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MICROENCAPSULATION TECHNIQUES USED IN FOOD TECHNOLOGY

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ABSTRACT

Microencapsulation technique is used in various fields such as medicine, environmental remediations, agrochemical, pharmaceutical, cosmetics and food industry. Generally, microcapsules are used to contain bioactive compounds and keep them safe from moisture, oxygen, light, and other environmental factors. Microencapsulation works as a shield to regulate release, bioavailability and solubility; facilitates handling and transportation; and can also hide unpleasant flavors and aromas. This review summarizes techniques of encapsulation according to previous research and its applications in food processing. There are various methods for the process of microencapsulation such as spray drying, spray chilling, fluidized bed coating, etc. All these methods were specified in this review along with the various applications of the process in food processing industry.

Keywords: Microencapsulation, Bioavailability, Spray Drying, Spray Chilling, Fluidized Bed Coating.

I. INTRODUCTION

Presently, food producers and scientists around the world aim to identify and produce food that can be used as a source of beneficial nutrients to promote the health and well-being of consumers. Based on this, development of new food products that must include novel technologies and the use of traditional methods to control the bioaccessibility of certain food components is required and one effective way to achieve these goals is microencapsulation (Do Amaral et al., 2019). Microencapsulation technique is used in various fields such as medicine, environmental remediations, agrochemical, pharmaceutical, cosmetics and food industry. Generally, microcapsules are used to contain bioactive compounds and keep them safe from moisture, oxygen, light, and other environmental factors. Microencapsulation acts as a shield to regulate release, bioavailability and solubility; facilitates handling and transportation; and can also hide unpleasant flavors and aromas (Dias et al., 2015).

Microencapsulation is a technology in which the target active compounds are incorporated into the wall materials, forming capsules protected from external influences. The wall materials used in the food business are distinct and vary from those used in other industries. Agents used in the food business for encapsulating materials must have a number of characteristics, including degradability, resistance to gastric fluids, low viscosity, hygroscopicity, and affordability (Petkova, et al., 2022). The encapsulating material's separation breaks when a specified stimulus, such as pH or heat, is applied, releasing the active chemical in the specific target location or under the suitable conditions. Food matrices are also more complicated than those utilized in the cosmetics and pharmaceutical industries. Furthermore, in the food industry, microcapsules must be ingested orally, withstand gastrointestinal tract adverse conditions, and have mucoadhesive properties (Suave et al., 2006). For improving the characteristics of food ingredients, microencapsulation of food ingredients is practised in the food processing. For example, an important and useful bacterium used in the food processing industry, lactic acid bacteria, was initially immobilized in 1975 (Desai & Park, 2005c). Another example is microencapsulation of enzymes. Immobilized enzymes are more stable, and they have a wide range of uses, from the food sector to biotechnology (Haider & Husain, 2008).

Antioxidants, polyphenols, flavors, colors, preservatives, sweeteners, proteins, minerals, lipids, probiotics, etc can be used as encapsulated material (Anandharamakrishnan and Ishwarya, 2015). Carbohydrates like starch, maltodextrin, modified starch, cyclodextrin, and cellulose; lipids like wax, paraffin, beeswax, and diacylglycerols; gums like gum acacia, agar, and carrageenan; and proteins like gluten, casein, and gelatine are some of the coating materials. Large number of techniques for microencapsulation includes spray chilling, spray cooling, fluidized bed coating, liposome entrapment, extrusion, freeze drying, and coacervation (Choudhury et al., 2021). Microcapsules are made up of an encapsulating or wall-material that covers a core containing an active substance and have a diameter ranging from 0.2 to 5000 m.. The final size of a particle depends upon numerous factors, such as method of processing and the nature of encapsulating material (Oxley, 2014). As a result, depending on the function or final destination of the microcapsule and the required particle size, it is critical to consider the type of wall-material that will be used in combination with a specific encapsulation process; the wall material also influences encapsulation efficiency and stability. (Gul, 2017). According to the physical and the chemical properties of the core, composition of the encapsulated material and the method of microencapsulation used, numerous types of capsules can be obtained such as simple sphere surrounded by the wall, irregular core capsules, multiple distinct cores within a continuous coating of wall material, microcapsules with multiple walls and core particles embedded within the matrix of wall material. Depending on the type of wall coating material used, Microcapsules are made using various methods and techniques, which result in changes in attributes such as capsule size, morphology, porosity, hygroscopicity, hydrophobicity, surface tension, and thermal behaviour. (Choudhury et al., 2021). This review summarizes techniques of encapsulation according to previous research and its applications in food processing.

II. IMPORTANCE OF MICOENCAPSULATION

Microencapsulation helps in increasing the stability and shelf life of the product being encapsulated. This technique is useful in converting liquid solution into powdered form. Bioactive components which are sensitive to moisture, light, pH and oxygen can be stabilized using encapsulation technique. Incompatibility between the different bioactive components and food matrix can be prevented. Microencapsulation prevents the volatile food components from vaporizing at room temperature. Controlled release of active components takes place. Therefore, it gives a wonderful opportunity to food manufacturers so as to produce healthy and economical food for the consumers of every segment.

III. TECHNIQUES

SPRAY DRYING

Since the 1950s, microencapsulation using the spray drying technology has been used in the food processing business. Spray drying was originally used to protect flavours from degradation and oxidation, as well as to dry solid solutions, but it is now being used to protect bioactive compounds and probiotics. (Gouin, 2004; Pu et al., 2011). When compared to other microencapsulation processes used in industries, spray drying is a relatively low-cost, rapid, and repeatable technique that allows for easy scale-up (Pu et al., 2011). It's a process in which a liquid is atomized in hot air to produce a powder in an instant (Estevinho et al, 2013). A suspension, an emulsion, or a solution can be used as the feeding liquid. The following are the main steps in this procedure: atomization, droplet-air contact creation, water evaporation, and dry product and humid air separation (Gharsallaoui et al., 2007). Spherical shape and smooth surface observed in dry powder is formed due the the generation of frictional forces and multidirectional rotation of particles. Particle friction along with the walls of the dryer and between the particles is generated by the high speed of air stream which results in the agglomeration of particles having polished surface. The dried product is gathered at the bottom of the cone - shaped drying chamber, owing to the centrifugal force produced on the particles by the gas stream, and the particles' subsequent impact on the surface of a collecting cylindrical blanket. Another separating method is the electrostatic precipitator, which uses an ionizing gas to charge the dried particles, and the charged particles settle on the collecting plates at the bottom of the drying chamber due to coulombic forces. (Piñón-Balderrama et al., 2020). The major disadvantages of this technique are: it is not a good option for thermolabile compounds, particles formed are non-uniform and can also form aggregates. The particle size of powders created by traditional spray drying can be divided into three categories: small (1–5 m), medium (5–25 m), and large (10–60 m). (Vicente et al, 2013).

SPRAY CHILLING

The use of spray chilling, which uses hydrophobic substances as wall material, has been exploited in different pharmaceutical and food industries (Okuro et al., 2013). As compared to other techniques of microencapsulation this is used under low temperature conditions and also has a successful release mechanism. This method is fast, easy-to-use, and relatively less costly. Due to these advantages, spray chilling has been widely used in the microencapsulation of functional and active materials that are volatile and/or heat/water-sensitive in nature (de Matos-Jr et al., 2017). The spray chilling wall materials are hydrophobic, and

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the powders obtained are water insoluble, which protects the core material inside. (Desai & Jin Park, 2005; Gadkari & Balaraman, 2015). Spherically solidified microcapsules obtained because of the atomization of emulsions prepared by spray chilling method into the cold air (Gunel et al., 2021). The spray chilling encapsulation technique is a promising alternative, since it can protect heat sensitive bioactive molecules such as vitamin-B12 without using high temperatures or organic solvents to encapsulate it, besides having a low cost (Mazzocato et al., 2019). It has certain limitations such as it is specific for hydrophobic compounds, has a rapid release rate of active compounds, non-uniform particle size and variable encapsulation efficiency.

COMPLEX COACERVATION

The term "coacervation" is used in colloidal chemistry to describe a process of bonding phase separation that occurs due to changes in the environment (pH, ionic strength, temperature, solubility) of the medium under controlled conditions. In this process, the colloid-rich phase is called the coacervate phase, and the colloid-free phase is called the equilibrium phase (Narim., 1995). The complex coacervation process involves three-phases: the solvent, the active material and the coating material. Generally, this process involves four steps: (a) preparing an aqueous solution of two or more polymers which is usually prepared above the gelling temperature and isoelectric point of protein; (b) mixing hydrophobic phase to the aqueous solution of one polymer, and homogenizing the resulting mixture to make a stable emulsion (c) The pH and temperature are adjusted to a specific level in order to cause coacervation and phase separation; and (d) hardening of the polymer matrices using high temperature, desolvation agent, or cross-linker (Ortega-Rivas et al., 2006). Although certain microencapsulation procedures for biofunctional compounds have been recognized, but complex coacervation remains the only approach with a high payload and 99 percent encapsulation efficiency. Furthermore, unlike other approaches, complex coacervation favours the creation of microcapsules with multiple cores, providing biofunctional compounds with a high level of protection against deterioration during processing and storage. This method has been utilised to encapsulate a variety of biofunctional components, including omega-3 oils, polyphenols, flavours, fat-soluble vitamins, and pigments, with great success. Compounds encapsulated using complicated coacervation processes have shown to exhibit exceptional oxidative stability and better controlled-release behaviour in previous investigations (Timilsena., 2019). However, the sensitivity of sophisticated coacervation technology to pH and ionic strength is one of the primary limiting issues for commercial implementation. (Augustin et al., 2006).

EXTRUSION

Extrusion technique is based on a polysaccharide gel that immobilizes the nucleus when in contact with a multivalent ion (Lai et al., 2021). This involves the inclusion of the core in a sodium alginate solution. Drop-extruded mixture is then incorporated into a curing solution, such as calcium chloride, through a reduced-caliber pipette or syringe (How et al., 2022). Rotating extrusion head containing concentric nozzles, are used for the encapsulation of liquids. A jet of core liquid is enveloped by a sheath of wall solution in this procedure. As it passes through the air, Jet breaks into droplets of core, each coated with the coating material solution. While the droplets are suspended in air, molten coating material may be hardened or a solvent may be evaporated from the coating material solution. Most of the droplets land in a narrow ring around the spray nozzle because their mean diameter is within 10% of the range. Therefore, if required, the capsules can be hardened after formation by keeping them in a ring- shaped hardening bath (Naveena and Nagaraju, 2020).

FLUIDIZED BED COATING

Fluidized bed coating is generally used for encapsulation of solid core materials including liquids absorbed into porous solids. This method is used widely to encapsulate pharmaceuticals but now its use in the food processing industry has been increased. The solid particles to be encapsulated are suspended in a jet of air and then covered by a spray of liquid coating material (Naveena and Nagaraju, 2020). After that, the capsules are carried to the solidification area, where their shells are solidified either by cooling or solvent vaporisation.. The process of suspending, spraying and cooling is repeated until and unless the capsule walls are of the desired thickness. By using this technique ascorbic acid has been microencapsulated in polymethacrylate as well as ethyl cellulose (Dubey, 2009). Fluidized bed granules are more efficient at coating, retain more bioactive compounds, and have superior flow characteristics than spray-dried powder. (Benelli et al., 2015).

INTERFACIAL POLYCONDENSATION

As the term "interfacial" suggests, this technique comprises the polycondensation (condensation polymerization) of two complementary monomers at the interface of a two phase system. Interfacial polymerization or polycondensation method has been used for microencapsulation of a wide variety of core materials, that includes aqueous solutions, water-immiscible solids and liquids (Marison et al., 2004). This method is one in which two monomers, one oil-soluble and other water-soluble, are used and a polymer is formed on the droplet surface. This polymerization process brings the two reactants together at the interface of the dispersed and continuous phases in the emulsion system. Polyurea, polyamide, polysulfonamide, polycarbonate, and polyurethane are polymeric materials that are used to make microcapsules using the polymerization procedure. But one of the problem with technique is that the reagent dissolves in the core material, resulting in a chemical interaction between the reagent and the core material.

IV. CONCLUSION

Encapsulation is a process for covering a bioactive molecule with a protective wall material that has a number of benefits. Microencapsulated foods offer a wide range of applications, including the preservation of diverse microbes, nutritional components, enzymes, colours, and other substances, as well as safeguarding food and other items from harsh processing processes and the environment. Every new microencapsulation application poses a new set of challenges. Solving these puzzles necessitates ability, expertise, and a thorough understanding of a variety of technology. We will be able to improve the nutritional characteristics and health advantages of food components by creating new methodologies and sophisticated strategies for food ingredient stability. Microcapsule preparation processes and materials are diverse, allowing for a wide range of applications and uses.

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