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Nanocapsules used in Drug Delivery System

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ABSTRACT:

Nanocapsules are microscopic vesicles composed of a core material encapsulated within a polymeric shell. The core typically contains the drug substance, while the shell controls its release and targeting. The development of novel nanocapsules included various methods for formulations with improved properties, like polymerization, solvent diffusion, dialysis, and supercritical fluid methods. They offer a promising approach to drug delivery by providing controlled release, enhanced bioavailability, and targeted delivery of therapeutic agents. Different applications of nanocapsules have been investigated for the delivery of a wide range of drugs, including anticancer agents, antibiotics, peptides, and proteins. Nanocapsules can modulate the release rate of drugs, extending their therapeutic effect and reducing side effects. Nanocapsules can improve the solubility and permeability of poorly soluble drugs, facilitating their absorption and distribution within the body. They have shown promise in treating various diseases, such as cancer, cardiovascular diseases, and infectious diseases. Overall, nanocapsules represent a promising technology for drug delivery with the potential to revolutionize the treatment of various diseases.

Keywords: Nanocapsule, encapsulated, polymeric membrane, salting out

Introduction:

A nanocapsule is defined as a hard polymeric membrane that retains the drug within the reservoir or the cavity. Nanocapsules are polymeric nanoparticles with a polymeric wall made up of non- ionic surfactants, macromolecules, phospholipids, and an oil core. Nanocapsules can be distinguished from other nanoparticles because they have well-defined cores and shells, whereas the latter do not. When it is made from polymers, Nanocapsules can be referred to as hollow Polymer nanostructures.

Nanocapsules range in size from 10 nm to 1000 nm and are available in a variety of sizes. They are popular, because of the protective coating, which is usually pyrophoric and easily oxidized and delays the release of active ingredients.

Nanocapsules have many uses, including promising medical applications for drug delivery, food enhancement, Nutraceuticals, and self-healing Materials. The benefits of encapsulation methods are for the protection of these substances in the adverse environment, for controlled release, and for precision targeting. (4)

Structure:

The nanocapsule structure consists of a nano vesicular system that is formed in a Core-shell arrangement. The shell of a typical nanocapsule is made up of a polymeric membrane or coating (5). Nanocapsules are similar to a vesicular system that contains the drug inside its cavity and consists of a liquid core or polymer matrix surrounded by a polymeric membrane. The cavity encloses the active substances in the form of liquid or solid as a molecular dispersion.

The type of polymer used is biodegradable polyester. Poly-caprolactone (PCL), poly(lactide) (PLA), and poly(lactide-co-glicolide) (PLGA) are typical polymers used in nanocapsule formation (6). Naturally Occurring polymers such as chitosan, Gelatin, sodium alginate, and albumin are Used in some drug-delivering nanocapsules (7). Other Nanocapsule Shells include liposomes, along with Polysaccharides and saccharides (8).

The core of a nanocapsule is composed of an oil surfactant that is specifically selected to coordinate with the selected drug within the polymeric membrane (9).

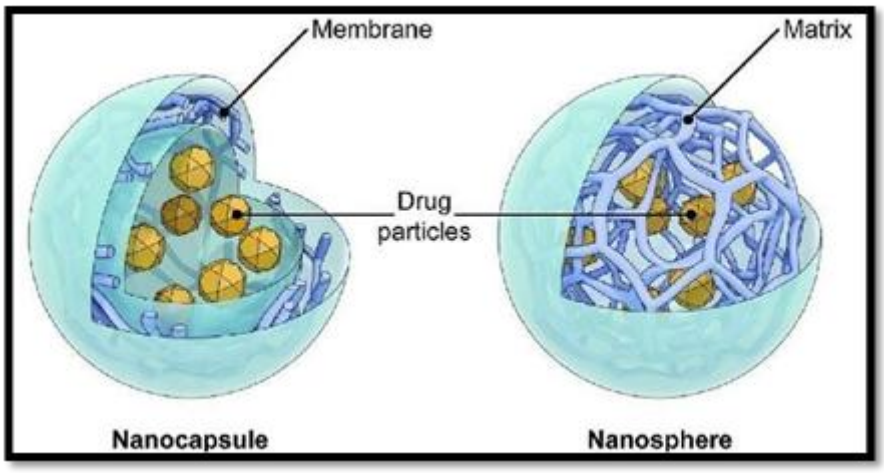

Fig.1 Structure of Nanocapsule

Method of Preparations:

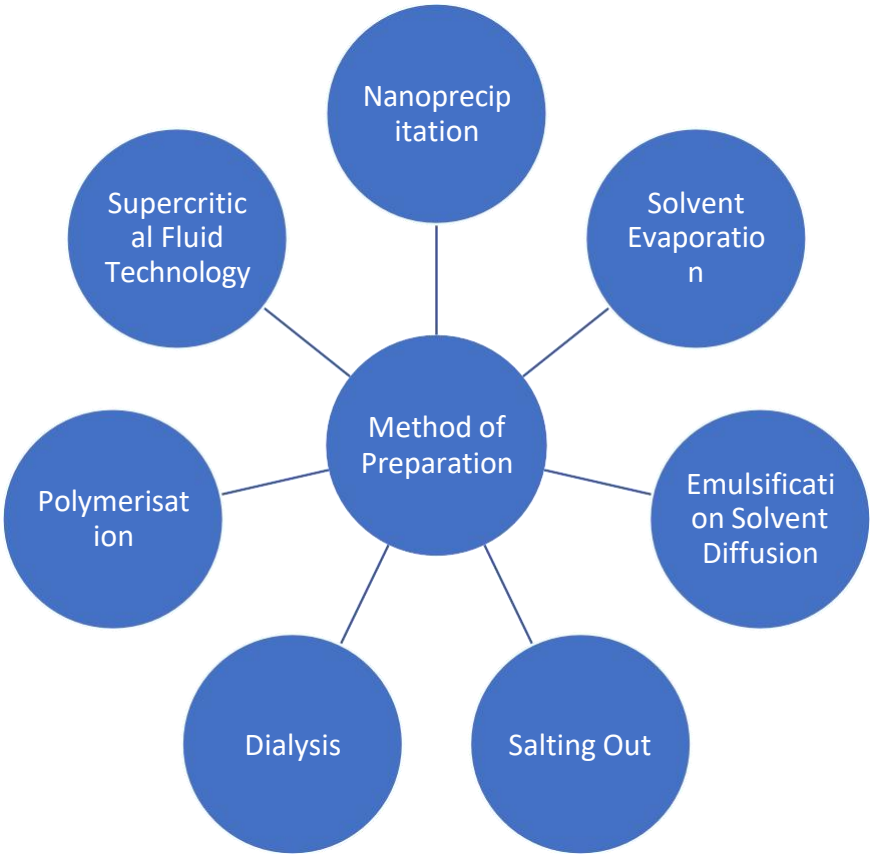

Fig. 2 Method of preparation

1. **Nanoprecipitation method:**

Nano-precipitation is a facile, mild, and low-energy input process to carry out polymeric nanoparticle synthesis (10).

The nanoprecipitation method is also called solvent displacement or interfacial displacement. From poly-ε-caprolactone, filled with liquid triglyceride oil (11). Ethyl acetate serves as a hydrophobic solvent with some solubility in water.

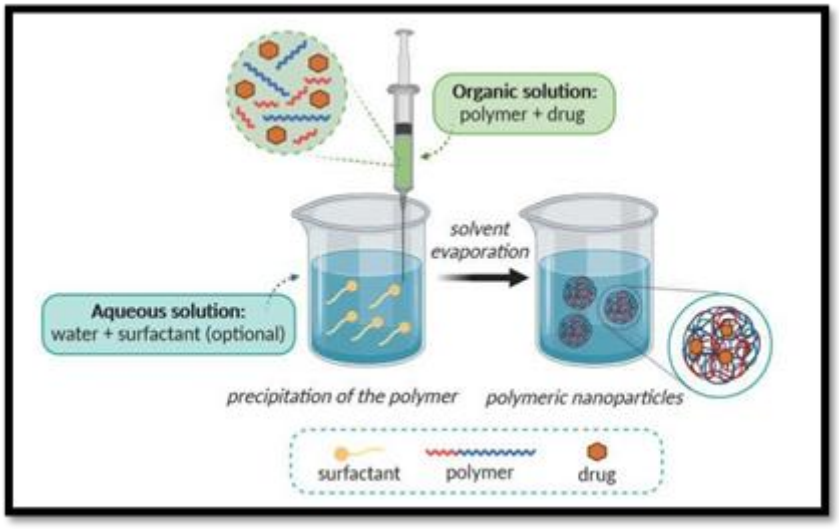

Fig.3 Precipitation Method

2. **Solvent- evaporation method:**

In this method, emulsion is converted into nanocapsules. The solvent evaporation method includes the dissolution of the polymer in a volatile organic solvent followed by the dispersion of the drug in the organic solvent (polymer-containing solution). To carry out this technique there are two methods i.e.

Single emulsions e.g., oil-in-water (o/w) and double emulsions (12). For example, w/o)/w and (water-in-oil)-in-water. These kinds of procedures use ultrasonication or high-speed homogenization, and then the solvent evaporates (13)(14).

3. **Emulsification solvent diffusion:**

In this method, an organic phase was injected into a chitosan solution containing a stabilizing agent under high shearing force, followed by a homogenization process under high pressure (15)(16).

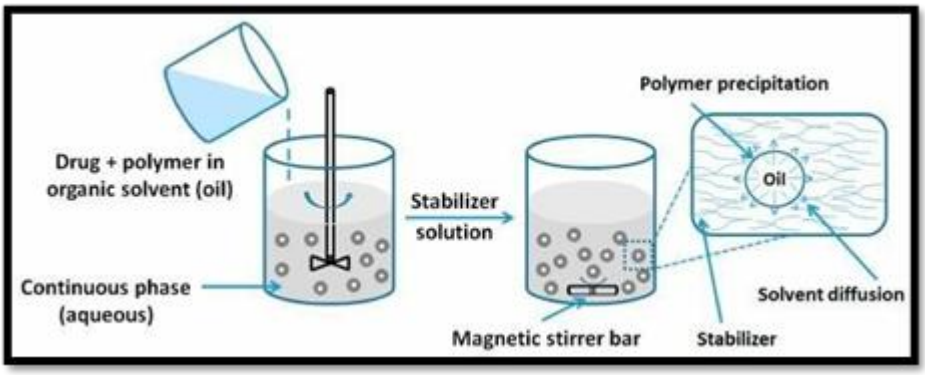

Fig. 4 Emulsification Solvent Diffusion

4. **Salting out method:**

By using the salting out process, the water-miscible solvent is extracted from an aqueous solution, modifying the emulsification solvent diffusion technique. Calcium chloride, magnesium acetate, and magnesium chloride are examples of electrolytes; sucrose is an example of a nonelectrolyte (17).

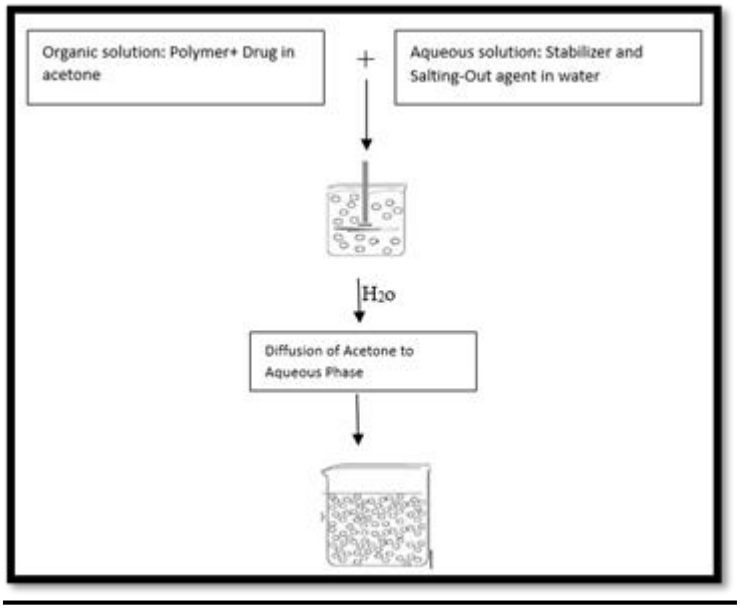

Fig. 5 Salting Out Method

5. Dialysis method:

A quick and efficient way to prepare small, narrowly dispersed nanoparticles is through dialysis (18)(19). Filled into a dialysis bag or tube that serves as the donor compartment, the nanoparticles are distributed in a release medium. The released drug is allowed to diffuse from the donor to the acceptor compartment as a result of the concentration difference when the bag is agitated in a large volume of release medium, also known as the acceptor compartment (20).

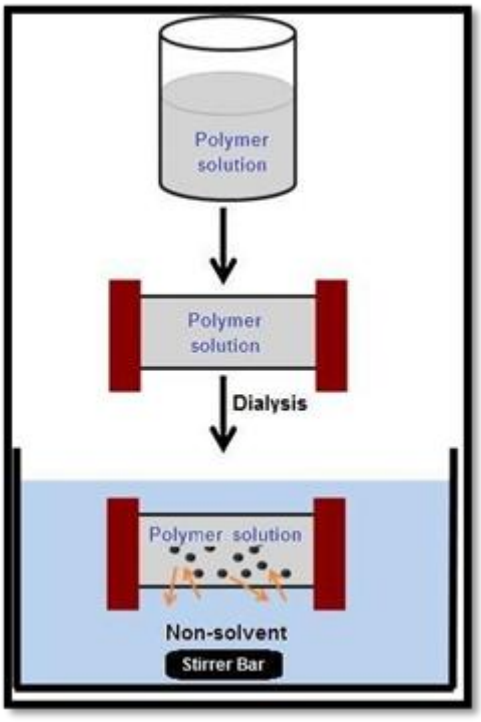

Fig. 6 Dialysis Method

6. Polymerization method:

It is the quickest technique for creating polymeric nanoparticles (21). The drug is subsequently added to the nanoparticles by either dissolving in the polymerization medium or by the nanoparticles adhering to the monomers in an aqueous solution through polymerization (22).

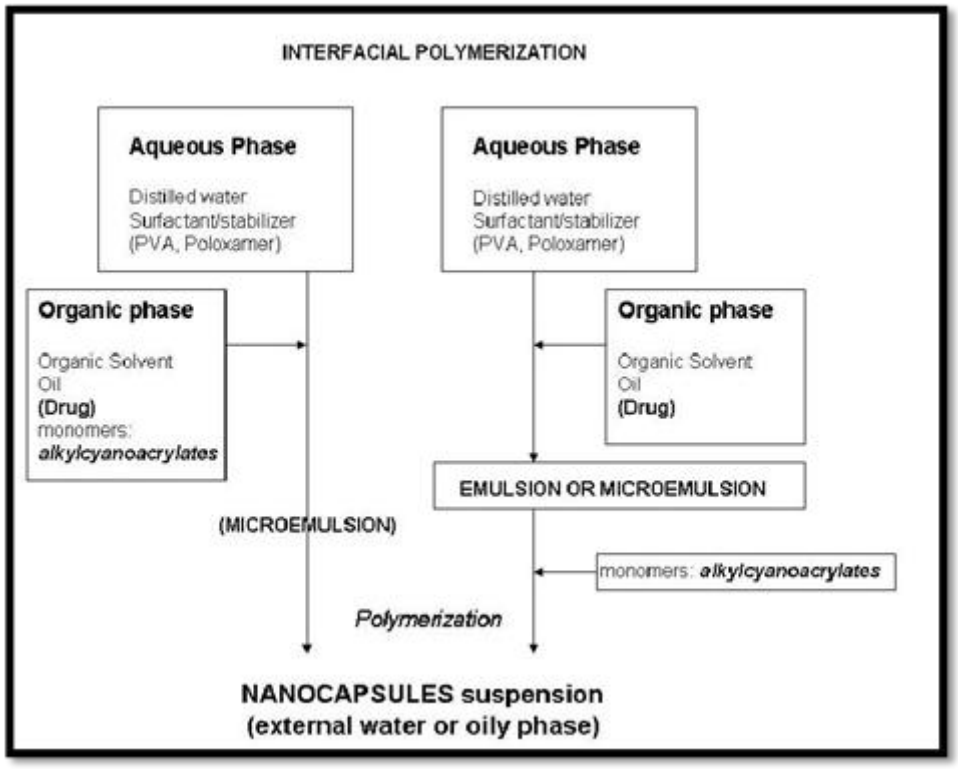

Fig. 7 Polymerisation Method

7. **Supercritical fluid technology:**

Solvents at temperatures above their critical temperature, where the single phase remains constant regardless of pressure, are referred to as supercritical fluids (23). Most commonly, supercritical CO2 is utilized as a supercritical fluid (24). While this method is most costly, it is more cost-effective and suitable for large-scale production.

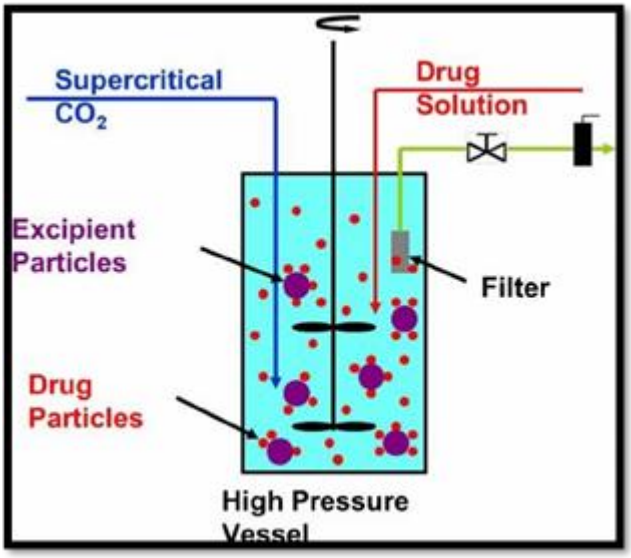

Fig. 8 Supercritical Fluid Method

Characterisation:

1. Dispersion pH
2. Determination of drug content
3. Shell thickness

4. In vitro drug release
5. Size, shape, and surface morphology

1. Dispersion pH:

Formulation of Nanocapsules At room temperature, the pH is measured using a digital pH meter. 3.0-7.5 is the pH range for the dispersion of nanocapsules.

2. Determination of drug content:

By dissolving 1 ml of the prepared nanocapsules in 20 ml of acetonitrile, the drug content was ascertained. The UV Spectrophotometer was then used to measure the appropriate amount of sample at 232 nm. Every sample's absorbance was calculated and contrasted with the reference.

3. Shell thickness:

A constant pressure of 2000 bar was used to create cryo-TEM and TEM nanocapsules through naturally occurring induced phase separation in a nanoconnement, where the polymer concentration was changed from 0.5 to 1.5% wt/v, respectively (26)(27).

4. Invitro drug release:

The USP type 11 dissolving apparatus was used to conduct in vitro dissolution tests. The study was carried out in 100 ml of buffer (PH 3.0). The nanocapsules suspension was placed in a dialysis membrane and dipped in a dissolution medium which was kept inert thermostatically at 37±0.50C. The stirring rate was maintained at 100 rpm. At predetermined time intervals, 5ml of the sample were withdrawn and assessed for drug release spectrophotometrically. After each withdrawal 5 ml of fresh dissolution medium was added to the dissolution jar.

5. Size, shape, and surface morphology:

Using transmission electron microscopy (TEM), different characteristics such as size, shape, and surface morphology can be ascertained. A Phillips Cm 200 operating at 20–200 kv was used to take micrographs of the nanocapsules, and a Hitachi S-4800 FE-SEM fitted with an energy dispersion spectrometer (EDS) was used for the Fe-SEM analysis. Charge on the surface of a nanocapsule can be effectively characterized using its zeta potential (25).

The Uses of Nanocapsules as Smart Drugs:

- Higher dose loading with smaller dose volumes
- Longer site-specific dose retention
- More rapid absorption of active drug substances
- Increased bioavailability of the drug
- Higher safety and efficacy
- Improved patient compliance

Future Nanocapsule Bandages to Fight Infection:

If the skin becomes infected, conventional dressings must be removed, which can be distressing for the child and slow down healing. Treatment will go more quickly with this advanced dressing because it releases antibiotics automatically only when the wound gets infected. This means that there will be no need to remove the dressing, which increases the likelihood that the wound will heal without leaving scars. The color shift serves as an early warning system for the presence of infection, allowing us to treat it much more quickly and lessen the child's trauma and hospital stay.

This bandage made of nanocapsules may also be utilized by the military in combat and for other wounds like ulcers. When disease-causing pathogenic bacteria are present, the medical dressing will release antibiotics from Nanocapsules, aiming to treat the infection before it worsens. When the antibiotics are released, the advanced wound dressing will also change colour, alerting medical professionals to the presence of an infection. Only bacteria capable of causing disease will cause this bandage to activate. The dressing will become coloured as a result of the toxins it releases cracking open the antibiotic-containing capsules. In this manner, the risk of the emergence of antibiotic-resistant bacteria, like MRSA (Methicillin-resistant Staphylococcus aureus), is decreased because the antibiotics will only be released when necessary.

Application of nanocapsules in different systems:

Application	Drugs	Mode of preparation
Agrochemicals	Abomectin nanocapsules pyrethrum	Emulsion polymerization, microemulsion

	nanocapsules	polymerization
Diabetes	Isobutylcynoacrylate nanocapsules	Interfacial polymerization
Cosmetic	Epsilon caprolactone nanocapsule	Emulsion diffusion method
Antiseptic	Indomethacin nanocapsules	Interfacial polymerization
Anti-inflammatory	Diclofenac sodium	Sol gel method

To improve the stability and the storage conditions of nanoparticulate systems:

Freezing is widely used. Current examples that illustrate this preservation mode are mRNA-lipid nanoparticle COVID-19 vaccines of which the storage temperature is very low. This particular case did not constitute an obstacle to its marketing given the global health context, but articles in the literature are currently looking to understand the mechanisms of instability of these nanoparticles to propose the most suitable drying process.

Conclusion:

Nanocapsules are highly recommended to be applied as carriers for active substances in various diseases. Thanks to their use, the release rate of active ingredients can be controlled. Nanocapsules can improve the stability of drug/active compound that is of particular interest for UV filters, vitamins, and their derivatives. Polymeric nanocapsules synthesized through solvent evaporation, emulsion polymerization, and surfactant-free emulsion polymerization have also been widely introduced. They are also capable of being released as monodisperse particles with well-defined biological, electrical, optical, and magnetic properties. Nanomaterials have a wide range of applications in the fields of biochemistry, pharmaceuticals, electronics, and molecular diagnostics. They offer a wide range of uses and good reproducibility due to their micronized size, and they can be used in life science applications. Nanocapsules are useful in a variety of fields, including agrochemicals, cosmetics, genetic engineering, wastewater treatment, and cleaning goods. Enzymes, organic or inorganic catalysts, oil nanoparticles, adhesives, surface polymers, and even biological organisms can all be encapsulated with them. Nanocapsules have the potential to be employed as a good medicine.

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