to dissolve into the processing solvent.
Spray drying [13]	1–50	Easy to Use, minimal process expenses, Simple method for scaling up.	Particles are not uniform, minimal degree of oil loading, need additional processing, low-boiling-point, aromatics may be lost.
Spray chilling [13]	20–200	Ideal for things that dissolve in water.	Increased process expenses, need particular care and storage circumstances.
Fluid bed spray coating [13]	>100	Minimal running expenses, enhanced thermal efficiency method, complete control over temperature.	Lengthy procedure.
Emulsification [13]	0.1–100	Tiny drops, limited distribution of particle sizes, suitable for a variety of liquid and solid core materials, as well as biodegradable and non-biodegradable polymeric microparticles.	Inadequate encapsulation effectiveness, generation of a large amount of leftover solvent, costly approach.
Interfacial polymerization [13]	0.5–1000	Simple method for scaling up, Quickly increased encapsulation effectiveness.	Challenging to manage, generation of a large amount of leftover solvent, Potential for monomers that are neither biocompatible or biodegradable.

Table 5. Types of microspheres and main characteristics

Type	**Function**	**Method of their production**	**Example of encapsulating materials**	**Advantages**
Core-shell [14]	To apply functional coatings on materials that are solid.	Spray drying	Proteins, phospholipids, colloidal particles, and electrolytes.	Mechanical strength, permeability, and stability.
Alginate microspheres/ nanospheres [14]	Gelation, either internal or external, and colloidal systems at the nanoscale.	Alginate microencapsulation	Functional substances that are brittle (such as proteins, EOs, extracts, enzymes, and transporters).	Thermostability, nontoxicity, immunogenicity, biodegradability, and biocompatibility.
Cationic starch nanoparticles [14]	A paperboard used for both medicinal and culinary purposes.	Extrusion or drying	Bioactive substances (such as bone protein-4 and albumin).	Pasting, rheological characteristics, temperature, solubility, and biodegradability.
Bioadhesive/ Mucoadhesive microspheres [14]	Mucosal barrier by using polymers that dissolve in water.	Emulsion	Adhesion of the drug delivery device (ranitidine) to the mucosal membrane (buccal, ophthalmic, rectal, nasal).	Extended duration of contact at the application site results in close interaction with the absorption site and enhances the therapeutic effect.
Magnetic microspheres [14]	The tailored medicine delivery device using magnetics.	Emulsion	Dextran, monoclonal antibodies, and chitosan.	Their subdivision is made up of floating, radioactive microspheres that are non-invasive and particular.

Future directions

1. Encapsulation technique optimization: In order to increase the stability, effectiveness, and controlled release of essential oils, future research should concentrate on encapsulation technique improvement. This can entail looking into novel encapsulating materials that preserve the aromatic and bioactive characteristics of the oils while improving their protective features, such biodegradable polymers or nanomaterials.
2. Creation of Multi-Component Formulations: More effective formulations may result from examining the synergistic effects of mixing several essential oils with various repelling and aromatic qualities. Research might concentrate on how well different oils work together in a single encapsulation matrix and how that affects repellent effectiveness and smell attractiveness as a whole.
3. Long-Term Efficacy Studies: It is crucial to carry out long-term research on the stability and effectiveness of encapsulated essential oils in actual conditions. To find out how long and how effective the repellent qualities are in varied conditions, this may need testing in a range of climates and situations.
4. Toxicological and Safety Assessments: Extensive toxicological analyses are required to guarantee the safety of essential oils in capsules for human consumption, especially for vulnerable groups like children and expectant mothers. Any possible allergic responses, skin irritation, or long-term exposure consequences should be investigated in research.
5. Mechanistic Studies on Repellency: More research into the molecular mechanisms behind the mosquito-repelling properties of essential oils and their bioactive constituents may shed light on how

best to formulate repellent products. Comprehending the olfactory reactions of diverse mosquito species to distinct constituents of essential oils helps steer the creation of more precise and efficacious repellents.

6. Assessment of client Preferences and Acceptance: Subsequent research endeavours ought to appraise client inclinations concerning the aroma, consistency, and efficacy of commodities that incorporate encapsulated essential oils. Product creation may be guided by an understanding of customer behaviour and acceptability to guarantee commercial success and broad adoption.

7. Scalability and Commercial Viability: The scalability of encapsulation methods for use in commercial production need to be the main emphasis of research. This entails creating large-scale production techniques that are affordable and assessing whether these technologies are viable for general consumer use.

8. Investigation of Alternative Uses: Encapsulated essential oils may be investigated for uses other than personal care products, such as in public health initiatives to lower mosquito populations in high-risk locations or in agricultural settings to protect crops from pests. The usefulness of these formulations in various situations and applications might be studied further.

9. Environmental Impact Assessments: It is critical to carry out research to assess how employing encapsulated essential oils may affect the environment, including any degradation products and interactions with creatures that are not intended targets. This study will contribute to ensuring the safety and ecological sustainability of these items.

10. Comparative Research with Synthetic Repellents: To emphasize the benefits and possible drawbacks of natural alternatives, more research comparing encapsulated essential oils with conventional synthetic repellents like DEET is required. To offer a thorough assessment, these studies should concentrate on effectiveness, safety, cost, and customer preference.

11. Integration with Other Technologies: To develop creative mosquito protection solutions, research might examine the integration of encapsulated essential oils with other cutting-edge technologies, including wearables or smart fabrics. This might improve the usefulness and efficacy of repellents and open up new product categories.

12. Policy and Regulatory Research: The regulatory environment around natural mosquito repellents should be covered in future studies. Studying the creation of new regulations and guidelines might make it easier for these items to enter the market, guaranteeing safety requirements and encouraging creativity in natural repellents.

The field can improve the knowledge and use of encapsulated essential oils by following these future research avenues. This will increase the products' potential to serve as dual-function products that combine fragrance and mosquito repellent, ultimately improving consumer satisfaction and public health.

Conclusion

The creation of essential oil components in microencapsulation for use as a mosquito repellent as well as in cosmetics is highlighted in this review. Since essential oils are ephemeral, the microencapsulation method was employed to maximize their potency and longevity, making them the greatest substitutes for synthetic repellent in preventing mosquito-borne illnesses by mosquitoes. Additionally, they are a safer substitute for ointments, lotions and perfumes compared to synthetic formulations which can lead to a variety of skin issues when administered topically. Repellents made from plants often don't represent a risk of toxicity to people or domestic animals and disintegrate quickly. Applying and terminating such formulations that are topically applicable will be convenient for individuals. Essential oils are widely available in nature, and in addition to its therapeutic and flavourful properties, their usage as a mosquito repellent can be viewed as a sustainable and biocompatible delivery method as a green option. They are frequently utilized as active ingredients and fragrances in the cosmetics industry. Furthermore, they are coveted and highly valued components in cosmetics and cosmeceutical goods because of their capacity to provide a broad range of distinctive and pleasant fragrances to cosmetic products while also functioning as bioactive agents (anti-aging, antibacterial, UV protection, and whitening). Moreover, the "back to nature" movement has greatly increased the usage of botanical oils and extracts at the expense of artificial and synthetic derivatives, which are regarded to be harmful to human health. Furthermore, due to growing consumer knowledge of the health advantages backed by scientific research, essential oils are more in demand than artificial perfumes, which may replicate some natural scents. This makes them more alluring and appealing to customers. Having said that, the future of the essential oil business is bright, with profitable opportunities in the fragrance and cosmetics sectors. A lot of work has gone into microencapsulating cosmetic ingredients in recent years due to its ability to preserve and protect the active compounds from evaporation and degradation as well as its controlled release. As a result, the formulation of cosmetics and personal care products finds microencapsulation of essential oils to be highly appealing. Multidisciplinary cooperation is required to improve the various microencapsulation techniques for effective large-scale implementation and to fully utilize this technology. Furthermore, gaining a better understanding of the biological activities of microencapsulated EOs is crucial for their safe use in cosmetics and the modulation of active ingredient release.

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