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Microencapsulation: Design, Characterization, and Evaluation

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ABSTRACT

Any compound can be enclosed inside a specific material utilizing the sophisticated food processing technique known as microencapsulation, creating a tiny sphere with a diameter ranging from 1 μm to several hundred μm. The purpose of microencapsulation is to ensure the safe delivery of sensitive substances by safeguarding them. The material used for encapsulation is known as the encapsulant, and the chemical or active ingredient that is enclosed is known as the core. Polymeric and nonpolymeric substances such as gelatin, cellulose, and ethylene glycol can be used as encapsulants. Microencapsulation is accomplished using a variety of methods. Extrusion, coacervation, fluidized bed coating, spray cooling, and spray drying are a few examples. The characteristics of the encapsulant, core material, and various required capsule morphologies all influence the choice of a certain procedure. A widely used technology in food products is microencapsulation, which can be utilized to create functional foods or as a fortifying agent. This review critically examines and compiles the use of this specific technique in foods, various encapsulation techniques, various capsule properties resulting from the various microencapsulation techniques, and various release mechanisms used to deliver the compounds. It is based on the basic understanding of encapsulation as well as the most recent research and findings from the literature.

Keywords microparticles, core, coacervation, design.

Introduction

The process of encasing a solid or liquid core material by trapping it with a wall-forming or carrier is known as microencapsulation. Typically, this process produces microscopic solid particles that range in size from measurement range between nanometers and micrometers [1, 2 19, 20]. Green and Schleicher created and patented the concept of the development of microencapsulation technology for the factory Cation of capsules with dyes that are specifically made for paper [3 21, 22]. Microencapsulation has since been utilized and studied in numerous fields and sectors, including food, electronics, medicine, and agriculture, biomedicine and cosmetics [4]. The use of microencapsulation has demonstrated a number of benefits, especially in the agricultural pharmaceutical, food, and other industries, and has provided their intriguing characteristics that include the encapsulation of colors, live cells, active enzymes, adhesives, perfumes, and medications, their regulated or postponed release of active ingredients in ingredients, a way to cover any bad tastes, and improved solubility [5, 6]. The microencapsulation method is renowned for its advantages. generating microparticles that are separated into microcapsules or crospheres. These microcapsules are different in size and form according on the materials and process used by combining several polymers or mon mers using various microencapsulation techniques [2]. These microcapsules fall into one of three groups, as mononuclear, as seen in Figure 3 (the core is surrounded by the polynuclear (having many encased core elements), inside the shell), as well as matrix (the cores are similarly or evenly distributed across the shell). [7]

To provide products to market, researchers are currently concentrating on developing new drug delivery systems (DDS) that can reduce adverse effects, be appropriate for site-specific delivery, increase shelf-life, enhance patient compliance, and potentially allow for sustained release [8]. Thus, microencapsulation emerges as a possible technical approach to accomplish the aforementioned objectives. Combinations of biomaterials and active pharmaceutical ingredients (APIs) can form microparticles. With respect to the microencapsulated APIs, these medicinal substances may have a brief half-life and be rapidly hydrolyzed or enzymatically broken down in vivo, which is linked to a more rigorous treatment regimen (several doses). Consequently, microencapsulation methods shield the API from deterioration, enabling these substances to be released in the right amounts over time to achieve the necessary treatment concentration of API [9].

This review discusses in details the several techniques that employed in microencapsulation and purpose of microencapsulation

Design of microencapsulation

The Response Surface approach (RSM) research approach in conjunction with the Central Composite Design (CCD) was used to optimize the microencapsulation process. 10 In the past, a typical method for determining the primary influencing elements in the field of microencapsulation has been to examine the impact of one variable while holding the others constant. This approach, sometimes referred to as one-factor-at-time (OFAT) or one-

variable-at-time (OVAT), results in less-than-ideal procedures or finished goods [11]. This could be explained by factor interactions, which are not taken into account by the OVAT technique. A particular system behavior can be caused by the interaction of multiple variables [12]. The comparatively large number of tests that must be conducted, which makes the OVAT technique a time-consuming approach, is another drawback of the methodology [13]. The primary drawbacks of OVAT processes have recently been addressed by the application of multivariate statistical techniques as design of experiments (DOE) [14]. RSM is the widely empolyed multivariate statistical technique in the field of microencapsulation. The pharmaceutical and food research industries have mostly described the use of RSM for microencapsulation optimization procedures.

Methods

Coacervation

The most used encapsulating method is coacervation. The process typically involves three steps with constant agitation: (1) creating the reaction medium (a coating polymer solution in which the core is suspended); (2) precipitating and depositing the coating material; and (3) solidifying or stiffening the deposited coating material [15].

Coating deposition

With the help of careful blending of the polymer and the core substance in the solvent. By lowering the system's overall interfacial energy, the polymer is encouraged to adsorb at the interface that forms between the solvent and core. To help the created coat over the core material solidify or harden, step three involves adding cross-linking agents or using heat or desolvation processes [16, 17].

Ionotropic gelation

One popular technique for producing hydrogels is ionotropic or ionic gelation. This method produces enclosed particles through the hydrophilic polymer-based interaction of an oppositely charged molecule with a cationic or anionic polymer [18]. This method frequently makes use of biodegradable polymers such as gellan gum, chitosan, sodium alginate, gelatine, and carboxymethylcellulose [19, 20]. At concentrations below the gel point, these polysaccharides form gels. Large amounts of water or other fluids can be absorbed by the hydrophilic, three-dimensional matrix that forms. This technique is ideal for encasing hydrophilic core materials and is non-toxic [21, 22]. It is straightforward, affordable, and perfect for low molecular weight substances, but one of its disadvantages is that it is not very mechanically stable in acidic environments [23].

Pharmaceutical and wastewater applications have documented the use of sodium alginate hydrogel beads with divalent cations including calcium, and barium salts as well as polyvalent cations such Al3+. In drug encapsulation applications, sophisticated coacervation involving two polymers, such as chitosan and alginate [20].

Solvent evaporation

Core materials that are hydrophilic or hydrophobic can be encapsulated using this technique. There are two steps in it [24]. The polymer and the core material to be encapsulated are dissolved by a volatile solvent during emulsification. At the same time, distilled water alone is utilized as the aqueous phase in a basic evaporation process, with additives such as surfactants in complex emulsification procedures to create a stable emulsion. Then, the organic solvent is removed to generate nanospheres, which can then be collected as a free-flowing powder, coated onto a substrate, or used in suspension. After being separated by ultracentrifugation, the generated nanoparticles are rinsed with distilled water to remove any leftover additive residues or free, non-encapsulated core material. They are then freeze-dried and kept as a freeze-dried powder. [25]

Supercritical fluid assisted encapsulation technique

Upper their critical temperature and pressure, supercritical fluids are very compressed gases that can exist as liquid and solid [26]. Their density varies significantly, with a minor variation in temperature and pressure. Because they are environmentally friendly, carbon dioxide (CO2) and water are frequently utilized as supercritical fluids in industrial and laboratory settings. Supercritical carbon dioxide, or SCO2, is frequently used in pharmaceutical and food encapsulation processes. SCO2 is a great solvent for encapsulation because of its special qualities, which include viscosity, excellent solubility, non-toxicity, non-flammability as well as its affordability [27].

Sol-gel method

A colloidal suspension (sol) is formed in the sol-gel process, and then a network is built in an external liquid phase (gel). This procedure utilizes core and polymer suspension formation (Sol), which converts a sol into a gel and then solidifies [28]. Metal substances include metal alkaloids, metal chlorides as oxides, water as hydrolysis agents, and alcohol as a solvent. The sol-gel technique often involves hydrolysis and polycondensation processes. Near room temperature, metal compounds quickly go through hydrolysis and polycondensation reactions, producing sols that contain small particles or polymers [29].

Liposomal encapsulation

A liposome is a spherical vesicle made up of water molecules encased in one or more phospholipid bilayers. It has a structure very similar to that of the human cell membrane and can be made from natural phospholipids [30]. A hydrophilic head and a hydrophobic tail make up a phospholipid bilayer, with the polar head arranged as inner and exterior aqueous phases. Liposomes are frequently employed as a nanocarrier because of their structure, which is both hydrophilic and hydrophobic [31].

Characterization

The morphology of microparticles is recognized by scanning electron microscopy (SEM). Their chemical composition by Fourier transforms infrared spectroscopy (FTIR), thermogravimetric analysis (TGA), and first-derivative curves (DTG) [32,33].

CONCLUSION

A microparticle is a flexible drug delivery system that can be administered orally or parenterally. It should ideally generate the necessary plasma level and keep it constant for an extended amount of time, solve issues with traditional therapy, and increase the therapeutic efficacy of a particular drug. The development of colloidal and nano drug delivery systems for a range of drugs was made possible by the methods for producing microparticles through the microencapsulation process.

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