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# A Review On: Recent Advantages Of Microencapsulation

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**Abstract:**

Microencapsulation has become a very effective and adaptable method for delivering, regulating, and safeguarding active pharmaceutical ingredients, nutraceuticals, and other bioactive substances. The stability, bioavailability, and targeted distribution of medications and delicate materials have been greatly improved by recent developments in microencapsulation methods. Its uses in pharmaceuticals, food, cosmetics, and agriculture have grown thanks to the creation of new polymers, biodegradable carriers, and cutting-edge coating methods like coacervation, spray drying, fluidized bed coating, and electrospinning. These contemporary methods provide flavor masking, regulated and prolonged release, protection from environmental deterioration, and fewer adverse effects. Additionally, smart microcapsules that react to physiological stimuli like pH, temperature, or enzymes are emphasized in recent trends as a means of delivering drugs precisely. In general, the latest developments in microencapsulation have transformed formulation design, guaranteeing increased industrial scalability, patient compliance, and medicinal efficacy.

**Keywords:** Microencapsulation, PLGA, chitosan, spray-drying, emulsion-solvent evaporation, coacervation, electrospray, microspheres , Recent developments include smart capsules, biodegradable polymers, controlled release, and medication delivery.

## 1. Introduction

Microencapsulation protects drugs from degradation, masks taste, enables controlled release, and can target delivery to specific tissues. In implantable systems, microencapsulated formulations (e.g., PLGA microspheres) allow prolonged, local or systemic delivery following a single administration. For mucosal delivery, micro/nanoparticles can enhance mucoadhesion, permeation, and antigen uptake for vaccines or biologics.

Microencapsulation is a contemporary industrial and pharmaceutical process that creates microcapsules—tiny particles—by encasing active ingredients in a protective shell or coating. These microcapsules typically include a core material (the active component) encased in a wall material (the coating) and range in size from 1 to 1000 micrometers. Controlling the release of the core material, improving its stability,

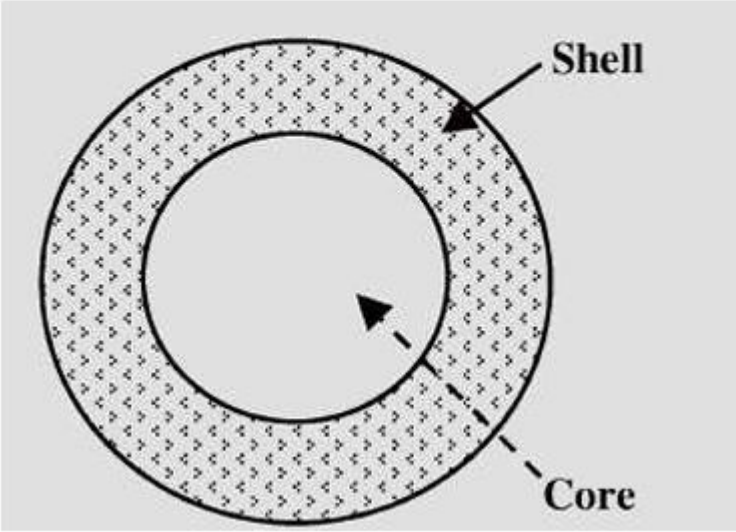
masking an undesirable taste or odor, and shielding delicate chemicals from environmental deterioration like light, heat, or oxygen are the primary goals of microencapsulation.

Because microencapsulation can deliver medications in a regulated, sustained, or targeted manner, it has become increasingly important in the pharmaceutical industry in recent years. By ensuring that the medication reaches the intended site of action at the appropriate timing and concentration, it enhances therapeutic efficacy and lessens adverse effects. Microcapsules are frequently made using a variety of methods, including fluidized bed coating, coacervation, solvent evaporation, spray drying, and interfacial polymerization. The physicochemical characteristics of the medication and the intended release profile influence the procedure choice.

**1.MICROENCAPSULATION :**

Micro-encapsulation is a process in which tiny particles or droplets are surrounded by a coating to give small capsules. In a relatively simplistic form, a microcapsule is a small sphere with a uniform wall around it. The material inside the microcapsule is referred to as the core, internal phase, or fill, whereas the wall is sometimes called a shell, coating, or membrane. Most microcapsules have diameters between a few micrometers and a few millimeters. The definition has been expanded, and includes more foods. Every class of food ingredient has been encapsulated; flavors are the most common. The technique of microencapsulation depends on the physical and chemical properties of the material to be encapsulated.1 These microcapsules have a number of benefits such as converting liquids to solids, separating reactive compounds, providing environmental protection, improved material handling properties. Active materials are then encapsulated in micronsized capsules of barrier polymers (gelatin, plastic, wax ...).2 Many microcapsules however bear little resemblance to these simple spheres. The core may be a crystal, a jagged adsorbent particle, an emulsion, a suspension of solids, or a suspension smaller microcapsules. The microcapsule even may have multiple walls.

**Figure No.1**
***Microcapsule with core and coat***




**MATERIALS INVOLVED IN MICROENCAPSULATION:**

Microencapsulation is the process by which individual particles or droplets of solid or liquid material (the core) are surrounded or coated with a continuous film of polymeric material (the shell) to produce capsules in the micrometer to millimeter range, known as microcapsules.

**Core Material:**

The material to be coated It may be liquid or solid Liquid core may be dissolved or dispersed material Composition of coating material: Drug or active constituent Additive like diluents Stabilizers Release rate enhancers

**Coating Material :**

Inert substance which coats on core with desired thickness Compatible with the core material Stabilization of core material. Inert toward active ingredients. Controlled release under specific conditions. The coating can be flexible, brittle, hard, thin etc. Abundantly and cheaply available Composition of coating

**3. Materials used for microencapsulation**

- **Biodegradable polyesters:** PLGA, PLA — widely used for implantable microspheres due to predictable degradation and regulatory acceptance.
- **Natural polymers:** chitosan, alginate, gelatin — valued for mucoadhesive and biocompatible properties (important in mucosal formulations).
- **Synthetic hydrophilic polymers and PEG derivatives:** for stealth and controlled swelling.
- **Lipid-based carriers:** liposomes, solid lipid microparticles — for lipophilic drug encapsulation.

**4. MORPHOLOGY OF MICROCAPSULES:**

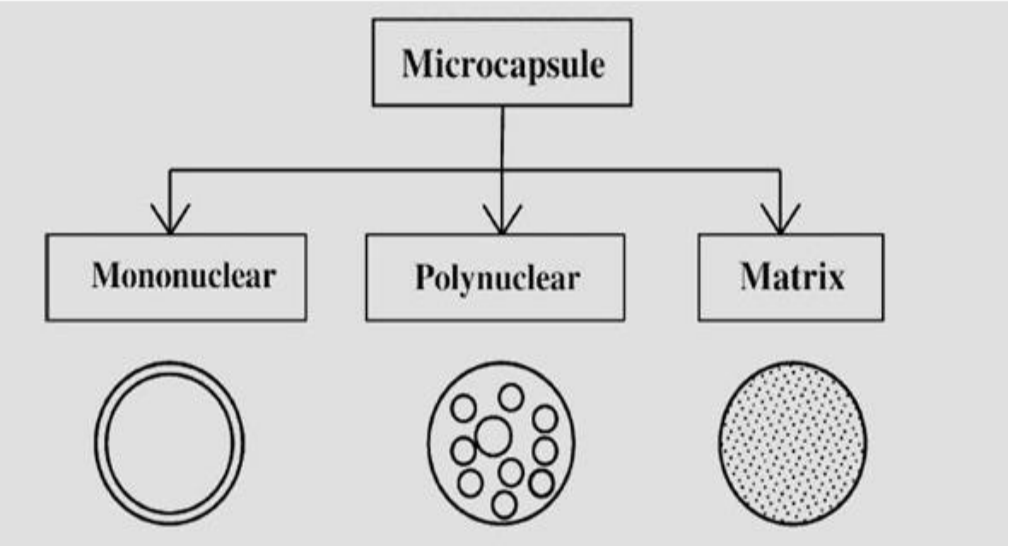
The morphology of microcapsules depends mainly on the core material and the deposition process of the shell.

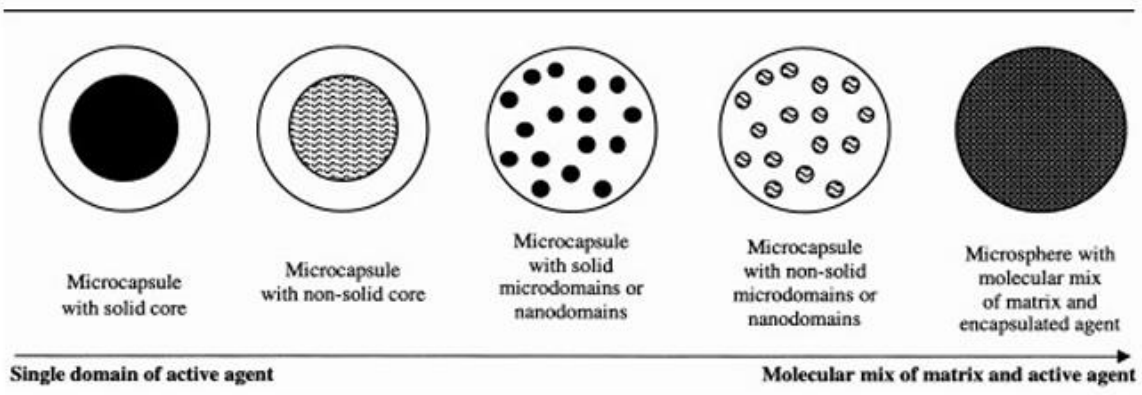
1.Mononuclear (coreshell) microcapsules contain the shell around the core.

2.Polynuclear capsules have many cores enclosed within the shell.

3Matrix encapsulation in which the core material is distributed homogeneously into the shell material. In addition to these three basic morphologies, microcapsules can also be mononuclear with multiple shells, or they may form clusters of microcapsules.

*Morphology of Microcapsules*






## 5.TYPES OF MICROSPHERES

**1.Bioadhesive microspheres:** Adhesion can be defined as the bond produced by contact between a pressure-sensitive adhesive and a surface.The American society of testing and materials has defined it as the state in which two surfaces are held together by interfacial forces, which may consist of valance forces, interlocking action or both. Bioadhesion is defined as an ability of a material to adhere to a biological tissue such as buccal, ocular, rectal, and nasal for an extended period of time. Adhesion of bioadhesive drug delivery devices to the biological tissue gives an intimate and prolonged contact at the site of administration. This prolonged contact time can result in increased absorption and controlled release of drug.

**2.Magnetic microspheres:** Magnetic microspheres are supramolecular particles that are small enough to circulate through capillaries without producing embolic occlusion

**3.Synthetic polymeric microspheres:** Synthetic polymeric microspheres are widely used in clinical applications mainly as fillers, bulking agent, drug delivery vehicles, embolic particles etc. and proved to be safe and biocompatible. The main disadvantage of these kinds of microspheres is the tendency to migrate away from injection sites leading to potential risk, like in embolism (obstruction of an artery, typically by a clot of blood) and further organ damage.

**4.Biodegradable polymeric microspheres:** Biodegradable polymers degrade within the body as a result of natural biological processes; avoiding the need to remove a drug delivery system after release of the active agent. Biodegradable polymers increases the residence time when in contact with mucous membrane due to its high degree of swelling property with aqueous medium, resulting in gel formation. The rate and extent of drug release is controlled by concentration of polymer and the release pattern in a sustained manner

**Mechanism and kinetics of drug release** :

**Diffusion :**Diffusion is the most commonly involved mechanism wherein the dissolution fluid penetrates the shell, dissolves the core and leak 69 M.N. Singh et al. / RPS 2010; 5(2): 65-77 out through the interstitial channels or pores. Thus, the overall release depends on, (a) the rate at which dissolution fluid penetrates the wall of microcapsules, (b) the rate at which drug dissolves in the dissolution fluid, and (c) the rate at which the dissolved drug leak out and disperse from the surface (3,4,16). The kinetics of such drug release obeys Higuchi's equation as below (4,5,8,50,51): $Q = [D/J (2A – \varepsilon CS ) CS t]^{½}$ Where, Q is the amount of drug released per unit area of exposed surface in time t; D is the diffusion coefficient of the solute in the solution; A is the total amount of drug per unit volume; CS is the solubility of drug in perme ating dissolution fluid; ε is the porosity of the wall of microcapsule; J is the tortuosity of the capillary system in the wall. The above equation can be simplified to $Q = vt$ where, v is the apparent release rate.

**Dissolution :** Dissolution rate of polymer coat determines the release rate of drug from the microcapsule when the coat is soluble in the dissolution fluid. Thickness of coat and its solubility in the dissolution fluid influence the release rate (5,6,52).

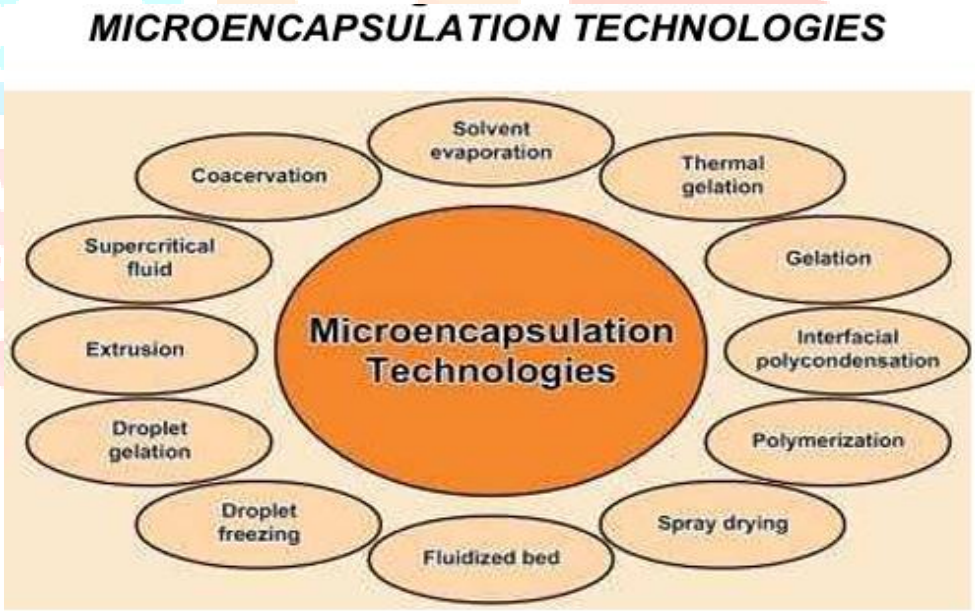
**Osmosis :** The polymer coat of microcapsule acts as semi permeable membrane and allows the creation of an osmotic pressure difference between the inside and the outside of the microcapsule and drives drug solution out of the microcapsule through small pores in the coat (7,53).

**Erosion :** Erosion of coat due to pH and/or enzymatic hydrolysis causes drug release with certain coat materials like glyceryl monostearate, bee's wax and stearyl alcohol . Attempts to model drug release from microcapsules have become complicated due to great diversity in physical forms of microcapsules with regard to size, shape and arrangement of the core and coat materials . The physiochemical properties of core materials such as solubility, diffusibility and partition coefficient, and of coating materials such as variable thickness, porosity, and inertness also makes modeling of drug release difficult. the following generalizations can be made:

1. Drug release rate from microcapsules conforming to reservoir type is of zero order.

2. Microcapsules of monolithic type and containing dissolved drug have release rates that are t 1/2 dependant for the first half of the total drug release and thereafter decline exponentially.

## 6. Microencapsulation techniques



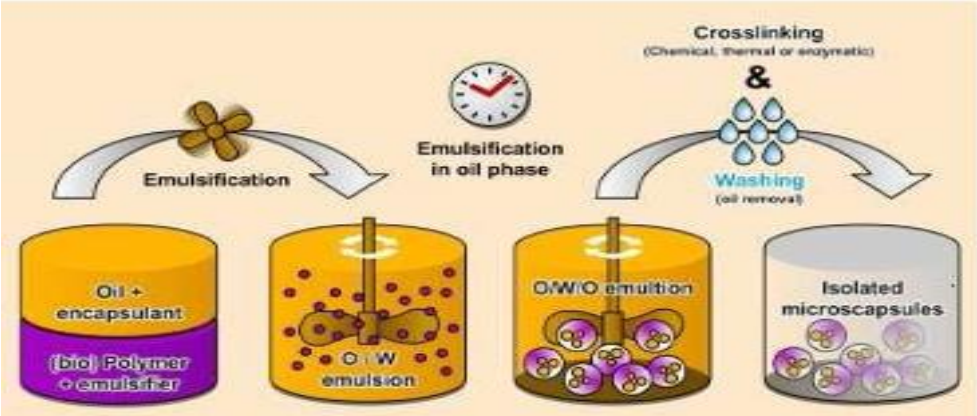

### 1 Emulsion–solvent evaporation/extraction

controllable In this technique the drug is dissolved in polymer which was previously dissolved in chloroform and the resulting solution is added to aqueous phase containing 0 .2 % sodium of PVP as emulsifying agent. The above mixture was agitated at 500 rpm then the drug and polymer (eudragit) was transformed into fine droplet which solidified into rigid microspheres by solvent evaporation

### 2.Microspheres by Double Emulsion Technique

In this method drug was dissolved in aqueous gelatine solution which was previously heated for 1 hr at 40 0C. The solution was added drop wise to liquid paraffin while stirring the mixture at 1500 rpm for 10 min at 35 oC, results in w/o emulsion then further stirring is done for 10 min at 150C .Examples for this technique is Gelatin A microspheres.

**Fig. Microspheres by double emulsion technique**

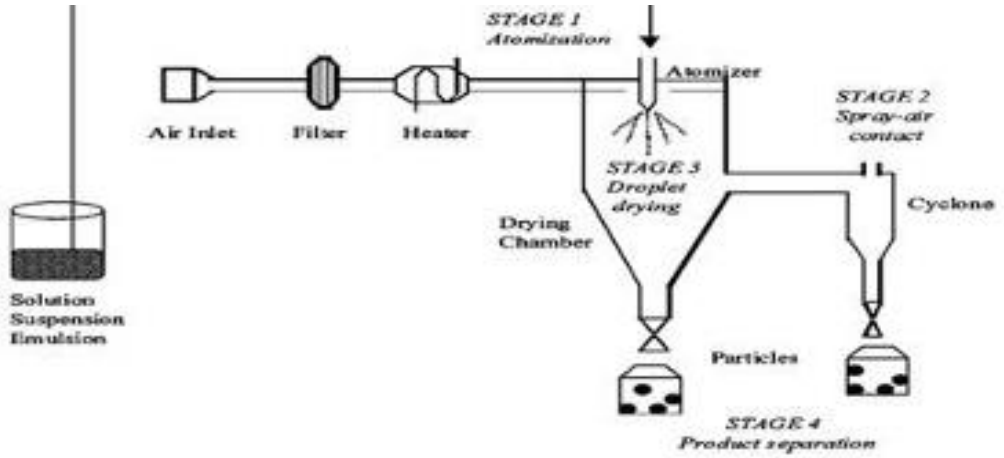



### 3.Coacervation Method:

Co-acervation thermal change Performed by weighed amount of ethyl cellulose was dissolved in cyclohexane with vigorous stirring at 800C by heating. Then the drug was finely pulverised and added with vigorous stirring on the above solution and phase separation was done by reducing temperature and using ice bath. Then above product was washed twicely with cyclohexane and air dried then passed through sieve (sieve no. 40) to obtain individual microcapsule25. Co acervation non solvent addition: Developed by weighed amount of ethyl cellulose was dissolved in toluene containing propylisobutylene in closed beaker with magnetic stirring for 6 hr at 500 rpm and the drug is dispersed in it and stirring is continued for 15 mins. Then phase separation is done by petroleum benzoin 5 times with continuous stirring.1After that the microcapsules were washed with n-hexane and air dried for 2 hr and then in oven at 50oC for 4 hr25.

**4. Spray Drying Technique:** This was used to prepare polymeric blended microsphere loaded with ketoprofen drug. It involves dispersing the core material into liquefied coating material and then spraying the mixture in the environment for solidification of coating followed by rapid evaporation of solvent29. Organic solution of poly (epsilon-caprolactone) (PCL) and cellulose acetate butyrate (CAB), in different weight ratios and ketoprofen were prepared and sprayed in different experimental condition achieving drug loaded microspheres. This is rapid but may loose crystalinity due to fast drying process29. Emulsion-Solvent Diffusion Technique: In order to improve the residence time in colon floating microperticles of ketoprofen were prepared using emulsion

**Fig. microspheres by spray drying technique**



**5. solvent diffusion technique :**The drug polymer mixture was dissolved in a mixture of ethanol and dichloromethane (1:1) and then the mixture was added dropwise to sodium lauryl sulphate (SLS) solution. The solution was stirred with propeller type agitator at room temperature at 150 rpm for 1 hr. Thus the formed floating microspheres were washed and dried in a dessicator at room temperature.

**Advantages of Microencapsulation**

1. **Controlled drug release:**
    - Allows sustained or targeted release of drugs over a prolonged period.
    - Reduces dosing frequency and improves patient compliance.
2. **Protection of core material:**
    - Shields sensitive substances (e.g., vitamins, enzymes, probiotics) from light, heat, moisture, or oxidation.
3. **Masking taste and odor:**
    - Unpleasant tastes or odors (like bitter drugs) can be masked, improving palatability.
4. **Improved stability:**
    - Increases the shelf-life of volatile or unstable compounds.
5. **Targeted delivery:**
    - Enables site-specific delivery (e.g., colon, mucosa, or implants), minimizing side effects.
6. **Reduction of toxicity and irritation:**
    - Prevents direct contact of the active ingredient with biological tissues until release is desired.
7. **Ease of handling and processing:**
    - Converts liquids or gases into free-flowing powders for easier formulation.
8. **Enhanced bioavailability:**
    - Controlled release can improve the absorption and therapeutic efficiency of poorly soluble drugs.
9. **Compatibility in combination products:**
    - Incompatible ingredients can be separated in different microcapsules within the same formulation.
10. **Industrial applications:**
    - Useful in pharmaceuticals, food, agriculture, and cosmetics for encapsulating flavors, nutrients, or pesticides.

**Disadvantages of Microencapsulation**

1. **High production cost:**
    - Equipment, materials, and process control increase manufacturing expenses.
2. **Complex processing:**
    - Requires precise control of parameters (temperature, pH, stirring speed, etc.) for consistent capsule size and quality.
3. **Limited core loading capacity:**
    - Only a certain amount of active material can be encapsulated effectively.
4. **Difficult scale-up:**
    - Laboratory methods may not easily translate to industrial-scale production.
5. **Potential leakage of core material:**
    - Imperfect coating can lead to premature release or degradation.
6. **Stability issues during storage:**
    - Microcapsules may break, agglomerate, or lose efficiency under improper conditions.
7. **Toxicity or incompatibility of coating materials:**
    - Some polymers or solvents used may not be biocompatible or safe.
8. **Regulatory challenges:**
    - Requires extensive testing to ensure safety, stability, and efficacy for pharmaceutical use.

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