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# OVERVIEW ON APPLICATION OF ENCAPSULATION TECHNOLOGIES FOR ACTIVE FOOD INGREDIENTS

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**Abstract–**Encapsulation is the technique of encasing macroscopic particles by coating in a homogeneous or heterogeneous matrix to produce miniature capsules. Food components, enzymes, cells, and other elements are incorporated into miniature capsules. Micro/nano capsules can be used to preserve sensitive food components, restrict nutritional loss, include unique or time-release mechanisms into the formulation, conceal or sustain flavors and odors, and modify liquids into readily handled solid materials for food processors. Wall materials are essential in the production of micro/nano capsules because they protect the bioactive substances from external influences. Different wall substances are utilized, including lipids, carbohydrates, proteins etc., Some of the different procedures used to produce capsules are spray drying/ chilling/cooling, fluidized-bed coating, coacervation, inclusion complexation, centrifugal/melt injection extrusion. This review highlights recent advancements in each of these technologies.

## INTRODUCTION

Today, food is being used to not only satisfy the primitive drive of hunger, but also to boost the consumer's health. And also, Consumers are paying more and more attention to the nutritional aspects of food. With respect to this, the recent developments in functional foods match the recent trends with the developing of novel health-promoting products. A higher stability among the nutriments and the addition of indigestible fractions and complementation of hint element, nutrients or additives seems as a requirement for the development of novel products (El-Kader and Abu Hashish, 2020).

The food industries lately demonstrated increasingly complex formulations such as the use of highly volatile flavour compounds in instant functional foods, microorganisms in fermented meat etc., (Silva *et al.,* 2014). Furthermore, there are significant difficulties in the development of functional foods, particularly when there is involvement of some bio-actives directly. These can be unstable, react with other elements in the food matrix, or have a strong odor or flavour. With this reference, encapsulation appears to be a promising approach for resolving these issues while also allowing for targeted or controlled administration (Dias *et al.,* 2015).

Encapsulation is a mechanical or physiochemical process that entraps an active ingredient within a wall material. Core material, active agent, fill, internal or payload phase are all the terms used for referring the encapsulated substance. The encapsulated substance is referred to as the core material, internal phase, fill, active agent or payload phase. The substance that is encapsulating is referred to as a coating, external phase, membrane, capsule, carrier material, shell or matrix (Nedovic *et al.,* 2011).

Encapsulation has enormous applications in industries such as pharmaceuticals, agriculture, medicine, and food. It is widely used to encapsulate natural food compounds such as carotenoids, volatile essential oils, colorings, enzymes, flavorings, vitamins, minerals, sweeteners,

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polyphenols, microorganisms etc., are entrapped in microparticles or nanoparticles to keep their properties unchanged (Eghbal and Choudhary, 2018; Silva *et al.*, 2014).

Encapsulation was primarily adopted in the area of biotechnology to improve the efficiency of product-processes. These technologies, which were invented more than 60 years ago, are of great importance to the pharmaceutical business (particularly for vaccine and drug administration), yet they are also relevant to the food industries (Poncelet *et al.*, 2011; Nedovic *et al.*, 2011).

The following are the main reasons for adapting encapsulation:

- It aids in the creation of barriers amongst sensitive bioactive components and the environment, allowing for the distinction of taste and aroma while masking out unpleasant odours or flavours.
- Ensures sufficient concentration and uniform distribution of active agents.
- It also involves in stabilizing or increasing the bioavailability of food components to avoid unfavourable interactions with the food matrix all through production and storage.
- Encapsulation is employed to improve the physical properties of the original substance so as to permit to make it easier to handle and to separate the components of a mixture that could otherwise react with each other.
- Dry processing by converting viscous liquids and sticky solids into free-flowing powders. (Saleh and Guigon, 2007; Balassa *et al.*, 1971; El-Kader and Abu Hashish, 2020; Nedovic *et al.*, 2011).

Spray drying and extrusion are the two foremost used industrial encapsulation processes. Whereas, Minor techniques, such as freeze drying, fluidized bed encapsulation, coacervation, wax or fat encapsulation, molecule inclusion in cyclodextrin, and co-crystallization (Luzzi, 1970; El-Kader and Abu Hashish, 2020). Micro- and nanoencapsulation technology in the food sector is a very promising area that will have a significant impact on a wide range of products, including functional foods, packaging, preservatives, antioxidants, flavors etc., (Bratovcic and Suljagic, 2019). The main objective of this paper is to review different encapsulation techniques, materials required for micro-encapsulations and recent trends employed in food industries.

## MATERIALS REQUIRED FOR ENCAPSULATION

### Capsules

Capsules with a diameter size between 1–1,000 μm are called as microcapsules and the capsules above (> 1 mm) are called as macro capsules, while Nano capsules are defined by their size range of 1 nm to 1,000 nm.

Capsules can have a wide range of morphologies based on the material used for their manufacture, but their ultimate outcome or design is also influenced by the preparation process. The two major different capsules based on their structure are microcapsules and microspheres. Microcapsules, on the other hand, are categorized into mono core/ shells, poly-core capsules, and continuous core capsules with several layers of shell material. Whereas, the encapsulated material encased within the shell material of the microsphere, also known as the matrix type. Different morphologies are produced based on the fabrication process utilized. Table 2 shows a rough approximation of the capsule size range achieved with each technique (Trojanowska *et al.*, 2017)

### Wall materials

Wall materials play a crucial role within the development of micro-/ nano capsules to shield the bioactive compounds against external factors. The ideal wall material selection is critical since it impacts the microcapsule's encapsulation efficiency and stability. The parameters for the matrices may vary depending on the component, the method, and the application, necessitating varied forms (films, spheres, irregular particles), as well as a wide range of structures, including rubbery or glassy, compact or porous, amorphous or crystalline (Wandrey *et al.*, 2010).

As almost no coating or wall material can fulfil all of the listed properties, they are usually combined with more than one coating materials and/or modifiers such as oxygen scavengers, antioxidants, chelating agents (Shahidi and Han,1993). Such coating or wall materials are listed below in the Table 1

The wall material must possess certain properties such as

- Inert to the active ingredients of the core
- Stabilize the core material, ability to form film
- Be flexible and tasteless, non-hygroscopic

**Table 1.** Different types of coating materials used and its properties:

| Coating Material | Source | Properties |
|---|---|---|
| Carbohydrate | Sucrose, dextrin, starch, corn syrup | higher tensile strength, hydrocolloidal |
| Gums | Arabic gum, carrageenan, gum acacia, agar, gum karaya, sodium alginate | Hydrocolloidal, low tensile strength, formation of soft elastic gel |
| Chitosan | Chitin from exoskeleton of crabs, shrimps, lobsters | poor solubility at physiological pH, biocompatibility, low production cost, susceptibility to enzymatic hydrolysis, good barrier to gases and water vapour |
| Protein | Gelatin, albumin | Greater stability, shape, water binding capacity, emulsification, formation of gel, foaming |
| Lipids | Fatty acids/ alcohols, bee wax, oils, tristearin, monoglycerides, phospholipids | Effective barrier to gas and water vapour, |
| Synthetic polymers | Acrylonitrile, polybutadiene, poly caprolactone | biocompatibility and slow biodegradability |

(Choudhury *et al.,* 2021; Vijeth *et al.,* 2019)

- Slightly viscous, cost-effective
- Soluble in aqueous media or solvents
- Coating should be soft, brittle, hard, and thin
- Should be regarded as food grade (GRAS)
- Controlled release under specific conditions (Vijeth *et al.,* 2019)

**Core Materials**

The particular material to be coated is referred to as the core material (a biologically active substance). The core material can possess diversed compositions, such as a liquid core with distributed and/or dissolved materials and solid core that can be single solid substance or mixture of active constitute. The typical core substances for food are as follow; colorants and dyes, flavors, minerals, vitamins, animal feed ingredients, deodorants, oils, perfumes, stabilizers, sweeteners, nutrients, and antioxidants (El-Kader and Abu Hashish, 2020).

**Controlled core release**

Microencapsulation process entails a number of steps:

1. Formation of a wall or shell around the core material
2. The core material must be kept inside the shell to prevent it from escaping and undesired materials from entering the core.
3. The core material is released at the appropriate time and at a regulated rate.

According to Shahidi (2011), One of the most essential aspects of the microencapsulation process is the well-controlled release of core material (Shahidi and Han, 1993). Therefore, well-controlled release delivery system increases the efficacy, lowers the amount of additives required, and broadening the applications of compounds of interest (Silva *et al.,* 2014).

Therefore, according to Robert Sobel, understanding the controlled release mechanism of food ingredients is essential so that the release of food ingredients can be controlled through microcapsules. The main mechanisms involved in the core release are fracturation (shear or pressure release), diffusion (temperature, pH), degradation, dissolution or melting (release of moisture or solvent). In practice, a combination of more than one mechanism is used (Sobel *et al.,* 2014) 16; Barbosa *et al.,* 2005).

**Encapsulation Techniques**

Encapsulation of food ingredients on a micro or nano scale are carried out by utilising various techniques. The method of encapsulation employed is constrained by a number of factors such as the characteristics of core and wall materials, particle size, intended release rate, processing steps, and the final application of the encapsulated particles (Saifullah *et al.,* 2019)

**Spray Drying**

Spray drying is the process of converting a feed from a liquid state (which can also be in the form of solution, dispersion, or paste) to a dried particle state by spraying it into a heated drying medium (I Ré, 1998). Spray drying is one of the oldest and widely used encapsulation methods in the food sector. The first spray-dried flavour powders were

developed in 1932 by A. Boake, Roberts & Co., Ltd., in which a thin layer of gum Arabic was used to encapsulate the flavours. Spray drying has emerged as one of the most important technologies in the food and beverage sector for producing dry flavors from liquids since then (Barbosa *et al.*, 2005).

The major benefits of spray drying are it is diversified, a cost-effective operation, continuous and most importantly it has the significant benefits of obtaining a high yield with the maximum encapsulation efficiency by using the ideal feed composition. However, this technique has a number of drawbacks which includes the complexities of the equipment, non-uniform drying chamber temperatures, and the inability to regulate particle size and this approach is only suitable for volatile or thermo-sensitive bioactive chemicals (Basar *et al.*, 2021; Nedovic *et al.*, 2011)

**Wall materials**

Various wall materials have been used in spray drying in which Gum Arabic and Polydextrose, is widely used encapsulating agents in spray drying. Gum Arabic includes properties such as low caloric value, has high prebiotic impact, high digestive tolerance, and high soluble fiber content. Polydextrose, on the other hand, is a non-digestible polysaccharide that is highly soluble, low in calories, and commonly used as a sugar replacement (Rigon and Norena, 2016). And hence, depending on the materials, temperatures between 150 and 300 °C can be operated, and generally, the mean size of the generated particles is in between 10-100 μm (Basar *et al.*, 2021)

**Process Conditions**

The major phases in spray drying microencapsulation are as follows: the emulsion or dispersion's preparation; homogenization; atomization of the infeed emulsion; and dehydration. The initial step involved is the preparation or formation of emulsions, comprising the combination of active core and wall materials. The matrix is dissolved in a solvent, with the active core usually being insoluble (solid) or immiscible (liquid), depending on the final application of the microcapsule. A vigorous mixing (homogenization) gives a dispersion (for solids) or an emulsion (for droplet liquids). The emulsion produced must remain stable over time. should be stable over time, the oil droplets has to be exceptionally small, and the viscosity of the liquid should be low enough to avoid entrapping of air in the particles prior to the spray drying step. Therefore, encapsulation by spay drying is influenced or affected by emulsion viscosity and particle size distribution. The mixture is then atomized using a nozzle. The atomized particles come into contact with a hot air chamber circulating in either a counter-current or concurrent direction, evaporating the water and encasing the core. The inlet and exit temperatures are 140-220 °C and 50-80 °C, respectively, to prevent thermal

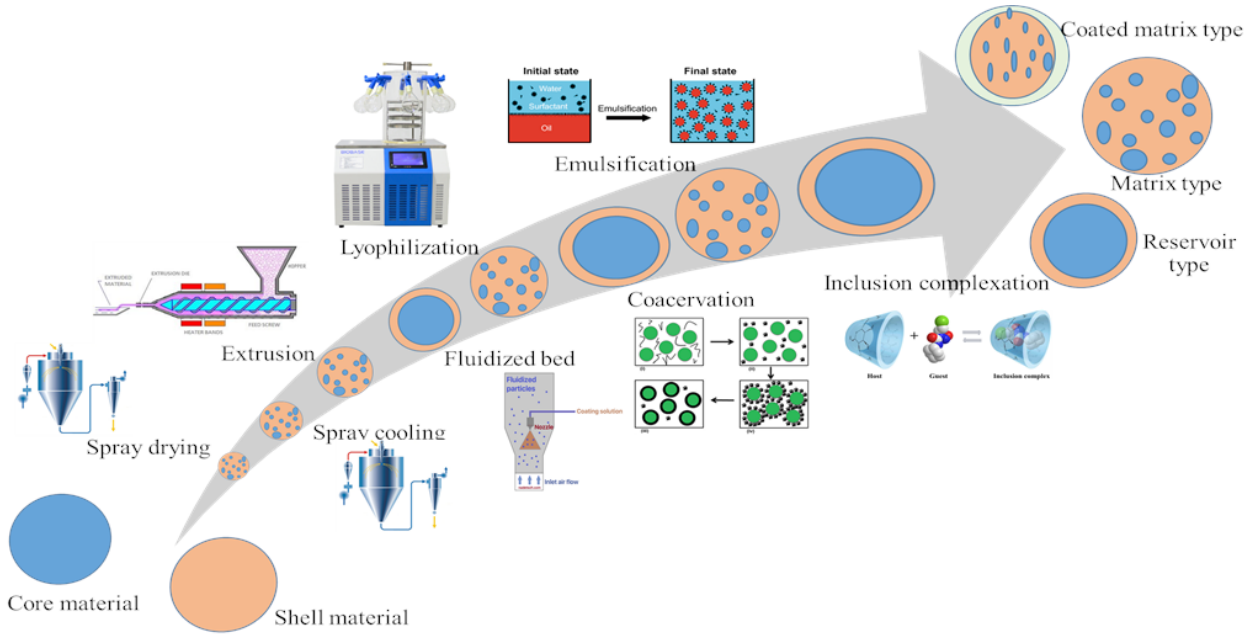


**Fig. 1.** Different encapsulation techniques and its morphology of shell materials.

damage. Then, the separator collects the dried capsules. The primary goal of the atomization process is to create a large heat transfer surface between the liquid and the dry air, which improves heat and mass transmission indirectly. The atomizer utilized is determined by the viscosity of the feed material. Thus, the three basic factors in spray drying that must be optimised are the feed temperature, air inlet temperature, and air output temperature (Kandansamy and Somasundaram, 2012; Gharsallaoui *et al.,* 2007; Patel *et al.,* 2009).

In an experiment conducted by Souza *et al.* (2018), Spray drying technology was employed to microencapsulation the tomato concentrates by using the concentrate solids and encapsulating agents in the ratio 1:3 with the operational conditions of feed flow rate of 34 mL/min; with compressed air pressure of 350 kPa; outlet and inlet air temperature of 80 ± 2 °C and 160 ± 2 °C respectively, resulted in a product with higher lycopene and carotenoid concentrations, and antioxidant capacity. Maltodextrin and Capsul modified starch, as well as the combination of the two, were observed to protect lycopene effectively during drying and storage. Consequently, these encapsulating agents were found to be appropriate for encapsulating tomato concentrate (Souza *et al.,* 2018).

Rigon and Norena, (2016) used Gum Arabic (GA) and polydextrose (PD) as encapsulating agents to microencapsulate the blackberry aqueous extract at concentrations of 10 and 15%, respectively. with the operational conditions at a flow rate of 0.60 L/h; drying air temperature of 140°C and 160 °C; compressed air pressure of 3.5 kgf/cm$^2$ and an airflow of 40.5 L/h. According to the findings, spray-

**Table 2.** Overview of encapsulation techniques and it's methods

| Method | Particle size [μm] | Process | Morphology |
|---|---|---|---|
| Spray Drying | 10–120 | 1. In an aqueous coating solution, disperse or dissolve the active substance.<br>2. Homogenization<br>3. Atomize<br>4. Dehydration | Matrix |
| Spray chilling/ cooling | 20–300 | 1. In a heated lipid solution, disperse or dissolve active substance<br>2. Atomization<br>3. Cool | Matrix |
| Extrusion | 1 – 10.000 | 1. Coating is melted<br>2. Disperse or dissolve active in the coating<br>3. Use a twin-screw extruder to extrude<br>4. Cool | Matrix |
| Fluidized-bed coating | 5–5,000 | 1. Preparation of coating solution<br>2. Fluidization of core particles.<br>3. Coating of core particles | Reservoir/ Matrix |
| Lyophilization | 1 – 1.000 | 1. Combining of core in a coating solution<br>2. Freeze-drying of the mixture | Matrix |
| Coacervation | 10–800 | 1. Emulsification/dispersion<br>2. Coacervation/ Deposition of the coating.<br>3. Hardening of the coating and rinsing/ filtering/drying | Reservoir |
| Emulsification | 1–100 nm; 0.2–5000 | 1. In a water or oil phase, dissolve the active ingredients and emulsifiers.<br>2. Under shear, combine the oil and water phases. | Matrix |
| Inclusion complexation | 0.001– 0.01 | 1. Combine the carrier, active ingredient, and water.<br>2. Incubate and dry if required | Reservoir/ Molecular inclusion |

(Jafari, 2017); Arenas *et al.,* 2020)

dried samples containing 15% gum Arabic at 140 °C retained more bioactive substances like anthocyanins, phenolic compounds. By the DPPH and ABTS method, the antioxidant activity was found to be 40.26 % and 45.15% respectively (Rigon and Norena, 2016)

**Spray chilling/ spray cooling**

Spray-chilling and spray-cooling are lipid-based system. The melting point of lipids distinguishes between these two methods. In spray chilling and spray cooling method, it utilizes carriers with a melting point of 32-42 °C and 45-122 °C for the production of spray particles respectively (Okuro *et al.,* 2013). The substance might be dissolved in lipids, as dry particles or aqueous emulsions. Spray cooling is a method that may be used in both continuous and batch processing modes to produce high yields. Spray-chilling involves keeping the particles at a low temperature in a similar setup to fluidized bed spray granulation (Nedovic *et al.,* (2011).

**Extrusion**

Extrusion based encapsulation is a convenient approach for producing exceptionally densed encapsulated products. Extrusion based encapsulation is a convenient method that can be applied to produce highly dense encapsulated products (Timilsena *et al.,* 2020). Extrusion is a process that involves forcing a material to flow through an orifice with varying diameters at a specified rate under different conditions (high and low temperature, high and low moisture, and high and low speed) to achieve various types of products (Bamidele and Emmambux, 2020). Extrusion consists of combining the bioactive substance with the encapsulant material and pass through the extrusion nozzle, thus resulting in droplets that are transformed into capsules in a solidification bath (Fangmeier *et al.,* 2019). The nozzle system relies on gravity and jet stream break-up for formation of capsules. The process of extrusion technology mainly consists of three phases: The initial step is to melt the carrier carbohydrate matrix with the plasticizer (often water or glycerol), if required. The wall materials used may be composed of more than one ingredient such as gelatin, sucrose, glucose, gum acacia, sodium alginate, glucose syrup, glycerin, carrageenan, starches, cellulose derivatives, maltodextrin, fatty acids, waxes, and polyethylene glycol. To avoid thermal deterioration of the active component, the melting temperatures are usually between 110 and 140 $^{o}$C, and the pressure is less than 690 kNm$^{2}$. Whereas, in the second step the active component is added directly or as an oil-in-water emulsion to the carrier mixture melt. And in the third step, through a die, the mixture is forced to evacuate. Extruded filaments are then dried and sized after being removed from the liquid bath (Castro *et el.,* 2016). The main benefits of extrusion encapsulation over other encapsulating technologies are that the resulting product has larger particle sizes (0.1-5.0 mm). The major benefits of extrusion-based encapsulation is that the resulting product has greater particle sizes (0.1-5.0 mm) than other encapsulation techniques (Timilsena *et al.,* 2020) Another advantage is that the wall material completely encloses the substance (true encapsulation). This gives the product high oxidation resistance and so extends the shelf life, without any significant quality loss the product can be stored for 1–2 years (Yuliani *et al.,* 2004). The absence of solvents and high temperatures are also the benefits of this method. However, as the microsphere production process is slow, the difficulty of scaling up the procedure to an industrial scale is a major drawback (Fangmeier *et al.,* 2019).

The co-extrusion process uses a concentric nozzle system and is carried out under the same parameters as extrusion. Vibrational technologies are used in this system to split the laminar liquid jet into equal-sized droplets, which are collected at the end of the operation (Silva *et al.,* 2018). Encapsulation by this technique is ideal for preservation of food components (Schlameus, 1995).

Melt injection extrusion is a low temperature extrusion technique that uses molten wall materials to encapsulate bioactive compounds. In Hot extrusion technology, the thermally stable bioactive compounds are encapsulated by distinct wall materials. In PGSS extrusion process, the supercritical fluid like $CO_2$ is used to encapsulate the bioactive compounds. Electrostatic extrusion is a relatively new technique for encapsulating bioactive substances. It is a batch method that allows heat-labile bioactive compounds to be encapsulated in smaller particle sizes (Bamidele and Emmambux, 2020).

Chang *et al.,* 2019, encapsulated ascorbic acid in maltodextrin matrix by using hot melt extrusion process, which resulted in encapsulation rate of 96% (Chang, D, 2019)

Lai *et al.* 2020, worked on microencapsulation of

*Lactobacillus rhamnosus* GG with Flaxseed Mucilage wall material using Co-Extrusion method, resulted in producing smooth surface microbeads and obtained high microencapsulation efficiency of 98.8% and also showed the ability to protect during microencapsulation and gastrointestinal environment (Lai *et al.,* 2021)

**Fluidized Bed Coating**

Fluidized bed coating involves spraying a bioactive chemical composition enclosed in an encapsulating matrix over a fluidizing bed of seed particles. The composition thus encroaches and spreads on the surface of the particles, and the solvent is evaporated by the fluidizing air to produce agglomerated/coating particles (Benelli and Oliveira, 2016). Water-insoluble and water-soluble polymers, lipids, and waxes are among the materials used in fluidized bed coating. At a particular temperature, coating solution is sprayed onto the particles/granules. Because high temperatures are not required, this technique is energy and time efficient (Timilsena *et al.,* 2020). Spray dried microcapsules can, however, be further coated with a fat layer using fluidized bed to improve protection and shelf life (Poshadri and Aparna, 2010). Therefore, this technique is frequently used to coat primarily encapsulated materials with a secondary layer. In addition to desirable characteristics of conventional fluidized bed, it also permits several elementary operations such as coating, wetting, drying and agglomeration to be carried out simultaneously in a single step of apparatus, all while being influenced by a number of processing factors (Saleh and Guigon, 2007)

A study conducted by Schell and Beermann (2014), it showed for *Lactobacillus reuteri* DSM 20016, fluidized bed technology with a mix of sweet whey and shellac as encapsulating material provides unique acid resistance and enhanced survival during gastro-intestinal transit (Schell and Beermann, 2014)

**Coacervation**

The separation of a liquid phase into a polymer-rich (coacervate) and a polymer-poor phase is known as coacervation (Aloys *et al.,* 2016). The process includes separation of a liquid coating material phase from a polymeric solution, coating of that phase as a homogenous layer surrounding the suspended core particles, and solidification of the coating. For coacervation microencapsulation, a wide range of coating materials have been explored, although the gelatin/gum acacia combination is perhaps the most researched and comprehended. Other wall materials are also being investigated, including gliadin, carrageenan, chitosan, soy protein, polyvinyl alcohol, gelatin/carboxymethyl-cellulose and guar gum/dextran (Poornima and Sinthya, 2017).

Coacervation process is classified as simple and complex. One coating material (usually pectin) is used in simple coacervation. The pH, ionic strength, temperature, and macromolecule structure influences the simple coacervation process. For example, the net charge of gelatin gets balanced when the pH is adjusted to a value around the isoelectric point of gelatin at low ionic strength and thus the microcapsules are formed when molecules expands and settle (El-Kader and Abu Hashish, 2020). Complex coacervation also known as "polymer-polymer interaction method" is a phase separation method, includes formation of a coacervate between oppositely charged polymers, usually proteins and polysaccharides. The pH and polymer concentration have significant influence on complex coacervation (Xiao *et al.,* 2014). Negatively charged polysaccharides (such as acacia, pectin, alginate, and carboxy methyl cellulose) interact with positively charged proteins (such as gelatin, soy protein isolate) (El-Kader and Abu Hashish, 2020). Thus, encapsulation by complex coacervation is a known approach for synthesizing nanoparticles with a lipid core. This procedure could be implemented to produce nano/microencapsulation systems to increase desirable functionality and multiple benefits including preservability, miscibility, deliverability, and controlled release of the ingredients, high payload of core ingredient, low fabrication loss, the finished powder product has a higher mechanical strength, and in the encapsulation of high-value bio functional ingredients (Wang *et al.,* 2018; Aloys *et al.,* 2016).

**Emulsification**

Emulsification is a chemical embedding procedure in which a dispersed phase of core and wall material is added to a continuous phase of vegetable oil, under the action of the cross-linking agent, comprising the emulsifier to form a stable emulsion and microencapsulate. The viable preparation process was accomplished by this method, despite the high survival rate and flexibility of encapsulated probiotics, and the manufacturing cost was usually

relatively high due to the enormous amount of vegetable oil required (Yang *et al.,* 2020).

**Lyophilization**

Lyophilization, often known as freeze-drying, is a method usually used for encapsulating the thermosensitive and aromatic compounds. The chemical composition of the system influences the preservation of volatile chemicals during lyophilization. This method is used to encapsulate pharmaceuticals as well as water-soluble essences and natural odors (Poshadri and Aparna, 2010). Lyophilization, a popular food-processing technique, can also be used to stabilize and preserve liposomes while also extending their shelf life (Lopez-Polo *et al.,* 2020). Its economic sdisadvantages are, the need for a long process time (24–48 hours), and limit its utilization. Lyophilization, on the other hand, provides a significant advantage in the encapsulation of therapeutic chemicals since high-value products will be developed, necessitating the use of bioactive chemicals with higher biological activity (Rezvankhah *et al.,* 2020). Several elements affecting the freeze-drying process success includes the formulation, container, equipment, and freeze-drying method itself. As a result, freeze-drying emulsified systems has proven difficult, as it necessitates a detailed analysis of the formulation and process conditions in addition to assure the systems' long-term stability (do Vale Morais *et al.,* 2016).

**Inclusion complexation**

Inclusion complexation is also known as molecular encapsulation uses β-cyclodextrins to complex and entraps molecules (Jackson and Lee, 1991). It is the process of encapsulating the supramolecular attachment of ligand into a cavity bearing wall material by different methods such as entropy-driven hydrophobic effect, hydrogen bonding or also by van der Waals force. The inclusion complexation is mostly employed to encapsulate volatile chemical compounds such as essential oils and vitamins. It can be used to conceal off odours and flavors while also preserving fragrances. This approach works well with β-cyclodextrins and β-lactoglobulins (Bratovcic and Suljagic, 2019).

**Nano encapsulation**

Nanoencapsulation is defined as a process that uses techniques such as nanocomposite, nano-emulsification, and nano-structuration at the nanoscale level, to encapsulate chemicals in miniature and bioactive packaging, resulting in a final product (Bratovcic and Suliagic, 2019). Nanoparticles are colloidal molecules with sizes varying from 10 to 1,000 nm that were already formed as nano capsules and nanospheres. Nano capsules constitute vesicular structures during which a bioactive material is enclosed in a chamber covered by a particular polymer membrane, however nanospheres are matrix systems whereby the bioactive substance is distributed uniformly (Ezhilarasi *et al.,* 2013). When particles are reduced to nanoscale, the surface-to-volume ratio significantly increases, providing nanoparticles a variety of appealing and unique features such as higher bioavailability, adsorption and solubility (Assadpour and Jafari, 2019). Nanoencapsulation also acts as a carrier for transporting the functional ingredient to the intended action site. They must be able to regulate the release of functional ingredient. And during production, storage, and usage, they safeguard the functional ingredient against chemical or biological deterioration (Bratovcic and Suljagic, 2019). Multiple nanoencapsulation methods had also were developed utilising food-grade components along with proteins, lipids and carbohydrates, making them suitable for application in food composition (Delshadi *et al.,* 2020). The most common nanocarrier food systems used for encapsulation are lipid or organic polymer biodegradable capsules. Nanoliposomes, archaeosomes, and nano-cochleates are three types of lipid-based nanocarrier systems that have potential in the pharmaceutical, cosmetics, and food sectors. Albumin, alginate, gelatin, chitosan, collagen and α-lactalbumin were among the natural polymers employed to produce nano delivery systems (Ezhilarasi *et al.,* 2013). Liquid-based nanoencapsulation procedures (emulsification-solvent evaporation, coacervation, nanoprecipitation, inclusion complexation, and supercritical fluid technology), electro-hydrodynamic procedures (electro spraying electrospinning and), and drying technologies are also available (freeze drying and spray drying) (Bharathi *et al.,* 2018).

**Conclusion and Future Prospects**

In light of modern food technology's health trends, many nutritionists and food research organizations are on the search for potential foods with health

implications. In the near future, purified phytochemicals, probiotics and prebiotics, new categories of carotenoids, trace minerals, polyphenols, and the utilization of bio-based active films as packaging materials will be available. In order to include them into food systems, suitable micro/ nano encapsulation methods and encapsulating materials are frequently required. Micro/nano encapsulation technology has yet to establish itself as a standard tool for the food industry to produce healthy and new food items, which can be accomplished through a multidisciplinary research approach that takes into account of industrial demands and requirements. And only FDA-approved goods and the generally recognized as safe (GRAS) list should be consulted before applying different encapsulation procedures for food ingredients. Furthermore, as a wall material, food grade polymers have various advantages, mostly due to their capability to be modified to deliver the desired qualities. As a result, their use in shielding active food ingredients should be investigated further. Also, the method of encapsulation and the type of encapsulants used have a significant impact on the release mechanism and physicochemical properties of bioactive substances, combining these parameters with improving the encapsulation process results in a cost-effective and well-encapsulated component that has a higher efficiency than its free form in extending food shelf-life has been compared in many studies.

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