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ADVANCES IN MICROENCAPSULATION TECHNIQUES AND APPLICATION

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ABSTRACT

Microencapsulation is a process where tiny particles of a core substance are surrounded by a coating material to form small capsules. This technique is used to protect, control the release, or enhance the properties of the core substance, which can range from less than one micron to several hundred micron in size.

Microencapsulation is a versatile technology used to enclose active ingredients within a protective shell, controlling their release and improving their stability. This technique has numerous application in pharmaceutical, enabling, the development of innovative products with enhanced functionality.

KEYWORDS: *Microencapsulation, Core materials, Coating materials, Conservation, Microcapsule, Release mechanism, Application*

INTRODUCTION

Microencapsulation is an advanced technique used to enclose active ingredients, such as drugs, nutrients, flavors, or fragrances, within a protective shell or coating. This process enhances the stability, controlled release, and bioavailability of the encapsulated substances. This involves the use of various methods like coacervation, spray drying, solvent evaporation, or extrusion to create microscopic capsules, often on the scale of micrometers of nanometers.

The primary purpose of microencapsulation is to protect sensitive substance from environment factors such as heat, moisture, or light, which can degrade them. It also allows for the controlled release of the active ingredient over time, improving effecting and targeting specific areas in applications such as pharmaceutical, food, cosmetics, and agriculture. Additionally, microencapsulation helps mask unpleasant tastes or odors and can improve the handling of certain materials.

In recent advancement, the development of more sophisticated and biodegradable materials for the capsules, such as biopolymers and liposomes, has further enhanced the versatility and environment sustainability of microencapsulation techniques. The use of nanotechnology in microencapsulation is also expanding, allowing for better precision in the design of capsules for highly targeted delivery in medical and industrial applications. Microencapsulation includes a Bio encapsulation which is more restricted to the entrapment of a biologically active substance (DNA to entire cell or group of cells for example) generally to improve its performance & enhance is shelf life. [1, 2]

MATERIALS INVOLVED IN MICROENCAPSULATION: [3]

Microencapsulation involves enclosing active ingredients, such as drug, nutrients, or fragrances, in a protective matrix to control their release. Various materials are used for microencapsulation, depending on the application, desired release profile, and stability requirements. Here are some common materials used in microencapsulation

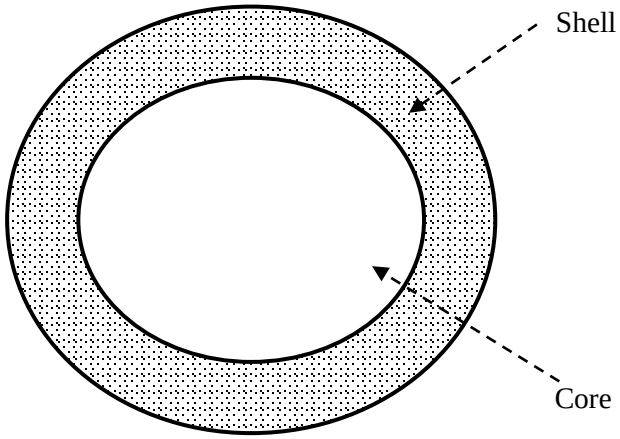


Fig. 1 Microcapsule With Core and Coat

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Natural Polymers

1. Cellulose: A plant-derives polymer used in food, pharmaceutical, and cosmetic applications.

2. Gelatin: A protein derives from animal collagen, commonly used in food, pharmaceutical, and cosmetic applications.

3. Alginate: A polysaccharide derived from brown seaweed, used in food, pharmaceutical, and biomedical applications.

4. Chitosan: A polysaccharide derived from crustacean shells, used in food, pharmaceutical and biomedical applications.

Synthetic Polymers:

1. Poly (lactic-co-glycolic acid) (PLGA): A biodegradable polymer used in pharmaceutical and biomedical applications.

2. Polyvinyl alcohol (PVA): A water-soluble polymer used in food, pharmaceutical, and cosmetic applications.

3. Polyethylene: A thermoplastic polymer used in food packaging and pharmaceutical applications.

Lipids

1. Waxes: Natural waxes, such as beeswax, carnuba wax, and candelilla wax, used in food, pharmaceutical, and cosmetic applications.

2.Fatty acids: Used in food, pharmaceutical, and cosmetic applications, and such as encapsulation of flavors and fragrance.

Other Materials

1. Silica: Used in food, pharmaceutical, and cosmetic applications, such as encapsulation of flavors and fragrances.

2. Starch: Used in food, pharmaceutical, and cosmetic applications, such as encapsulation of flavors and fragrances.

MORPHOLOGY OF MICROCAPSULES

The morphology of microcapsules depends mainly on the core material and the deposition process of the shell. It is classified into three basic categories as mononuclear, polynuclear, and matrix type as shown in Fig.2.

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

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

3. Matrix encapsulation in which the core material is distributed homogeneously into the shell material.

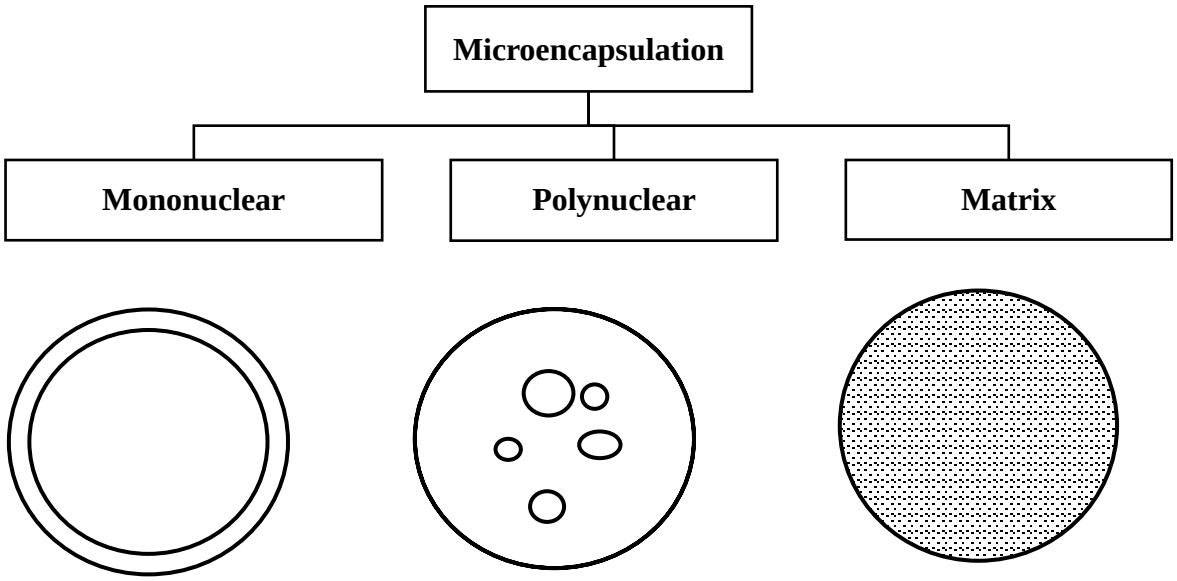
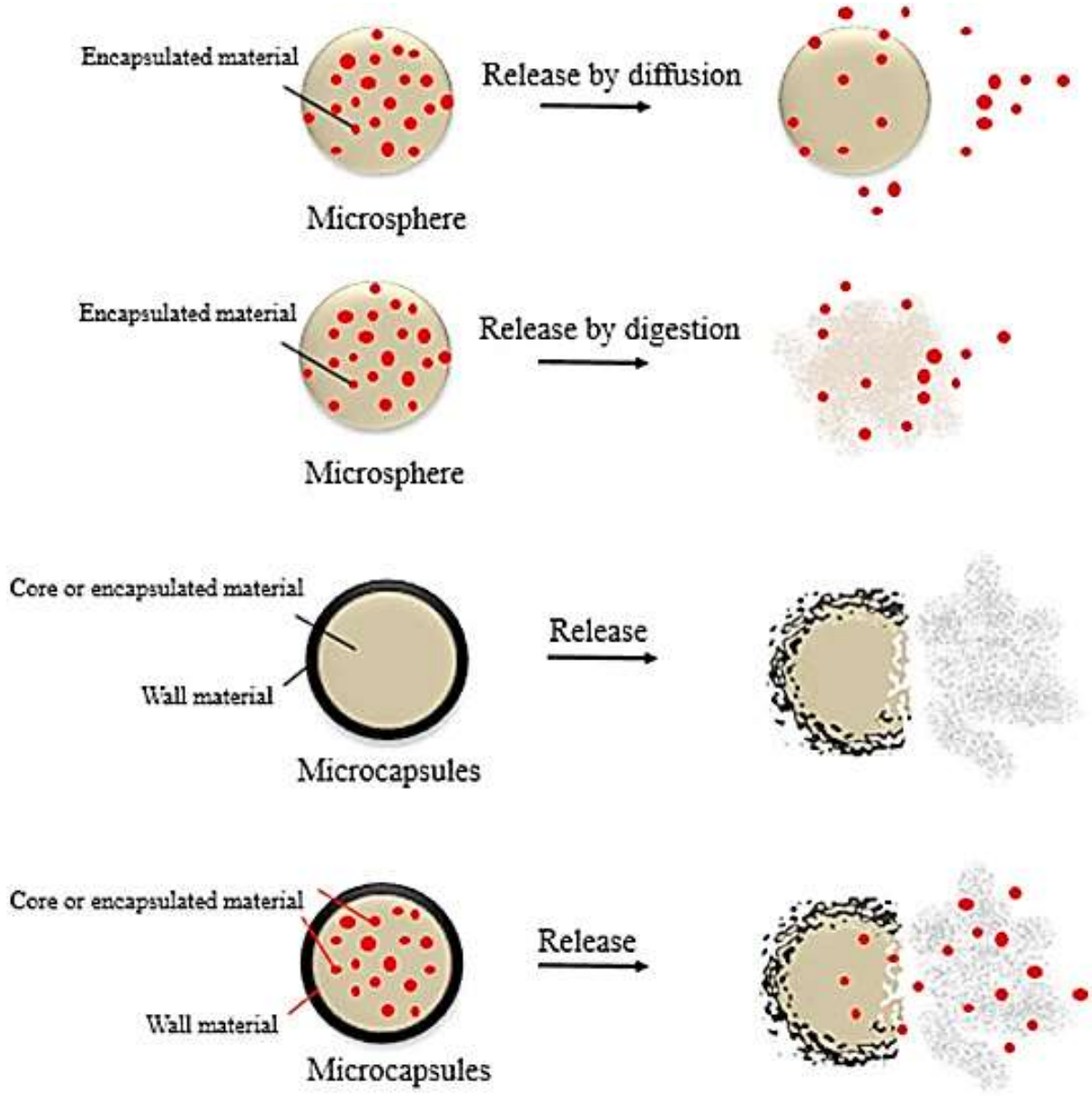


Fig. 2
Morphology of Microcapsules

However, the morphology of the internal structure of a microparticle depends largely on the selected shell materials and the microencapsulation method that are employed. In addition to these three basic morphologies, microcapsules can also be mononuclear with multiple shells, or they may form clusters of microcapsules.

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REASON FOR MICROENCAPSULATION AND RELEASE MECHANISM: [4] [5]



Mechanism of drug release in microencapsulation involves several steps: [6, 7]

Diffusion: Diffusion is the most commonly involved mechanism wherein the dissolution fluid penetrates the shell, dissolves the core and leak out through the interstitial channels 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.

(c) the rate at which the dissolved drug leak out and disperse from the surface.

Diffusion mechanism depend on Fick's Law and Concentration Gradient.

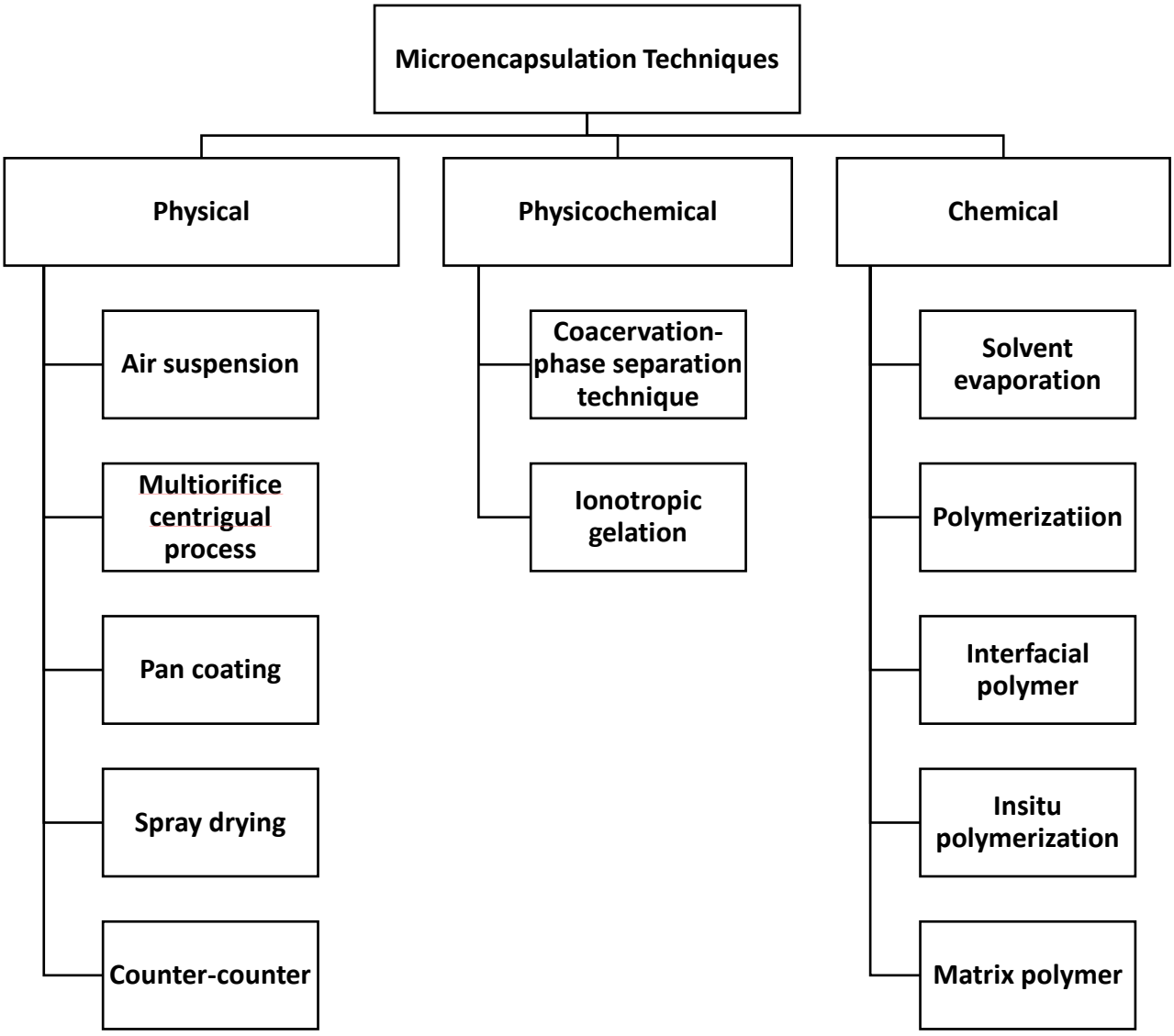
Dissolution: Dissolution rate of polymer coat determines the release rate of drug from the microcapsule when the coat is soluble in the dissolution fluid. Thickness of coat and its solubility in the dissolution fluid influence the release rate.

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.

Erosion: Erosion of coat due to PH and/or enzymatic hydrolysis cause drug release with certain coat materials like glyceryl monostearate, bee's wax and stearyl alcohol.

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TECHNIQUES OF MICROENCAPSULATION



The techniques of microencapsulation can be divided into three main categories.

1.Air Suspension Technique: [8, 9]

This method is invented by Professor **Dale. F. Wurster** & the name is given as the **Wurster air suspension apparatus.**

Basically the process consist of,

1. Dispersing of solid particle core materials in a supporting air steam.
2. The spray coating of the air suspended particles.

Mechanism of Action

1. Within the coating chamber, particles are suspended on an upward moving air stream.
2. During each pass through the coating zone, the core material receives in increment of coating material (polymer solution).
3. The cyclic process is repeated, depending on the purpose of microencapsulation, the coating thickness desired or whether the core material particles are thoroughly encapsulated.
4. The supporting air steam also serves to dry the product while it is being encapsulated.
5. Drying rated are directly related to the volume temperature of the supporting air steam.

The spray is in 3 forms.

- ✓ Top spray
- ✓ Bottom spray (Wuster Technology)
- ✓ Tangential spray

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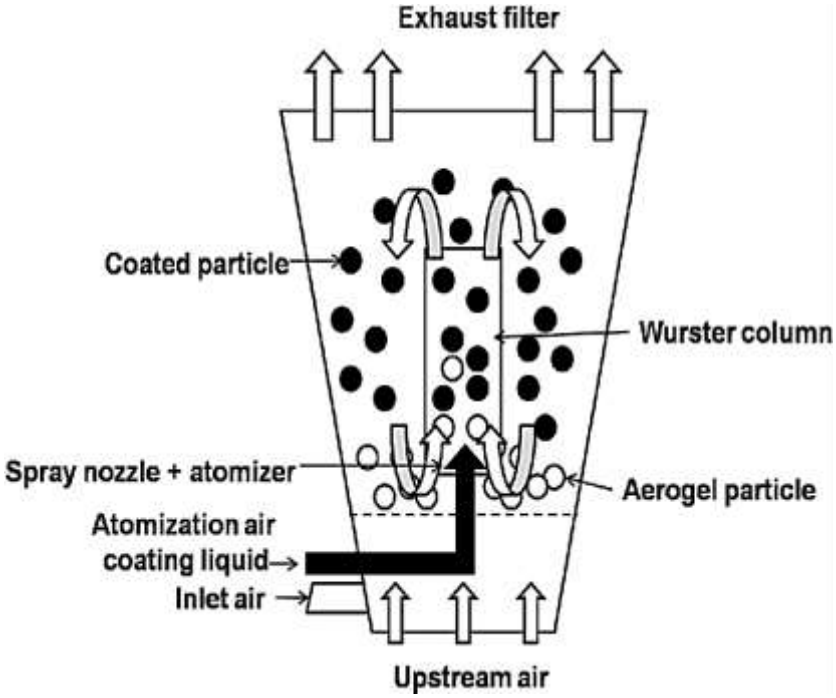


Fig. 3
Air Suspension

Advantages: The process has the capacity of applying coating in the form of solvent, solution, aq. Solutions, Emulsions, hot melt in equipment ranging in capacities from 1 to 990 pond. Applicable for both micro and macro encapsulation.

Disadvantages: This process is applicable to only encapsulation of solid core materials. Agglomeration of particles to some larger size is normally achieved. Heat sensitive drug/material not used.

2. Coacervation-phase separation Technique: [10, 11]

Microencapsulation by this method consist of 3 steps

i. Dispersion step
ii. Deposition step
iii. Solidification/ Rigidizing of coating material(phase separation)

Mechanism of Action

Step-1 Dispersion step:

Formulation of 3 immiscible phase

- Liquid manufacturing phase
- Core material phase
- Coating material phase

To form 3 phases, the core material is dispersed in a solution of coating polymer, the solvent for the polymer being liquid manufacturing vehicle phase.The coating material phase, an immiscible polymer in liquid state is formed by utilizing one of the methods of phase separation.

Step-2 Deposition

Deposition of liquid polymer coating solution upon core material due to adsorption upon core material.

Step-3 Solidification

Rigidizing the coating, usually by thermal, cross linking or desolvation techniques to form a self sustaining microcapsules. The microcapsules are usually collected by Filtration or Centrifugation. Then washed with suitable drying method such as spray drying which gives free flowing powder.

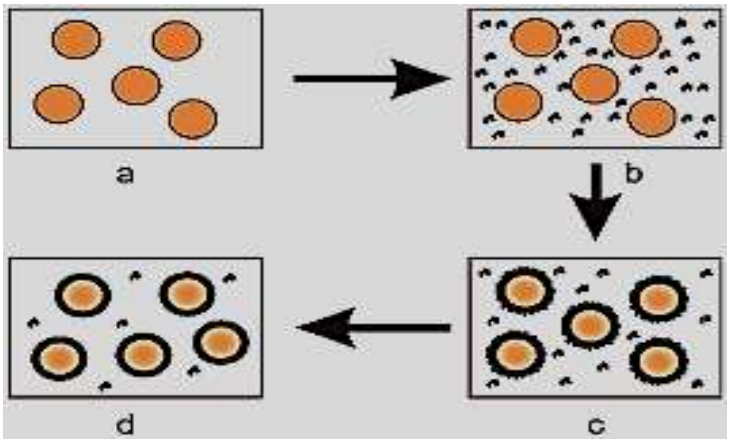


Fig. 4
Coacervation Phase Separation Technique

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3. Pan Coating

The relatively large particles, which are greater than 600 micron in size, microencapsulation can be done by pan coating method, which is being widely used in pharmaceutical industry for the preparation of controlled release particulate. [12]

In this method, various spherical core materials, such as nonpareil sugar seeds are coated with a variety of polymers.

In practice the coating is applied as a solution or as an atomized spray to the desired solid core material in the coating pan.

Generally warm air is passed over the coated material as the coating are being applied in the coating pans to remove the coating solvent.

In some cases, the process of final solvent removal is accomplished in the drying oven.

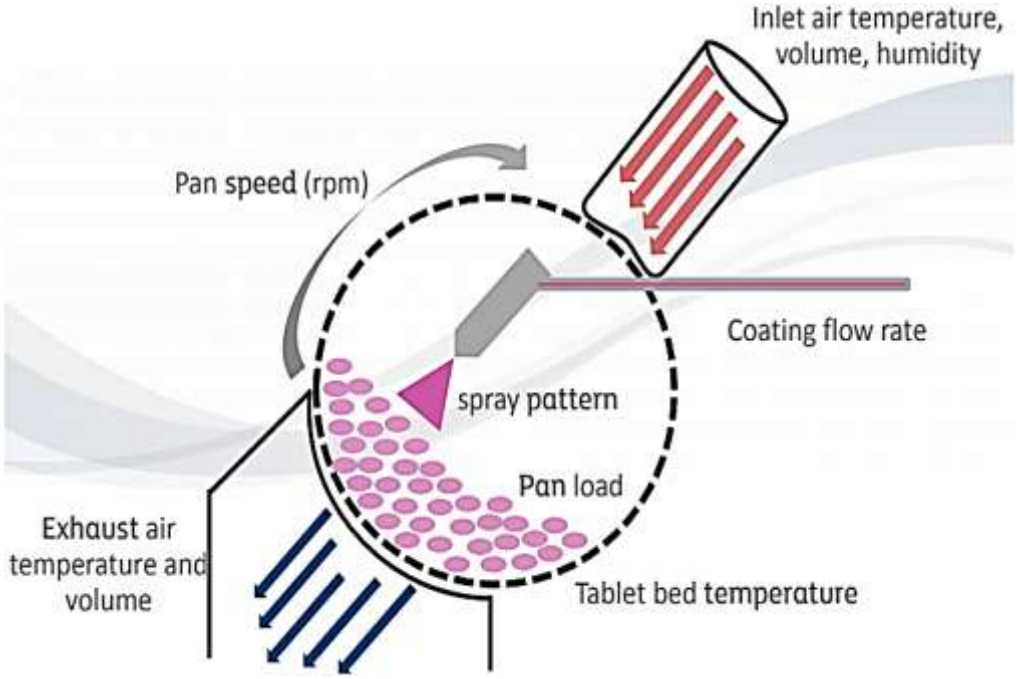


Fig. 5
Pan Coating

4. Spray Drying and Spray Congealing: [13, 14]

The microencapsulation techniques of spray drying and spray congealing are nearly identical. Both techniques include dispersing the core material in a liquefied coating agent and then spraying or introducing the core coating mixture in to an environment that influences the coating's comparatively quick solidification. The Procedures use to carry out the coating solidification are the primary distinction between these two microencapsulation techniques.

The rapid evaporation of a solvent in which the coating material dissolves affect the solidification of the coating in the spray drying procedures. The spray congealing method involves either thermally congealing molten coating material or injecting the coating core material mixture into a non-solvent to solidify a dissolved coating. [15]

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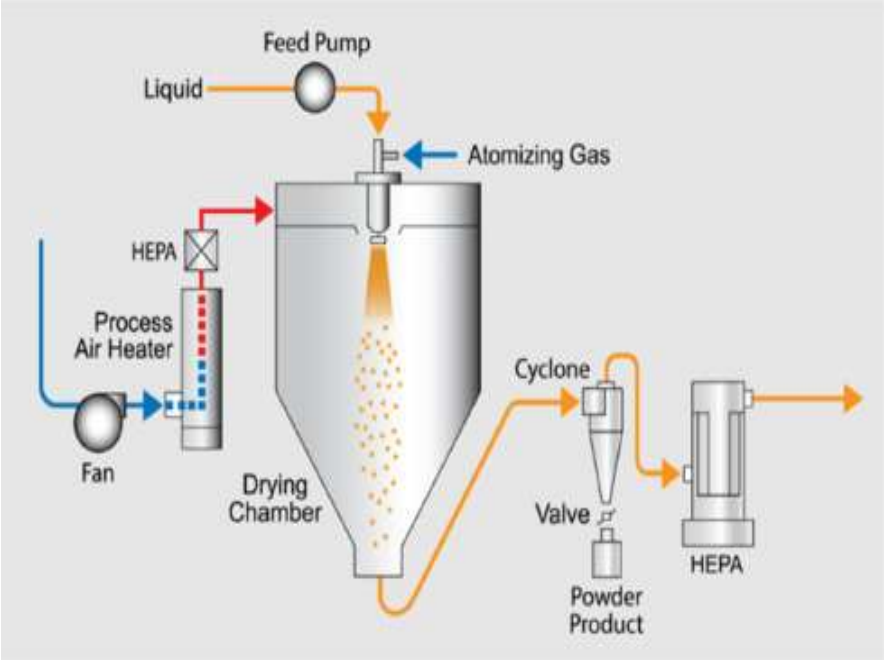


Fig. 6
Spray Drying

APPLICATIONS: [16]

- ✓ It can be used to formulate the various sustained controlled dosage forms by modifying or delaying release of encapsulated active agents or core materials.
- ✓ It can also be employed to formulate enteric coated dosage forms, so that the drugs will be selectively absorbed in the intestine rather than the stomach.
- ✓ Gastric irritant drugs are being microencapsulated to reduce the chances of gastric irritation.
- ✓ The taste of bitter drug candidates can be masked by employing microencapsulation techniques.
- ✓ Through microencapsulation, liquids and gases can be changed into solid particles in the form of microcapsules.
- ✓ It provides environmental protection to encapsulated active agents from various environmental issue such as light, heat, humidity, oxidation, etc.
- ✓ The hygroscopic characteristics of many core materials can be reduced by microencapsulation.
- ✓ The separation of incompatible substances can be achieved by microencapsulation. For Example: Pharmaceutical eutectics can be separated by microencapsulation. This is a case where direct contact of materials brings about liquid formulation. The stability enhancement of incompatible aspirin-chlorpheniramine maleate mixtures is accomplished by microencapsulation both of them before mixing.
- ✓ Microencapsulation is used to less the potential danger of toxic substances handling.
- ✓ Aspirin controlled release version ZORPPIN CR tablets are used for relieving Arthritis.
- ✓ Quinine gluconate CR tablets are used for treating and preventing abnormal heart rhythms.

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