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Microencapsulation: A Review

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Abstract:
A process known as "microencapsulation" forms thin wall material coverings around things, which can be gases, liquids, or even solids, and encases them in tiny particles. Small entities with an active ingredient known as the core material encased in a covering substance or embedded in a matrix structure are known as microencapsulated products, or micro particles. The overview includes information on encapsulating materials, preparation methods, the physics of release through the capsule wall, microcapsule characterization, and the many applications of microcapsules. The review, "State of Art of Microencapsulation of Microcapsule Preparation Process Technology," is a reputable resource on the creation, characteristics, and applications of novel small particles that are individually encapsulated. It also covers popular microencapsulation techniques and their benefits and drawbacks, as well as the broader applications of these techniques in the fields of pharmaceuticals, cosmetics, agriculture, food technologies, and textiles.

Keywords: Microencapsulation techniques, Centrifugal extrusion, Polymerization, Coacervation

INTRODUCTION

The method of micro-encapsulation involves enclosing microscopic particles or droplets in a covering to create tiny capsules. A microcapsule is a tiny spherical with a homogeneous wall surrounding it in its most basic form. While the wall is frequently referred to as a shell, covering, or membrane, the substance inside the microcapsule is known as the core, internal phase, or fill (01). It also goes by the name "micro balloons." procedure for encasing inert shells around microscopic solid, liquid, or gas droplets (02). The physical and chemical characteristics of the capsules are dictated by the material selection for the shell. Therefore, the choice of shell material must take into account a number of crucial criteria in order to accomplish the intended goal of encapsulation, including the needs of the product, the environment, the characteristics of release, and compatibility with the micro-encapsulation technique (03). In this approach, surfactants are occasionally added to film coating particles, which range in size from a tenth of a formulation to be poured or sprayed into a micrometer to around 5000 micrometers (04). The process of microencapsulation typically consists of four stages: integration, solidification, and the development of the core and encapsulants (05). Spray chilling, spray cooling, fluidized bed coating, liposome entrapment, extrusion, freeze drying, and coacervation are only a few of the many methods used in microencapsulation (06). At last, the microcapsules are released into several dosage forms, like suspensions in liquids, soft gelatin capsules, or hard gelatin capsules that can be enteric coated. All of these forms enable the release of individual microcapsules (07). The tiny size of the coated particles and their subsequent usage and

customization to a wide range of dosage forms and product application are the advantages of microencapsulation (08).

A technique called microencapsulation can lengthen the time that nutrients remain in food and enable controlled release throughout mealtimes or in the intestines. The technology in question is not new; it was first used in a business setting for carbonless copy paper in 1954 (09). The pharmaceutical industry has developed many coating materials and application procedures for the microencapsulation of medications. Pharmaceutical businesses that produce microencapsulated medications have obtained multiple patents within the past 25 years (10).

The US National Cash Register, which started the commercialization of carbonless copy paper in the 1950s, acted as a go-between for the initial investigations into the application of the microencapsulation process in the (11). Colorless ink microcapsules were applied in a thin coating to this paper. Colorless ink microcapsules were applied in a thin coating to this paper. Pen writing caused the microcapsules to burst, releasing colorless ink that, upon reacting with the reagent, turned colored and produced a duplicate of the text being written in the first role on the sheet beneath. This process occurred when the pen was pressed under the paper's surface.

The size of the capsule is essentially what distinguishes encapsulation, microencapsulation, and nanoencapsulation. Rebello (2009) claims that the capsules can be divided into three groups based on diameter: microcapsules (>5000µm), microcapsules (0.2-5000µm) and nanocapsules (<0.2µm) (12).

It has the following benefits: (13)

1. Decreases the frequency of dosing
2. Enhanced practicality
3. Patient acceptance.
4. Particular to the target.
5. being really productive.
6. Increases a compound's lifespan.

IMPORTANT FEATURE OF MICROCAPSULES (14)

The most important characteristic of microcapsules is their minuscule size, which permits a large surface area. For instance, it has been claimed that a single millimeter of hollow microcapsules with a 0.1 mm diameter have a total surface area of almost 60 m2. The diameter and total surface area have an inverse relationship. This huge surface area can be used for chemical reactions, light scattering, adsorption and desorption sites, and other processes. In-depth descriptions of microcapsule characteristics can be found in works written by Gutcho12 and Arshady13.

REASONS FOR MICROENCAPSULATION (15)

1. The primary goal of microencapsulation is to provide a medication with delayed or sustained release.
2. This method has been widely used to mask the organoleptic qualities, such as taste and odour, of many medications, hence improving patient compliance. Examples of such medications are nitrofurantoine, which masks the bitter taste, and paracetamol.
3. Liquid medications can be transformed into a powder that flows freely by employing microencapsulation procedures.
4. Microencapsulation can provide protection for medications that are susceptible to light, moisture, and oxygen.

5. Nimedipine, for instance, is shielded from photo instability.
6. The microencapsulation technology is also beneficial in preventing drug incompatibilities.
7. At room temperature, medications that are volatile in nature may evaporate. Microencapsulation can stop the effects of medications like aspirin and peppermint oil.
8. Microencapsulation can help reduce toxicity and GI discomfort, especially when combined with ferrous sulphate and KCL.
9. Using microencapsulation has also been used to alter the absorption site. For medications whose toxicity increases with decreasing pH, this application has been helpful.
10. Bakan and Anderson found that vitamin A palmitate microencapsulated showed improved stability and resistance to oxidation.
11. The preparation of intrauterine contraceptive devices has also been done using the microencapsulation technique.

ADVANTAGES (16, 17)

1. Exorbitant production costs and output repeatability of product powder with easy management low level of activity. It is widely used in the synthesis and extraction of a wide variety of compounds with different compositions and polarity. Quick process
2. Resistance to warmth exceptional intermediate chemical that may be applied to a solid product
3. Controlled actives' release hydrophobic actives' solubility reduces the compound's lack of volatility.
4. Low operating cost suitable for heat-sensitive actives
5. Cost-effective techniques that don't require high temperatures or the usage of natural solvents in certain pH ranges for their development
6. A good substitute for a temperature-sensitive substance.

DISADVANTAGES (16, 17)

2. The use of thermo labile compounds is no longer recommended since nonuniform waste can shape aggregate
3. Unique rather than depending on fabric with drastically fluctuating encapsulation efficiency and natural solvent use
4. Aggregate can be shaped by steeply priced materials limited to low molecular weight.
5. Scaling parameters (melting, feed flow, cooling temperature, atomizer air temperature and pressure): quick active launch, special for hydrophobic compound nonuniform particle changeable encapsulation efficiency.
6. Unique product challenges with viscous solution in terms of size and shape.
7. The expense of the foam texture product made gradually.

RELEASE MECHANISMS

Degradation controlled monolithic system:

The medication dissolves in the matrix and is dispersed evenly throughout. When the matrix degrades, the drug, which is firmly connected to it, is released. When compared to the matrix's breakdown, the drug's dispersion is more gradual (18).

Diffusion controlled monolithic system:

Diffusion releases the active drug in this case either before or at the same time as the polymer matrix brea-

ks down. The location of homogeneous versus heterogeneous polymer degradation affects the rate of release as well. (19).

Diffusion controlled reservoir system:

Here, a rate-controlling membrane encapsulates the active agent, allowing it to diffuse through it. The membrane only begins to disintegrate after the drug has been delivered. In this instance, matrix deterioration has no effect on drug release (18).

Erosion:

Certain coatings can be engineered to progressively deteriorate over time, allowing the medication within the particle to be released. Accumulation of monomer in the release medium occurs concurrently with polymer erosion, or the loss of polymer. When water seeps into the carrier and causes changes to its microstructure, the polymer starts to erode and the matrix becomes plasticized (10).

The terms or materials used in encapsulation process

The words "core material" and "wall material" are the foundation of the entire microencapsulation. Micro capsules come in a range of sizes from micrometers to millimeters (20).

Process Selection

The factors to be considered during process selection are:

1. Whether the core is solid or liquid,
2. The solubility characteristics of the core,
3. The reactivity of the core with the wall material and solvent,
4. The size of desired capsule, the method of attaching the capsule to the desired substrate, The method of core release, And the process and product economics

CORE MATERIALS (15)

The specific substance to be coated, referred to as the core material, may consist of a liquid or a solid. The liquid core may dissolve or scatter components, changing the composition of the core material. The solid core is composed of the active chemicals, stabilizers, diluents, excipients, and accelerators or retardants of release rates. The desired microcapsule qualities can be effectively designed and developed thanks to the use of the distinct flexibility offered by the alteration in the composition of the core material.

Liquid Core Material Examples:

fragrances, lubricants, oils from vegetables, insecticides, fertilizers, dyes, catalysts, bleaches, sugars, salts, acids, pigments, fungicides, and nutrients

Solid Core Material Examples:

Minerals, Dextrin’s, Bases, Herbicides, and Pharmaceuticals

COATING MATERIALS (16)

A coherent, chemically well-matched, and nonreactive movie that is formed by the coating cloth and the centre cloth should be possible. stability using the centre cloth, Apathetic towards components with energy, the coating may be thin, hard, brittle, flexible, or launched under specified conditions. Easily accessible and reasonably priced. Strength, flexibility, impermeability, stability, and optical qualities are among the other desired coating features that are provided. Some degree of in situ modification is possible for the coating materials used in microencapsulation procedures. The selection of a particular coating can be facilitated by examining recent literature and watching uncut or fake films; however the practical application of uncut film records is hindered for the following reasons:

1. Movies that are cast or unfastened and arranged using traditional casting techniques produce films that are noticeably thicker than those made by microencapsulating tiny particles; as a result, the conclusions drawn from the solid films cannot be applied to the thin microcapsule coatings.
2. The exact and intrinsic dwellings produced by the precise microencapsulation technique used for the deposition of a particular coating can be difficult to replicate with current movie-casting techniques.
3. The middle fabric's coating substrate may also have a significant influence on coating homes. Therefore, selecting a particular coating fabric requires consideration of both conventional unfastened-movie facts and executed outcome.

COATING MATERIAL PROPERTIES (17)

1. The core material's stabilization.
2. Indifferent to the active components.
3. Controlled release subject to predetermined parameters.
4. Stable, flexible, tasteless, and film-forming.
5. Economical, non-hygroscopic, and low viscosity.
6. Melting or soluble in a solvent or watery solution.
7. The covering may be thin, rigid, brittle, flexible, or any of these.

TYPES OF COATING MATERIALS: (11, 19, 21, 22)

Types	Examples
Water soluble resins	Gelatin, Methylcellulose, Gum Arabic, Polyvinyl alcohol, Polyvinylpyrrolidone, Carboxymethylcellulose, Arabinogalactan, Hydroxyethylcellulose, Starch, Polyacrylic acid.
Water insoluble resins	Ethylcellulose, Polyethylene, Polymethacrylate, Cellulose nitrate, Polyamide (Nylon), Poly (Ethylene-Vinyl acetate), Silicones, Poly (lactide-co-glycolide).
Waxes and lipids	Paraffin, Stearic acid, Carnauba, Spermaceti, Beeswax, Stearyl alcohol, Glyceryl stearates.
Enteric resins	Cellulose acetate phthalate, Shellac, Zein.

Factors influencing encapsulation efficiency (23)

There exist multiple characteristics that impact the encapsulation effectiveness of micro particles, microcapsules, and microspheres. The various factors affecting encapsulation efficiency are shown in Figure.

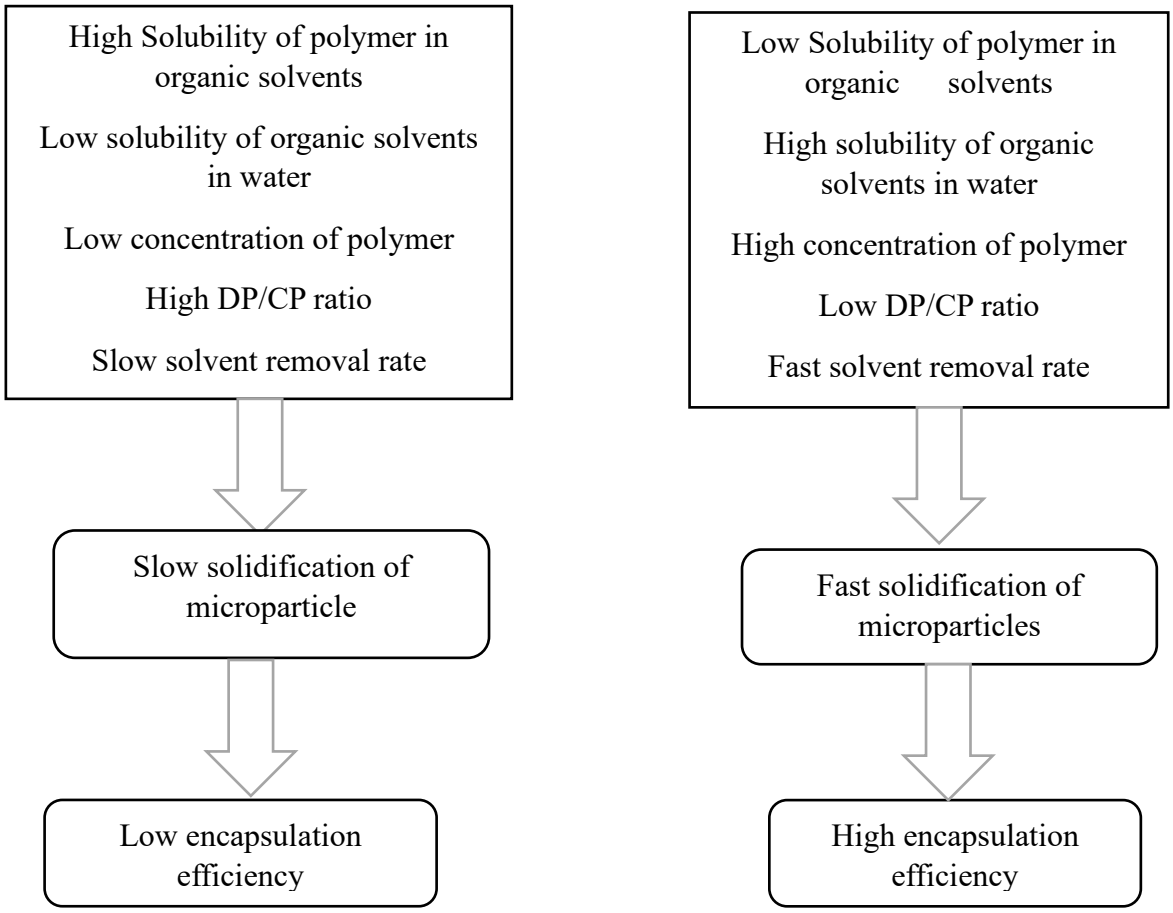

Figure -Factors influencing encapsulation efficiency

- Viscosity of dispersed phase
- Volume fraction of both dispersed to continues phase.
- Drug quantity in dispersed phase
- Surfactant concentration.
- Operating parameters.
- Agitation rate/time.
- Temperature.
- Pressure.
- Geometry of agitator and reactor.

Tecshniques to Manufacture Microcapsules

1 Physical methods

Air-suspension coating:

Professor Dale E. Wurster created the air suspension coating method while he was employed at the University of Wisconsin's Department of Pharmacy. The air suspension apparatus is divided into various elements, including the coating chamber, air distribution plate, control panel, and nozzle used to apply film coatings. Particles are suspended in the coating chamber of the air suspension apparatus by an upward-moving air stream. Coating material is sprayed onto the moving core particles in the coating zone. The recirculating flow of the core particles through the coating zone is influenced by the chamber's design

and operational settings. With each pass through the coating zone, the core material gets a little bit more coating material—typically a polymer solution. The cycle is continued until the required coating thickness is attained. During the encapsulation process, the supporting air stream aids in drying the product. Typically, air suspension methods are limited to encasing the solid core components. The encapsulating materials had a major influence on the pace at which the medication was released from the microcapsules (15).

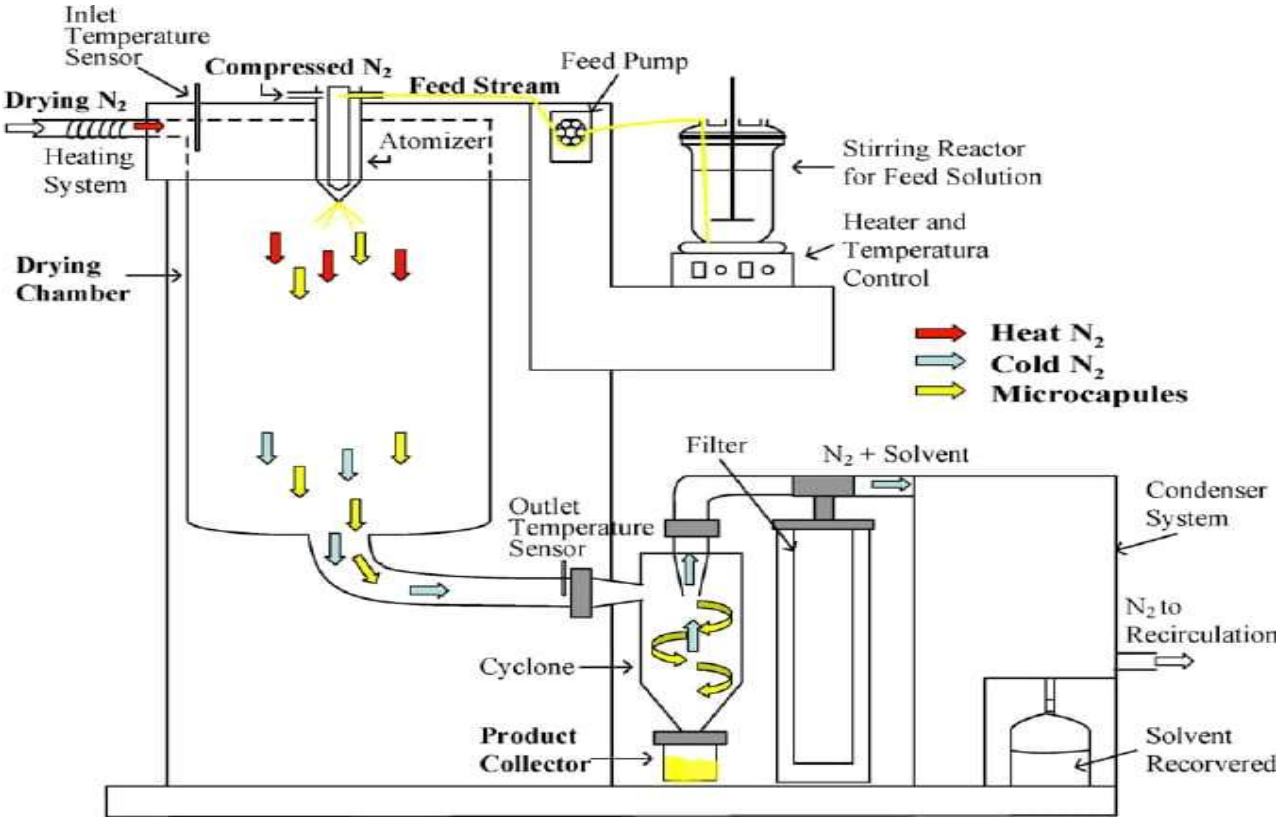

Fig. Fluidized bed used by (24).

Advantages:

1. The materials can be coated with solutions, aqueous solutions, emulsions, or hot melts.
2. Because of the tiny particle size, it can be used for both macro and micro encapsulation.
3. Greater flexibility and control over pan coating (11).

Disadvantages:

1. Exclusively relevant to solids.
2. A high level of competence is necessary.
3. Solid agglomeration could occur (11).

Coacervation Process:

Coacervation, also referred to as "phase separation," is regarded as a genuine microencapsulation method since the matrix entirely encloses the core substance. This method entails the precipitation or division of an aqueous phase from a colloidal phase (25). Using this technique, one or more hydrocolloids that are suspended in the same reaction media are phase separated from a polymeric solution layer around the core

material (26). Coacervates are formed over a limited pH range and involve the electrostatic interaction of two biopolymers with opposing charges. Using this method, the polymer-rich (coacervate) phase and the liquid phase separate (27). The coating material solution is used to spread the core material during this operation. The maximum solubility of the core material in the coating material's solvent is 2%; it should not react or dissolve in it. Dispersion characteristics, including surface tension, viscosity, stirrer shape, and stirring speed, determine the size of the particles. The range of particle sizes is 2µm–1200µm. The first step in aggravating a dispersion's pH is to add H2SO4, HCl, or organic acids, for example. The dispersion phase's (shell material's) solubility is lowered as a result (28).

Three main phases are typically included in the continuous agitation process of coagulation-phase separation:

1. In the first stage, three immiscible chemical phases are generated.
2. The coating is deposited in the second step.
3. The coating is hardened or rigidized at this point (29).
4.

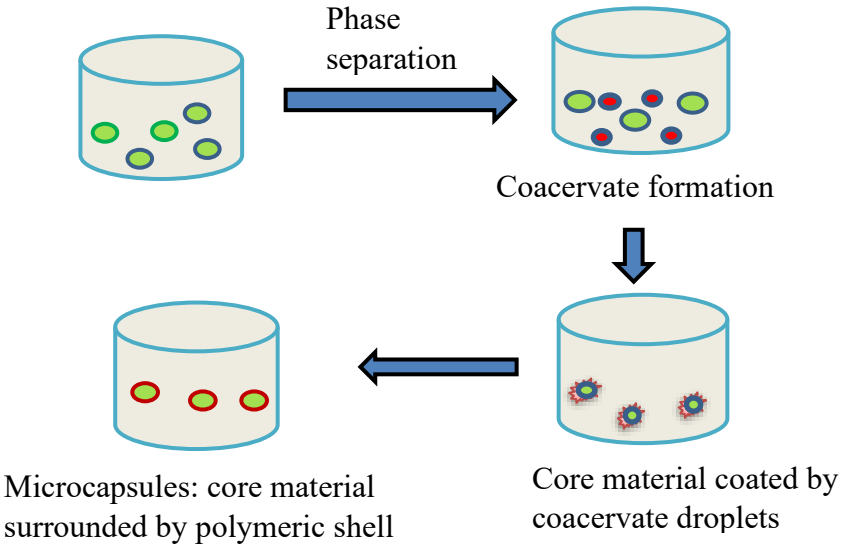

Fig. Conservation (06).

Centrifugal extrusion:

Concentric nozzles on a spinning extrusion head are used to encapsulate liquids. In this procedure, a sheath of wall solution or melt encircles a jet of core liquid. Because of Rayleigh instability, the jet breaks apart as it travels through the air, forming droplets of core that are each covered in the wall solution. It is possible for a molten wall to solidify or for a solvent to evaporate from the wall solution while the droplets are in flight. The majority of the droplets settle in a narrow ring surrounding the spray nozzle because they are within ± 10% of the mean diameter. As a result, the capsules can be placed in a ring-shaped hardening bath to harden them if necessary after production (30).

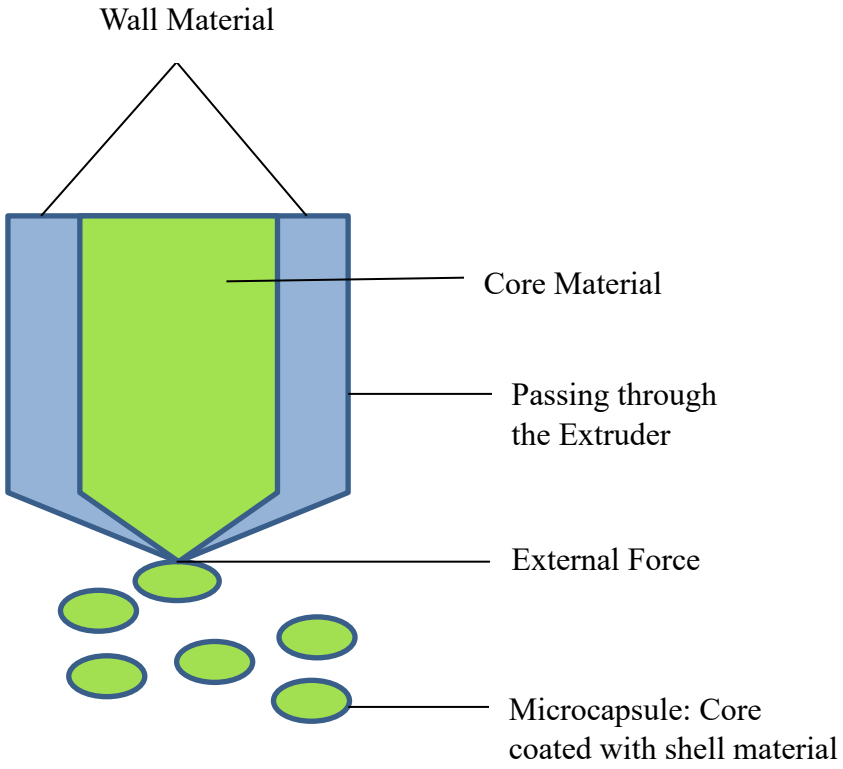

Fig. Extrusion (06).

Pan coating:

One of the earliest methods used in industry to generate small, coated particles is the pan coating technique, which finds widespread application in the pharmaceutical sector. While applying the coating material gently, the particles are tumbling in a pan. Solid particles larger than 600 µm are usually thought to be necessary for efficient coating in the context of microencapsulation. Applying the coating on the chosen solid core material in the coating pan can be done in two ways: as an atomized spray or as a solution. As the coatings are applied in the coating pans, heated air is typically passed over the coated items to remove the coating solvent. The last step of solvent elimination is sometimes completed in a drying oven (28).

Spray–drying:

Microencapsulation is the technique of using spray drying to combine the wall and centre components to create an emulsion, solution, or suspension. In a drying chamber with heated air moving, this is evident as nebulization or atomization. The water instantly evaporates upon contact with the fresh air, and the centre substance is encased in the matrix. Spray drying is the most widely used microencapsulation technique in the food business. In 1937, Boake Roberts accidently added acetone to tomato puree and used the spray drying technique to create encapsulated flavouring. This allowed Roberts to maintain the flavor and colour of the tomato powder during spray drying. After that, use spray drying is now the most important commercial process in the manufacturing of dry flavorings. This technique has been used to contain enzymes, oleoresins, fat and oil flavour, colourants, vitamins, and fragrance compounds. This economical and effective technique of material preservation is most commonly used with tastes, for which specific equipment is not required. To be used as the wall material or carrier during the encapsulation process,

modified starch, maltodextrin, gum, or other materials are hydrated. Using the carrier material, the encapsulating material is homogenized, usually 1:1:4. The liquid is then delivered into a spray drier, where a revolving wheel or nozzle is used to atomize the mixture. When atomized material and heated air come into contact, water evaporates. The capsules are collected once they have sunk to the dryer's bottom (31).

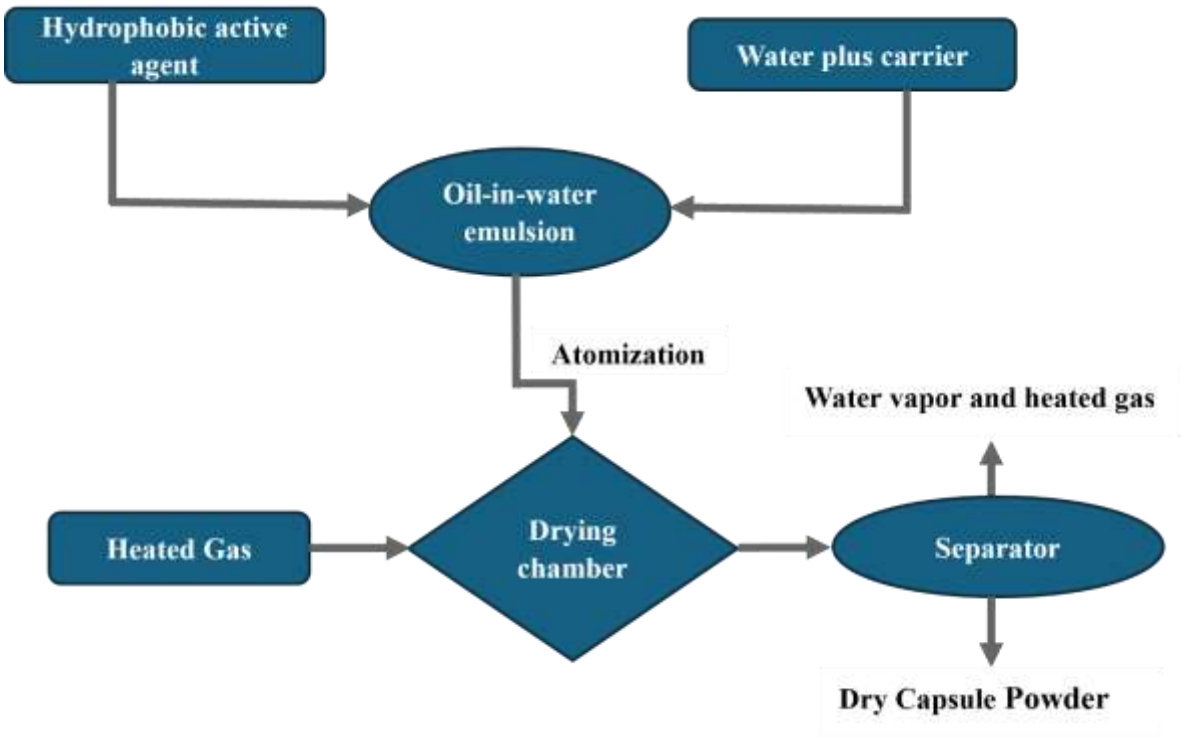

Fig. Flow diagram of a typical spray drying encapsulation process (24).

Airflow

Co-current:

Particles and drying air flow through the drying chamber in the same direction. This is the best mode for drying heat-sensitive materials since the product temperatures upon discharge from the dryer are lower than the exhaust air temperature. The air disperser generates a high degree of air rotation when using a rotating atomizer, providing consistent temperatures throughout the drying chamber. Nevertheless, tower or FILTERMAT-style spray dryers frequently employ a different non-rotating airflow method using nozzle atomizers and achieve comparable performance (18).

Counter-current:

The direction of movement of the drying chamber's particles and drying air are opposing. Products that need to be heat-treated to some extent during the drying process might use this option. The powder typically exits the dryer at a temperature greater than that of the exhaust air (19).

Mixed-flow:

Particles move through the drying chamber in two stages: co-current and counter current. This mode works well for heat-sensitive products whose air inlet and outlet are located at the top of the drying chamber and where the atomizer sprays droplets downward towards an integrated fluid bed, or for heat-stable products

whose coarse powder requirements require the use of nozzle atomizers that spray upward into an incoming airflow (19). Take studies on spray-drying lycopene microencapsulation, for instance (18).

2 Chemical process

Solvent Evaporation:

This system has been used in a vehicle for liquid manufacture. An unpredictable detergent that's immiscible with the liquid product vehicle phase is used to dissolve the microcapsule coating. In the coating polymer result, a core material to be microencapsulated is dissolved or distributed. To produce the right size microcapsule, the liquid product vehicle phase's core coating material admixture is stirred and distributed. The detergent for the polymer is also faded by hotting the admixture, if demanded. The polymer shrinks around the core when the core material is distributed throughout the polymer result. A matrix- type microcapsule is created when the core material dissolves in the covering polymer result. With nonstop shifting, the liquid vehicle temperature is lowered to room temperature (if necessary) once the polymer's detergent has fully faded. The microcapsules can now be insulated as maquillages, carpeted on shells, or employed in suspense form. There are several different liquid and solid core accoutrements that can be used with the solvent evaporation system to produce microcapsules. Either water-answerable or water- undoable accoutrements could make up the core factors. As coatings, a range of film- forming polymers are available (32).

Polymerization:

A. Interfacial polymer:

In order to produce microcapsules, a chemical process known as interfacial polymerization takes place, for instance, between an alcohol or an amine and a diacyl chloride. Polyester, polyurea, polyurethane, or polycarbonate are possible wall polymers that arise. Pheromones and pesticides can be microencapsulated using this technique (33).

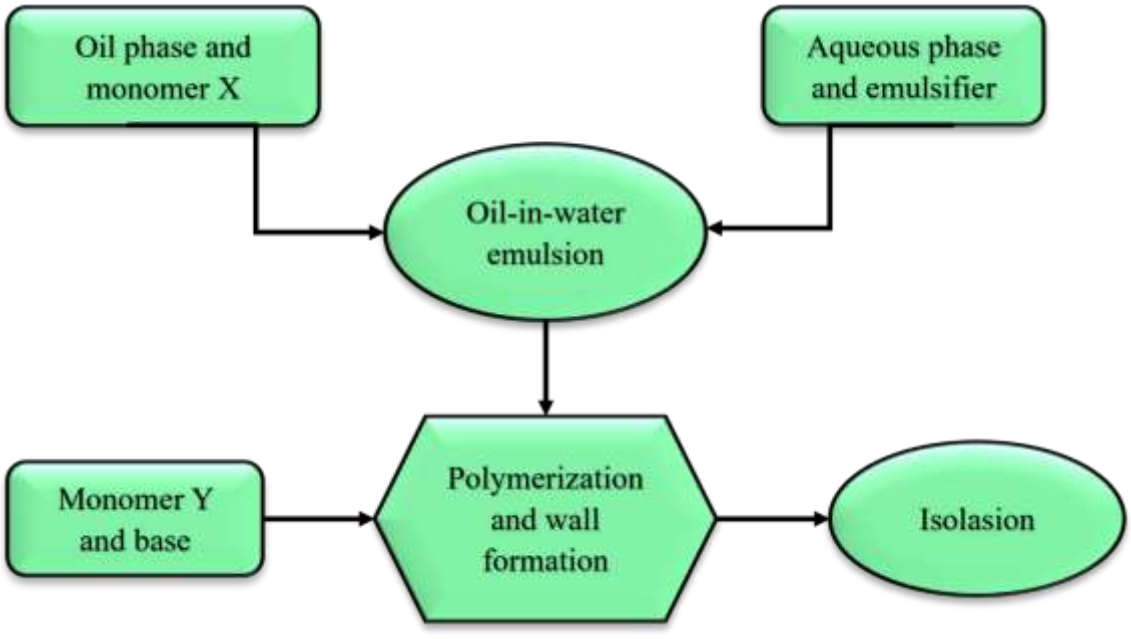

Fig. Flow diagram of a typical interfacial polymerization encapsulation process (24).

B. In-situ polymerization:

The pill shell is formed by the polymerization of monomers added to the encapsulation reactor, same like in IFP.This approach introduces the core material to no reactive retailers. Polymerization takes place completely inside the continuous segment and at the non-stop segment side of the interface formed, assisted by the dispersed core material and non-stop segment. A prepolymer with a low molecular weight will initially assume shape and then grow larger over time.To deposit at the floor of the dispersed middle material there, it employs the procedure for making a sturdy pill shell (31).

C. Matrix polymer:

A core material is inserted by a variety of processes into a polymeric matrix during the particle's production. This type of fundamental process, known as spray-drying, creates the particle by allowing the solvent to evaporate from the matrix material. However, the matrix's solidification could also be the result of a chemical change. Using this phenomenon, Chang incorporates the protein into the aqueous diamine phase to create protein solutions in microcapsules. Chang has established the permselectivity by demonstrating the conversion of blood urea to ammonia, the enzyme that stays in the microcapsules when integrated into an extracorporeal shunt system. To accomplish microencapsulation, numerous groups are using polymerization techniques. Two instances are the National Lead Corporation and Eurand America (19).

APPLICATION OF MICROENCAPSULATION:

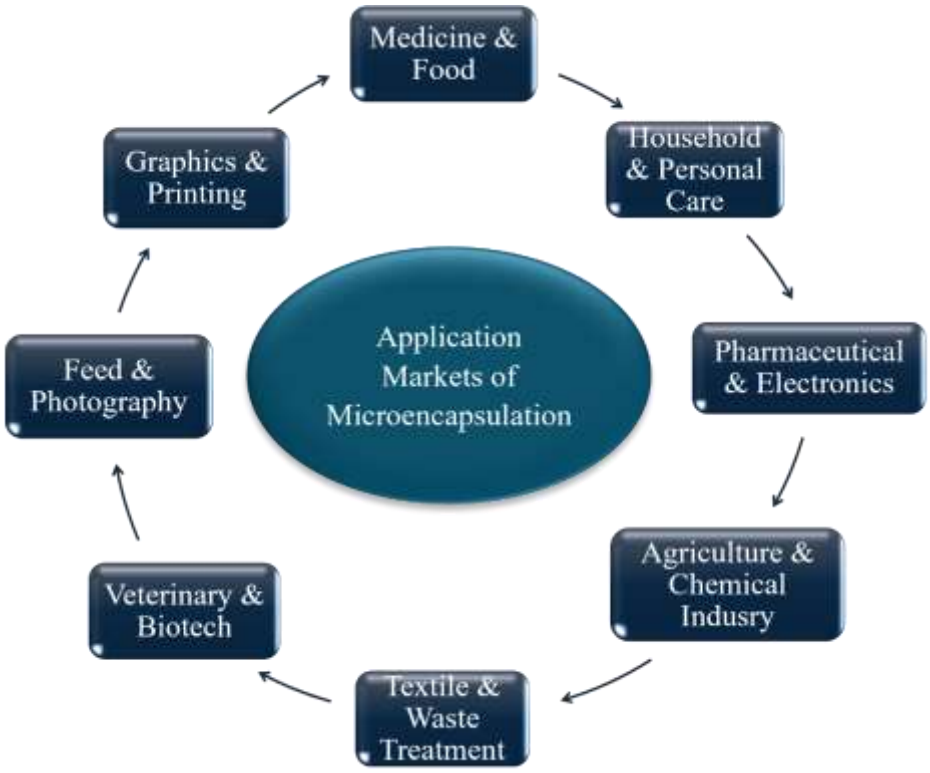

Fig. Applications of Microencapsulation (22, 31).

1. Food

Currently, people are moving towards a better life, which includes getting more conscious of what they eat and the advantages that some foods offer for conserving good health. Salutary forestallment of sickness

is a special immolation of slice- edge" functional foods," numerous of which are enhanced with factors to support health. But just adding factors to food particulars to increase their nutritive content can also affect how they taste, look, feel, and smell. At times, they may gradationally deteriorate and cease to serve, or they may turn dangerous due to oxidation processes. Likewise, relations between constituents and other rudiments in the food chain may reduce a component's bioavailability. Microencapsulation is used to overcome all these challenges by furnishing feasible texture blending, appealing aroma release, and taste, odour and colour masking. The technology enables food companies to incorporate minerals, vitamins, flavours and essential canvases. In addition, microencapsulation can simplify the food manufacturing process by converting liquids to solid greasepaint, dwindling product costs by allowing batch processing using low cost, greasepaint handling outfit. Microcapsules also help fragile and sensitive accoutrements survive processing and packaging conditions and stabilize the shelf life of the active component (34).

2. Beverages

The fastest growing and largest market segment is functional items, which also represent a distinct trend in the production of healthful food. Customers like probiotics and prebiotics because they are essential components of a healthy diet. Prebiotics are indigestible food components that support the growth and activity of one or a few beneficial bacteria UN the intestine. Curcumin and catechin microcapsules made of water-in-oil-in-water emulsions are intended to halt the degradation of both curcumin and catechin in beverage systems. Maltodextrin and lemon oil are encapsulated using the spray-drying technique. Lemon oil's rich, pleasant aroma makes it a popular choice for seasoning food and beverages. One kind of water-soluble pigment that is often used as food and beverage colourants is called anthocyanin. Nevertheless, anthocyanins are unstable pigments that, depending on a range of factors such as pH, temperature, light, oxygen, and the food matrix, can decompose into colourless compounds. Therefore, this compound's stability is increased through the use of microencapsulation (35).

3. Cosmetics application :

There are several applications for encapsulates in cosmetics and home goods, where perfumes, gels, shampoos, creams, soaps, and surface cleaning solutions are commonly concealed. Customers' demands and interest in natural scents are both rising. The aroma of a product is meant to last for a very long time after usage. Scent components may be enclosed in order to match the high expectations of customers. It has been shown that substituting essential oils with antibacterial properties for preservatives can have positive business effects as well. Essential oils that are volatile can be encapsulated and applied gradually with controlled release (23).

4. Textile

a. Phase-change materials:

Within a specific temperature range, phase-change materials change the aggregation from solid to liquid. Phase-change material microcapsules lessen the impact of abrupt temperature changes. This maintains a steady temperature and makes it easier for garments to thermo regulate. These microcapsules are used on a variety of textiles, including blankets, mattresses, parkas, snowsuits, vests, and more.

b. Fragrance finishes:

Although fibers and textiles have had fragrance finishes applied directly to them multiple times, the scent only lasts for two washing cycles. One technology that delivers a longer-lasting effect on cloth is microencapsulation of perfumes. Using this method, essential oil tastes like lavender, rosemary, pine, and so forth may be contained in microcapsules for use in aromatherapy. Primarily, this is done to address headaches, sleeplessness, and unwanted odours.

c. Fire retardants:

To address the issue of decreased softness brought on by the direct application of fire retardant ingredients, microcapsules with a fire retardant core were created. They are applied to textiles like tentage that are employed in military applications.

d. Polychromic and thermo-chromic microcapsules:

One color-changing system is thermo-chromatic—it changes colour in response to temperature—while the other is photo-chromatic—it changes colour in response to UV radiation. Textile applications such as product branding, medicinal, and security use thermochromic and polychromic microcapsules. Certain thermochromatic dyes are microencapsulated and react to human touch to change colour at a given temperature.

e. Antimicrobials:

Many times, bacteria lead to the microbiological deterioration of textiles, which results in the loss of many beneficial qualities. Anti-microbial coatings, which can be applied with the aid of microencapsulation, can be used to avoid this issue. This particular treatment is intended specifically for technical and medical textiles.

f. Counterfeiting:

Microencapsulation can be used to prevent imitations of high-end textiles, branded products, and designer items. The labels are coated with microcapsules that are either activators or colour formers. In order to achieve detection, light or a solvent causes the microcapsules to burst open, releasing the substance and developing colour (36).

5. Pharmaceuticals

Encapsulation technology has pharmaceutical uses in the biomedical field for regulated and sustained drug delivery systems.

- Gene therapy, vaccinations against AIDS, cancer, tumours, and diabetes, and the substitution of medicinal molecules are potential uses.
- A novel method of oral medication delivery called protein, such as erythropoietin, insulin, and growth hormone, is used to treat anaemia.
- The plasmid DNA delivery of gene sequences, which may offer a practical treatment for disorders like haemophilia.
- The spheres are designed to adhere firmly and even pierce gastrointestinal tract linings (37).

6. Agriculture

Crop protection is one of the most important applications for microencapsulated products.From 87 to 93. As a biorational substitute for conventional harsh pesticides, insect pheromones are becoming more and more viable. In particular, by interfering with the mating process, sexattractant pheromones can reduce insect populations. Because of this, throughout the mating season, modest amounts of a species' specific pheromone are distributed, increasing the pheromone's heritage degree to the point where it conceals the pheromone plume released by its female mate.91–93. Gum arabic93, polyurea92, polymer microcapsules, and gelatin work as green transport motors to provide the pheromone by spraying the pill dispersion. Additionally, the pheromone is shielded by encapsulation against mild oxidation during storage and release (16)

7. Printing and Paper Industry

One of the first industries to effectively exploit microcapsules was the production of carbonless copy paper, which is among the most well-known and early applications of mechanically activated functionality

on paper substrates. Pressure-sensitive films with microcapsules are used in the production of paper, packaging, and other graphic materials, along with other pressure measuring applications, to track and control the pressure difference and intensity. The printing industry's opinion of product quality is almost entirely based on the visual effect of the printed matter. Humans may now employ their senses of smell and touch in addition to their sensory awareness thanks to developments in printing technology that apply smells that are safely encapsulated inside microcapsules(35).

Some applications commonly used are (38)

1. Paper exports without carbon
2. Sniffing and scratching
3. Perfume and taste
4. Microencapsulation has medical applications.
5. Microencapsulation: everyday use (mineral (iron) and vitamin encapsulation)
6. Another method to lower any dangers associated with handling toxic or hazardous chemicals is microencapsulation. The application of fumigants, herbicides, insecticides, and toxins has effectively reduced toxicity following microencapsulation.
7. Formulation (oral and injectable medicinal formulations)
8. Drug flavour masking (masking the taste of tinidazole and optimising the microencapsulation procedure)
9. Defence
10. Convenience
11. Exclusion of reactants
12. Improved surface usability of microcapsules
13. To reduce toxicity
14. In an effort to lower volatility
15. Diminishing ambiguity.
16. Lowering the risk of fire. Long-term release methods. Since microencapsulation is most successful when used to prepare pills, capsules, or other forms of parenteral delivery, a prescription must be written for the microencapsulated drug.
17. Dividing volatile substances to eliminate incompatibility
18. Transforming a liquid into a solid
19. Protecting the environment by stabilizing atmospherically sensitive products
20. To lessen GI tract and stomach irritation
21. Targeting medications
22. An overview of the meat, consumer goods, and cosmetics industries
23. Agricultural product encapsulation methods
24. The development of an intrauterine contraceptive method using microencapsulation was also recommended.
25. A wide range of uses are necessary to increase space capacity.
    - To increase emulsion stability.
    - To enhance the ease of flow.
    - To modify the solubility of chemical reactants at different levels when taking a medication, get rid of any bad taste or smell.

- To increase the dosage of a medication (as the capsule is not totally cracked, the contents may gradually leak out).
- To protect the drug against deterioration in the environment.

CURRENT & FUTURE DEVELOPMENTS

This review concentrated on examining the most recent and, if required, the oldest patents that use emulsion solvent removal techniques for drug and biologically active agent encapsulation, taking into account the encapsulation goal, methodology, shell or matrix formers, and drugs or active agents. Large-scale microsphere production remains a challenge, despite the annual emergence of new patents utilizing the emulsion solvent removal process to create robust, consistent, and highly reproducible microparticles. Furthermore, before the microparticle may be utilized for other purposes, it needs to undergo a thorough washing procedure to eliminate the solvent. These drawbacks lead to inefficiencies, which raise the price of the resulting microparticle. Furthermore, the organic solvent that was used to create the microemulsion is a dangerous substance that should be handled, stored, and disposed of with caution due to its potential risks to human health and the environment. In light of this, it is expected that future years will bring forth even more creative concepts, such as a notable enhancement of the physicochemical and toxicological characteristics of the commercial formulations. Therefore, it is necessary to have preparation technologies that can produce more microspheres in a way that is reliable, affordable, safe, and well-controlled (39).

CONCLUSION:

One way to preserve the quality of delicate materials is by microencapsulation, which is also a process for creating new, valuable materials. The most practical method for protecting and masking, lowering the rate of dissolution, making handling easier, and spatially targeting active chemicals is the widely used microencapsulation approach. The process of encapsulating an active component inside a capsule that ranges in size from a single micron to several millimeters is known as microencapsulation. Until the proper time, the capsule shields the active substance from its surroundings. The substance then melts, dissolves, diffuses, or ruptures through the capsule wall. For medications that need to dissolve in the intestine rather than the stomach, the microencapsulation method is also advantageous.

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