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Microencapsulation: A Review

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ABSTRACT: Microencapsulation Review is a comprehensive review of the preparation, production and use of new small self-encapsulated products, including time-tested technologies associated with improved micro and large nanoparticles. Expansion beyond conventional microcapsules is used for all other microsystems, both the structure itself and the preparation of the work. This review includes information on encapsulation, the physical principle of release from the capsule wall and/or desorption from the carrier, preparation and bulk use of microcapsules.

KEYWORD: Microencapsulation , Coating , Corematerial , Microparticle , Matrix , Microcapsulation

I. INTRODUCTION:

Concrete is the most commonly used building material globally because of its strong compressive strength, durability, affordability, design options, and fire resistance [1]. Microencapsulation involves encasing solids, liquids, or gases in a second material with a polymer coating to create tiny particles. During this procedure, tiny solid particles or liquid droplets are covered with a thin coating to protect them from the environment and regulate the release of active ingredients. The process of microencapsulation is commonly used to alter and prolong drug release in various types of pharmaceutical dosage forms. The substances contained inside the microcapsules are referred to as core materials, pay-load materials, or nucleus, while the materials surrounding them are known as coating materials, wall material, shell, or membrane.Concrete is the most commonly used building material globally because of its strong compressive strength, durability, affordability, design options, and fire resistance. Microencapsulation involves encasing solids, liquids, or gases in a second material with a polymer coating to create tiny particles. During this procedure, tiny solid particles or liquid droplets are covered with a thin coating to protect them from the environment and regulate the release of active ingredients. The process of microencapsulation is commonly used to alter and prolong drug release in various types of pharmaceutical dosage forms. The substances contained inside the microcapsules are referred to as core materials, pay-load materials, or nucleus, while the materials surrounding them are known as coating materials, wall material, shell, or membrane [2].

.**Microparticles:**
"Microparticles" refers to the particles having the diameter range of 1-1000 μm, irrespective of the precise exterior and/or interior structures.

Microspheres:
"Microspheres" particularly refers to the spherically shaped microparticles within the broad category of microparticles.

Microcapsules: "Microcapsules" refers to microparticles having a core surrounded by the coat or wall material(s) distinctly different from that of the core or pay-load or nucleus, which may be solid, liquid, or even gas.[3]

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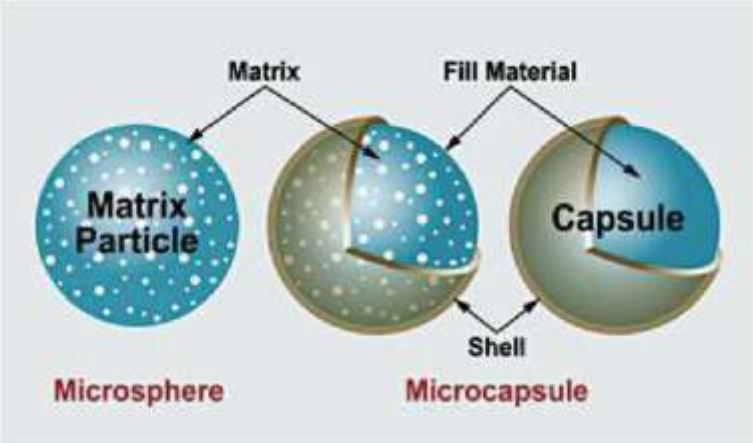

Fig.1.Digramatic presentation of microsphere and microcapsule[4]

However, concrete cracks are a significant issue that can impact the strength and longevity of concrete structures. Repairing cracks in the concrete structure can enhance the building's durability and safety, potentially preventing collapse and extending its lifespan. Numerous conventional techniques have been employed to mend cracks, such as using epoxy or latex sealants, stitching, overlay, and grouting. Nevertheless, they come with a high price tag, diminish the visual appeal, necessitate manual labor, and have a negative environmental impact. Furthermore, the cement sector contributes significantly to carbon dioxide (CO2) emissions, accounting for approximately 8% of global CO2 emissions. This is due to the release of CO2 from carbonate decomposition and fossil fuel combustion needed to achieve the high temperatures required for carbonate decomposition (~1000 °C). Additionally, chemical bonding substances like acrylic, polyvinyl acetate, and butadiene styrene pose health risks because of their toxic nature [5].

Definition of microencapsulation:

The word capsule refers to a firm structure comprised of a core and shell, or core material and coating material, as depicted. Microcapsules are defined as particles or droplets enclosed by a membrane and dispersed within a solid matrix [6].

or

Microencapsulation is described as the act of enclosing a polymer substance within extremely small solid or liquid particles to create microcapsules or microparticles consisting of natural or synthetic polymers. The sizes of these free particles vary from 1 to 1000μm in diameter.[7]

REASONS FOR MICROENCAPSULATION:

- Microencapsulation is primarily used for either prolonging or sustaining drug release.
- This method is commonly utilized to cover up the taste and smell of numerous medications in order to enhance patient adherence.
- This method is capable of transforming liquid medicines into a powder that flows freely.
- Microencapsulation can stabilize sensitive drugs from exposure to oxygen, moisture, or light.
- Microencapsulation can prevent incompatibility between medications.
- Microencapsulation can prevent the vaporization of various volatile drugs like methyl salicylate and peppermint oil.
- Bakan and Anderson discovered that microencapsulated vitamin A palmitate displayed increased stability.
- Insecticides and other toxic chemicals can be encapsulated in microcapsules to lower the risk of causing sensitization in individuals.
- Microencapsulation can also lead to a change in the location where absorption occurs.[8]

II. MATERIALS AND METHODS:

Bacterial spore preparation:

In this research, Bacillus sphaericus LMG 22257 from the Belgian Coordinated Collection of Microorganisms in Ghent was utilized and cultivated in YU medium (consisting of Nutrient broth 3 g/L, NaHCO3 2.12 g/L, and urea 10 g/L) that had been sterilized at 121 °C for 15 minutes prior to usage. The cultures were placed in a 30 °C incubator for 7 days with stirring at 100 rpm. The bacterial cells in their vegetative state were

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triggered to develop spores through exposure to heat at 80 ℃ for 10 minutes in a water bath, followed by rapid cooling in crushed ice water for 5 minutes. Spore germination was initiated by growing in YU medium at 30 °C with agitation at 100 rpm for 2 days to verify that over 90% of the cells had become spores. The spores were collected at a temperature of 4 °C through centrifugation at 8,000 rpm (2,862 × g with a rotor radius of 4 cm) for 15 minutes. The spore suspension was rinsed two times with 0.1% (w/v) NaCl-peptone buffer and then placed in sterile distilled water at 4 °C. It should be mentioned that the spore suspension was washed with NaCl-peptone buffer after harvesting to ensure an isotonic environment. This is especially crucial when attempting to retrieve cells or spores that could be under stress or sensitive to osmotic pressure.

Microscopic analysis and endospore gram staining were conducted to confirm that the majority of cells transition into spores during the heat-shock and spore germination stages. The spore count was measured before and after the induction process. Malachite green staining, an exclusive stain for endospores, definitively verified the occurrence of sporulation. Around 90% of rod-shaped bacterial cells, which were red in color, had a green spore in their terminal region, showing the presence of spores..

Microencapsulation of the bacterial spores:

2% (w/v) spore suspension with a concentration of 10^6 cells/mL in 200 mL of sodium alginate solution was utilized in every microencapsulation method. The specifics of every method are given as follows:

Extrusion technique:

The spores were evenly distributed in 200 mL of a 2% (w/v) sodium alginate solution, then transferred through a silicone tube with a peristaltic pump set at 120 rpm, into a syringe needle (6 mm diameter) for extrusion as droplets into a 2% (w/v) CaCl2 solution. They were allowed to solidify at room temperature for 30 minutes. The firm capsules produced were rinsed with sterile distilled water, dried on clean paper until fully dry, and then saved in a desiccator.

Spray drying technique

In this research, a pilot-size spray dryer (BUCHI™ B-290, Switzerland) was utilized. The air entering the system was warmed up to 105 °C once it went through a fan. A peristaltic pump transported the blended spore and 2% (w/v) sodium alginate solution to a liquid stainless-steel atomizer. The temperature of the outlet air (73 °C) was regulated by varying the flow rate of the input solution and the aspiration rate of 10% and 100%, respectively. The dried capsules were gathered from the cyclone vessel, placed in a tightly sealed bottle, and stored in a desiccator.

Freeze drying technique

Prior to sublimation, the spore suspension was frozen in 2% (w/v) sodium alginate solution at −46 °C using liquid ethanol. Subsequently, the combined solution underwent freeze drying for 24 hours in a laboratory-scale freeze dryer (Christ Alpha 2–4/LD Plus, Germany) with a condenser temperature below 0 °C and a chamber pressure of 0.05 mbar (5 Pa). The dehydrated items in sheet form were crumbled into small pieces and then placed in a desiccator for storage.[9]

Classification of microencapsulation:

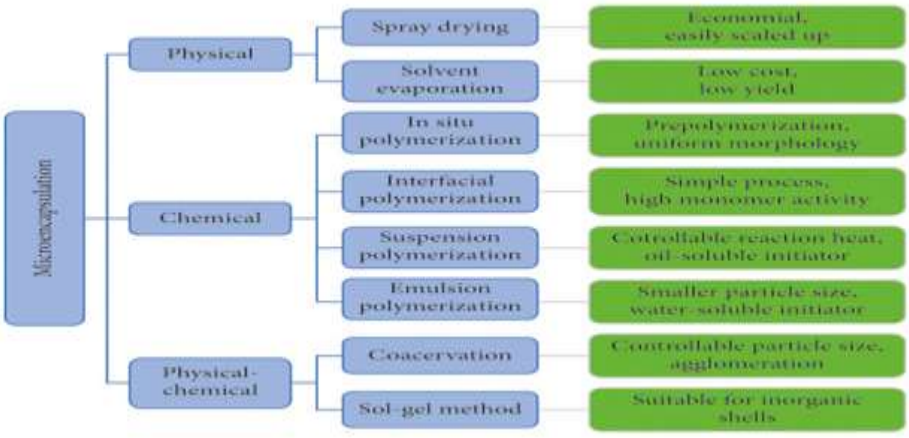

Fig.2 The classification of microencapsulation methods for PCMs[10]

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Microencapsulation of classification:

1] Physical: During the physical process, the shell is compressed mechanically above the main active ingredient without engaging in any chemical reactions, resulting in microcapsules that have an average diameter greater than 100 µm. Pan-coating, fluidized bed, air-suspension coating, spray drying, centrifugal extrusion, and electrohydrodynamic processes are all frequently employed physical techniques [11].

A) Spray drying: The spray drying method, developed in the 1930s, is a straightforward and easily reproducible drying technique that is also scalable. It has high encapsulation efficiency

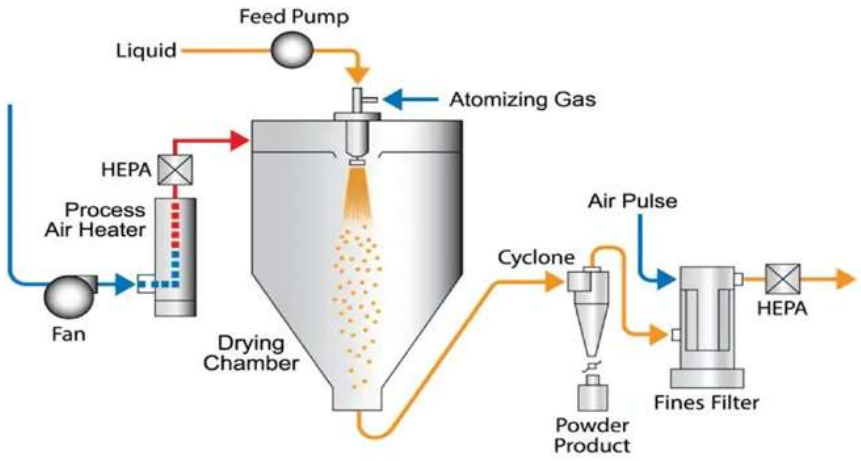

Fig.3 Spray drying[17]

and is popular for its advantages including lower production costs, reduced energy usage, and suitability for temperature-sensitive materials like food and biological products [12,13]. It is a frequently used encapsulation method because of its practical processing steps and long history[14]. They achieved uniform microcapsules with tiny particles and excellent microencapsulation efficiency. The microcapsules collected in the collection vessel had a clearer and more uniform shape compared to those collected in the drying chamber. However, a major downside of this procedure is the aggregation that occurs in the drying chamber, which can be reduced by temperature control or using a high flow of the gas carrier. Zuo et al. utilized a spray-drying technique for the production of microcapsules containing polylactic acid (PLA) and sodium monofluorophosphate [15]. Nonetheless, a disadvantage is the high cost and size of the spray drying apparatus. Additionally, it creates powder microcapsules that need additional processing such as agglomeration. The final product has minimal thermal efficiency due to a significant amount of heated air passing quickly through the chamber without making direct contact with the particles for drying. On the other hand, the effectiveness of this method is restricted by the availability of shell materials that can dissolve in water, such as hydrophilic materials [16].

B] Solvent evaporation : Solvent evaporation occurs routinely in nature when water gains energy, often as heat, and transitions from a liquid state into a gaseous one. Thermal molecular agitation is what underlies this change, hence you apply heat to water and molecules with energy in excess of the thermodynamic potential escape from the water surface as water vapour.

Methods of Solvent Evaporation:

- **Rotary Evaporation**: A rotary evaporator is employed for the precise and cautious removal of solvents. Rotary evaporation involves rotating a solvent in a vacuum to increase surface area, lower the pressure to decrease boiling point of the solvent, and heat the solution. The procedure decreases the likelihood of collisions and enables a gradual evaporation process.
- **Tube Evaporation**: Evaporating solvents from parallel tubes is part of the tube evaporation process. It is a quick and effective technique that reduces the chance of solvent bumping. Tube evaporation enables the concentration of high boiling solvents without needing to

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subject them to high temperatures. These solvent options consist of DMSO, DMF, and water.

- **Centrifugal Evaporation**: Centrifugal evaporators are used for evaporating multiple liquid solvents at low temperatures. A vacuum pump is utilized to facilitate solvent evaporation for removing solvents from the samples; nevertheless, as this takes place in a vacuum, the samples become cold. A advantage of centrifugal evaporation is that the solvent evaporates starting from the surface and moving down, diminishing the risk of solvent bumping. Boiling samples with surface-down orientation decreases the chance of cross-contamination and sample loss.[18]

2] Chemical :

a) In-situ polymerization:-

Only a small number of microencapsulation methods entail directly polymerizing a monomer on the surface of the particle. During a single process, for example, cellulose fibers are enclosed in polyethylene while being surrounded by dry toluene. Deposition speeds reach approximately 0.5 micrometers per minute. The coating thickness varies from 0.2 to 75 micrometers. The uniform coating covers sharp projections [19]

b) Interfacial Polymerization:

Interfacial polymerization saw significant advancements in the late 1960s [20,21] eventually leading to the production of microcapsules by the mid-1970s.[21,22]. One important aspect of microencapsulation through interfacial polymerization is the movement of the reagents to the reaction boundary [23]. Typically, one phase will be water-based while the other will be composed of an organic solvent. If the water-based layer is the scattered layer, the center of the capsules will be water-loving, but switching the layers would result in a water-repelling center. This technology enables the encapsulation of various core materials, including aqueous solutions, liquids that are not soluble in water, and solid particles [24,25]. The process has been demonstrated in a scenario where two reactive monomers, each soluble in its own immiscible phase, meet at the interface, leading to the encapsulation of liquid droplets with a polymeric membrane.

c) Suspension Polymerization:

This chemical process is employed in certain encapsulation techniques to produce core-shell particles. Polymerization is carried out using a soluble initiator in the monomer, with both insoluble monomers and initiators present in the polymerization medium. During the initial stage, microdroplets are created by mixing the monomer phase, which includes monomers, a blowing agent, and an initiator, with a stabilizing agent in a medium using a stirrer. Next, the polymerization starts within the monomer droplets in the second step of the process and progresses until finished. In the end, the monomer microdroplets transform into polymer microbeads with identical dimensions. The polymer separates from the monomer droplets due to its lack of solubility. A mixture is created with monomer, polymer, and water in a three-phase system[26,27].

d) Emulsion polymerization method:

Emulsion polymerization is a form of radical polymerization common in polymer chemistry, typically initiated by an emulsion containing water, monomer, and surfactant. The prevalent form of emulsion polymerization is an oil-in-water emulsion, where monomer droplets (the oil) are emulsified (using surfactants) in a continual water phase. Water-soluble polymers like certain or hydroxyethyl can also serve as emulsifiers/stabilizers. The incorrect term "emulsion polymerization" comes from a misunderstanding in history. Instead of happening in emulsion droplets, polymerization occurs in the particles that are created naturally in the initial stages of the process. These latex particles are usually around 100 nanometers in size, consisting of numerous polymer chains. Each particle is surrounded by a surfactant, preventing them from clumping together as the charge of the surfactant pushes the particles apart. Water-soluble polymers act as stabilizers instead of soap, creating repulsion between particles by forming a 'hairy layer' around each particle. This layer repels other particles as compressing the chains would be necessary to push particles together. [28]

3) Physical Chemical:

a) Coacervation method:

Coacervation is a popular and effective technology for encapsulating probiotics. It operates by creating a liquid with a high polymer concentration that is in balance with another liquid phase. It is a phenomenon involving colloids, where the colloid rich phase can be present in either a lowly dispersed state or a highly dispersed state. Different researchers have examined how the coacervation process impacts probiotics. Typically,

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probiotics in coacervated form are dehydrated to reduce costs related to packaging, storage, transportation, and distribution due to the material remaining dispersed. [29]

b) Sol-gel method:

The S-G method, short for sol-gel method, involves using a compound with a highly reactive component as a precursor, mixing these materials uniformly in liquid form, and then carrying out hydrolysis and condensation reactions to create a stable and transparent sol system in solution. The aged colloidal particles gradually combine with the sol to create a gel with a three-dimensional structure. This gel is then filled with a solvent that solidifies, forming a gel. The gel is dehydrated, fused, and hardened to create molecular and nano-substructure materials. In the sol-gel technique, the initial step involves dispersing the raw ingredients in a solvent, followed by a hydrolysis reaction to generate an active monomer. The monomer that is active undergoes polymerization and transitions into a sol, eventually leading to the formation of a gel with a specific spatial arrangement. Preparation of nanoparticles and necessary material following drying and heat treatment[30].

Application of Microencapsulesion:

1. Microencapsulation helps maintain the viability of both probiotic and starter culture bacteria, enhancing the sensory characteristics of sausages. [31]
2. Microencapsulation is employed to protect vitamin-A from the damaging effects of oxygen..[32]
3. In some situations, the goal is not to completely separate the core but to manage how quickly it releases its contents, such as in drug controlled-release..[33]
4. Certain sunscreens are trapped inside silica gel. A brand called "Eusolex UV-Pearls" is one option. The encapsulation shields the user from potential hormone disruption caused by these chemicals until they are applied..[34]
5. Formulations of medication with a delayed release. Since microencapsulation is especially advantageous for the production of tablets, capsules, or parenteral medication forms..[35]
6. Microencapsulation can decrease the hygroscopic characteristics of various core materials.[36]
7. Numerous medications have been encapsulated on a small scale to minimize stomach discomfort..[37]

Advantages of microencapsulation:

- Disguises the flavor of bitter medications to make them more enjoyable and enhance patient adherence. Eudragit E100 is frequently utilized as a coating material for this aim. The taste receptors do not come into contact with the microencapsulated drugs because they are not soluble in the mouth. Ofloxacin is an example.
- Transforming a liquid medication into a solid or easily pourable powder. For example, Eprazinone.
- It improves the ability of poorly soluble drugs to dissolve and the safe management of toxicmedications.
- To release the encapsulated material at the intended location.
- Changing the physical and surface characteristics of specific medications, such as decreasing the hygroscopic nature of sodium chloride..[38]

Disadvantages of microencapsulation:

fig.4. Disadvantages of microencapsulation [39]

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III. CONCLUSION:

Microfabricated systems have the potential to be more efficient than chemical systems. Microspheres and microcapsules have been designed to be system-specific for many drugs and can be modified to adhere to target tissue. Therefore, microcapsules and microspheres can be used not only for controlled release but also for targeted drug delivery to specific sites in the body. Although significant progress has been made in the field of microencapsulation, the field still faces many challenges. The development of cheaper biopolymers for microencapsulation technology and the development of international research, especially for bioadhesive microspheres, are of particular importance. Therefore, future development of security and specific benefits will require in-depth investigation of the biological and technological properties of these systems.

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