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Application of Various Encapsulation Techniques in Food Industries

K. Poornima[1], R. Sinthya[2]

[1]*(Department of food processing and preservation technology, Avinashilingam University, India)*
[2]*(Department of food processing and preservation technology, Avinashilingam University, India)*

Abstract: Encapsulation is a process in which tiny particles are surrounded by a coating in a homogeneous or heterogeneous matrix, to give small capsules. In this review paper we have discussed about various encapsulation technique such as spray drying, Fluidized bed coating/Air suspension particle coating, spray chilling/coating, coacervation and extrusion, also there application in food industry

Keywords: Spray drying, Fluidized bed coating, Spray chilling/coating, Coacervation, Extrusion

I. INTRODUCTION

Encapsulation may be defined as a process to entrap one substance within another substance, there by producing particles with diameters of a few nm to a few mm. The substance that is encapsulated may be called the core material, the active agent, fill, internal phase, or payload phase. The substance that is encapsulating may be called the coating, membrane, shell, carrier material, wall material, external phase, or matrix. The carrier material of encapsulates used in food products or processes should be food grade and able to form a barrier for the active agent and its surroundings.

II. METHODS

Methods	Process step	Morphology	Particle size (μm)
Spray-drying	1. Disperse or dissolve active in aqueous coating solution 2. Atomize 3. Dehydrate	Matrix	10-400
Fluid bed coating	1. Fluidize active powder 2. Spray coating 3. Dehydrate or cool	Reservoir	5-5000
Spray-chilling/ cooling	1. Disperse or dissolve active in heated lipid solution 2. Atomize 3. Cool	Matrix	20-200
Coacervation	1. Prepare o/w emulsions with lipophilic active in oil phase 2. Mix under turbulent conditions 3. Induce three immiscible phases 4. Cool 5. Crosslink (optionally)	Reservoir	10-800
Extrusion	1. Melt the coating 2. Disperse or dissolve active in the coating 3. Extrude with twin-screw extruder 4. Cool	Matrix	300–5,000

COATING MATERIALS FOR MICROENCAPSULATION OF FUNCTIONAL FOOD ADDITIVES

CATEGORY	COATING MATERIALS	WIDELY USED METHODS
Carbohydrate	Starch,maltodextrins, chitosan, corn syrup solids, dextran, modified starch, cyclodextrins	Spray- and freeze-drying, extrusion, coacervation, inclusion complexation
Cellulose	Carboxymethylcellulose, methyl cellulose, ethylcellulose, celluloseacetate-phthalate, celluloseacetatebutylate- phthalate	Coacervation, spray-drying and edible films

Gum	Gum acacia, agar, sodium alginate, carrageenan	Spray-drying, syringe method (gel beads)
Lipids	Wax, paraffin, beeswax, diacylglyerols, oils, fats	Emulsion, liposomes, film formation
Protein	Gluten, casein, gelatin, albumin, peptides	Emulsion, spray-drying

Spray Dryer

Traditionally, the most common method of encapsulating food ingredients was by spray drying. It is a unit operation by which a liquid product is atomized in a hot gas to obtain a powder. The gas generally used is air or more rarely an inert gas as nitrogen. The initial liquid feeding the spray dryer can be a solution, an emulsion or a suspension. In addition to being an encapsulation process, spray drying is also a dehydration process and is used in the preparation of dried materials such as powdered milk. To prepare materials for spray drying, the carrier or wall material (such as malt dextrin, modified starch, gum or combination of these) is hydrated. The flavour or ingredient to be encapsulated is added to the carrier and homogenized or thoroughly mixed into the system. A typical ratio of carrier to core material is 4:1, however, in some applications higher flavour loads can be used. The mixture is homogenized to create small droplets of flavour or ingredient within the carrier solution. The creation of a finer emulsion increases the retention of flavour during the drying process. Numerous studies have been conducted to evaluate the properties of wall materials, including a comparison of encapsulating agents for artificial and comparisons of retention of volatiles in systems including combinations of carbohydrate, protein and lipids. The core/wall material mixture is fed into a spray dryer where it is atomized through a nozzle or spinning wheel. Hot air flowing in either a co-current or counter-current direction contacts the atomized particles and evaporates the water, producing a dried particle that is a starch or carrier matrix containing small droplets of flavour or core. The dried particles fall to the bottom of the dryer and are collected. A thorough understanding of the core material and intended application is important to select the appropriate wall material and to optimize drying conditions. The design of a spray drying process includes establishment of the operating conditions that increase product recovery and produce an end product of a precise quality specification. Product recovery is mainly determined by powder collection efficiency. Material loss in a spray drying system is due mostly to the attachment of sprayed droplets and dry powder to the wall of the dryer. Particle adhesion to the wall is affected by the nature of the spray-dried material and spray drying conditions, and is a commonly recognized effect in spray drying solutions containing sugars, such as fruit juices and tomato product. During the drying process they may either remain as syrup or stick on the dryer chamber wall. The advantages of spray drying include low processing costs and readily available equipment. It generally provides good protection to the core material and there is a wide variety of wall materials available. One main disadvantage is that it produces a very fine powder which needs further processing such as agglomeration to instantize the dried material or make it more readily soluble if it is for a liquid application.

Wall Material Selection

An important step in developing microcapsules is the selection of a wall material that meets required criteria (mechanical strength, compatibility with the food product, appropriate thermal or dissolution release, appropriate particle size, etc. The selection of wall materials for microencapsulation by spray-drying has traditionally involved trial-and-error procedures in which the microcapsules are formed. The latter are then evaluated for encapsulation efficiency, stability under different storage conditions, degree of protection provided to the core material, surface observation by scanning microscopy, among other evaluations.

Gum Arabic

Gum Arabic is odourless, colourless, tasteless, and does not affect the odour, colour, and taste of the system to which it is added. It is highly soluble in water and dissolves in both cold and hot water. It has the ability to create a strong protective film around oil droplets which results from the highly branched arabinogalactan-protein structure containing both protein and polysaccharide moieties. It forms a thin and impenetrable film around the flavour particle, protecting it from oxidation and evaporation and preventing it from absorbing moisture from the air.

Malto Dextrin

Malto dextrin is creamy white hygroscopic polysaccharide powders, which are almost tasteless or only moderately sweet and easily digestible. Fruit or vegetable powders obtained by spray drying of juice solution containing carriers like malto dextrins were close to spherical shape with numerous dents.

Air-Suspension Particle Coating / Fluidised Bed Coating

Air-suspension particle coating is a process where thin coatings are applied to powder particles. It is different to spray drying encapsulation, which produces particles consisting of a homogeneously blended matrix of the polymer entrapping the particle. The basic principle of both air-suspension particle coating and air-suspension agglomeration is to atomise a fine liquid spray into a bed of fluidised particles. The spray consists of a solute which acts as a coating medium, and a solvent in which the solute is dissolved or slurried. The liquid impinges and spreads on the particles. The fluidisation air evaporates the solvent, leaving a layer of solute on the surface of the particle. Particle growth can occur by either inter-particle agglomeration or surface layering. Agglomeration occurs when liquid bridges form between colliding particles that are strong enough to prevent rebound. This study concentrates on surface layering which is enhanced by solvent lean conditions with intense fluidisation. These conditions prevent particles from agglomerating.

Coating Materials

The solvent in the coating solution is merely a vehicle to transport the coating material to the substrate surface and can be either aqueous or an organic liquid. Most food processes are limited to an aqueous carrier because of stringent food regulations as well as the high costs involved with solvent recovery systems. The choice of an appropriate coating material is influenced mainly by the specified core and the ability of the coating material to impart the desirable characteristics to the product. Although the performance of the coating material in the final application is crucial, matching of the material to the process technology and process conditions is likely to be of equal importance, and yet is almost certainly overlooked in practice. This lack of matching helps to explain why a large number of coating materials must typically be tested in order to determine their suitability when a product is developed. To speed up product development, it is important to establish guidelines for polymer selection, based not only on their performance in the final application but also on their behaviour in a coating process.

Spray Chilling and Spray Cooling

Spray chilling and spray cooling is similar to spray drying in that core material is dispersed in a liquified coating or wall material and atomized. However, unlike spray drying, there is generally no water to be evaporated. The core and wall mixture are atomized into either cool of chilled air which causes the wall to solidify around the core. In spray chilling, the coating is typically a fractionated or hydrogenated vegetable oil with a melting point in the range of 32 – 42 $^{\circ}$C. In spray cooling, the wall is typically a vegetable oil, although other materials can be used. The normal melting point is 45 - 122° C. These two methods, which differ only in the melting point of the wall material used, are most often used to encapsulate solid materials such as vitamins, minerals or acidulants. With the ability to select the melting point of the wall, these methods of encapsulation can be used for controlled release.

Coacervation

Coacervation involves the separation of a liquid phase of coating material from a polymeric solution followed by the coating of that phase as a uniform layer around suspended core particles. The coating is then solidified. A large numbers of coating materials have been evaluated for coacervation microencapsulation but the most studied and well understood coating system is probably the gelatine/gum acacia system. However, other coating systems such as gliadin, heparin/gelatin, carrageenan, chitosan, soy protein, polyvinyl alcohol, gelatine/carboxymethylcellulose, B-lactoglobulin/gum acacia, and guar gum/dextran are also studied. In recent years, modified coacervation processes have also been developed that can overcome some of the problems encountered during a typical gelatine/gum acacia complex coacervation process, especially when dealing with food ingredients; for example, a room-temperature process for the encapsulation of heat-sensitive ingredients such as volatile flavor oils In this process, the coating materials are mixed and then phase separation (coacervation) is achieved by adjusting the pH. The newly formed coacervate phase is allowed to separate and sediment, most of the supernatant water is removed, and the flavor oil is then added to the mixture kept at 50 $^{\circ}$C and emulsified rapidly. The initial volume of water is restored with room temperature water, causing a quick drop in the temperature, which means that the flavor oils experience a high temperature for only a few minutes, compared to several hours for a typical coacervation process. Another process involves the formation of a multilayered coacervated microcapsule. This process consists of multiple coacervation stages in which an additional layer of wall material is applied to the microcapsule at each passage and the final shell layer can reach a thickness up to 100 mm.

Extrusion

Extrusion methods consists of dropping droplets of an aqueous solution of polymer (most often this is 0.6-3 wt% sodium alginate) and active into a gelling bath (in case of alginate, gelling bath is 0.05-1.5 M calcium-chloride solution). The dripping tool can be simply a pipette, a syringe, a vibrating nozzle, a spraying nozzle, jet cutter or atomizing disk. In comparison to other extrusion techniques, JetCutter was found to be the best technology for large-scale/industrial applications. Electrostatic extrusion is especially effective for production of very small particles, down to 50 µm. An alternative extrusion technology is co-extrusion. It might be utilized to prepare spherical microbeads with a hydrophobic core and a hydrophilic or hydrophobic shell.

Examples of microencapsulates in food products

One of the most important reasons for encapsulation of active ingredients is to provide improved stability in final products and during processing. Typical carrier materials are mixture of carbohydrates and/or (dairy) proteins. Usually, protein isolates, gum Arabic, pectin skim milk powder, non-fat dry milk solids, soy, modified starch, maltodextrin and sugars are employed. Another benefit of encapsulation is less evaporation and degradation of volatile actives, such as aroma, which usually contains mixture of volatile and odorous organic molecules. Besides, flavours are usually expensive and therefore food manufacturers are usually concerned about the preservation of aromatic additives. Flavour encapsulation can be accomplisheby a variety of methods: spray-drying, spray-chilling or -cooling, spray bed drying and others. Examples of carrier material used for spray-drying are mono- and disaccharides, maltodextrin, corn syrup solids, modified starches, gum Arabic, larch gum, milk or soy proteins, hydrolysed gelatin and their variousmcombinations. Spray-chilling is a convenient technology to produce lipid particles with aroma. Also, another goal of employing encapsulation is to prevent reaction with other components in food products such as oxygen or water, e.g. in case of essential oils. Essential oils are slightly soluble in water and they transfer to the water their odour and taste. Essential oils contain terpenes, phenols, alcohols, aldehydes, esters, ketones and other compounds. Essential oils have a wide spectrum of biological activities, including growth inhibition observed against bacteria, yeasts and fungi. The encapsulation of essential oils into different nanospheres has being used as a controlled release vehicle with site-specific delivery properties to maximize the antimicrobial activity of the oils.

III. CONCLUSION

Encapsulation provides an effective method to cover an active compound with a protective wall material and thus, offers numerous advantages. These bioactive components include lipids, vitamins, peptides, fatty acids, antioxidants, minerals and living cells such as probiotics. Some of the main benefits are protection of various actives against evaporation, chemical reactions or migration in food, controlled delivery and preservation of stability of the bioactive compounds during processing and storage, prevention of undesirable interactions with other components in food products and masking unpleasant feelings during eating. Encapsulation is an important approach to meet all demands by delivering bioactive food components at the right time and right place. An attractive possibility is to use a methodology where two or more bioactive components can be combined to have a synergistic effect. It may be foreseen that encapsulated bioactive will play a significant role in increasing the efficiency of functional foods over the next period. With advanced strategies for stabilization of food ingredients and development of new approaches, we will be able to improve nutritional properties and health benefits of food compounds.

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