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Microencapsulation Techniques for Food Ingredients

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ABSTRACT

The development of new functional foods requires technologies for incorporating health promoting ingredients into food without reducing their bioavailability or functionality. In many cases, microencapsulation can provide the necessary protection for these compounds. Microcapsules offer food processors a means to protect sensitive food components, ensure protection against nutritional loss, utilize sensitive ingredients, incorporate unusual or time-release mechanisms into the formulation, mask or preserve flavors/aromas and transform liquids into easy to handle solid ingredients. Various techniques can be employed to form microcapsules, including spray drying, spray chilling or spray cooling, extrusion coating, fluidized-bed coating, liposomal entrapment, lyophilization, coacervation and centrifugal suspension separation.

Key words: Bioavailability, Functionality, Functional foods, Microcapsules

I INTRODUCTION

Microencapsulation is defined as a technology of packaging solids, liquids or gaseous materials in miniature, sealed capsules that can release their contents at controlled rates under the influences of specific conditions [1, 2]. A microcapsule is composed of a solid/liquid/gas core surrounded by a semi permeable, spherical, thin and strong membrane, the diameter ranges from one micrometre to one millimetre. The shell or matrix materials are generally polymers or waxes. Food grade polymers such as alginates, chitosan, carboxymethyl cellulose (CMC), hydroxypropyl methylcellulose (HPMC), carrageenan, gelatin, pectin and proteins and/ or waxes are mainly applied using various microencapsulation technologies.

The selection of the microencapsulation process depends on the properties (physical and chemical) of core and coating materials and the intended application of food ingredients [3]. Many available technologies for microencapsulation can be divided into two categories, one which uses a liquid as a suspending medium (complex coacervation, interfacial and in situ polymerization or solvent evaporation from emulsions) and one which uses a gas as a suspending medium into which a liquid phase is sprayed (spray-drying or spray-congealing, fluidized-bed coating) [4].

There is not a single universal methodology to encapsulate bioactive molecules because of the enormous difference in chemical structure of the molecules and because of the high variety of products that are being applied. Some of the microencapsulation techniques for food components are discussed below:

1.1 Emulsification

The process in which one liquid is dispersed in a second immiscible liquid is known as Emulsification. The bioactive component can be encapsulated by including the core material in the shell. The encapsulation of the bioactive molecules in food grade (Generally Regarded as Safe (GRAS)) molecules by applying electrostatic interactions hydrogen bonding, or hydrophobic interactions between the bioactive molecule and an encapsulating molecule is mostly chosen by companies and researchers. The molecule already present in the food usually acts as an encapsulating agent [5]. Moreover, addition of a surfactant that induces encapsulation by forming micelles, vesicles, bilayers, and reverse micelles around the bioactive molecules is generally proposed as a solution [5, 6]. Generally, it protects the bioactive molecules in the products and facilitates their release in the duodenum as soon as lipase is being released. The application of biopolymers like a variety of proteins and polysaccharides that can envelop the sensitive bioactive molecules by forming a random coil, sheet, or rod like structures around the molecules is another approach of encapsulation. Its exact release in the gut is determined by the type and digestibility of the applied biopolymer [7]. Apparently, the composition of the product determines the choice of the biopolymer. Bulk emulsification approaches are applied in some cases to increase the efficacy of packing. This usually is enveloping the bioactive molecules in fat-droplets, or water-oil-water emulsions. This bulk emulsification is generally considered to be more a technique to provide fine controlled release of molecules and is usually not considered to be a true encapsulation system. An enormous quantity of food components may be applied as building blocks for emulsions. We can produce simple and very complex emulsions, depending on the type of molecules for forming the emulsions. The possibilities are abundant and have been extensively reviewed. To self-ensemble in water in a wide variety of structures is a characteristic of monoglycerides. We can manage the creation of micelles, hexagonal, cubic or even lamellar shapes of glycerides that envelope one or more bioactive molecules by nominal and non-laborious manipulation. It is a simple technology that is already extensively applied for controlled release of aromas and flavors [5].

1.2 Spray Drying:

One of the oldest processes to encapsulate active ingredients is Spray-drying. It is not always perceived as an encapsulate for being so common in foods, e.g., aroma in a spray dried form. By dissolving, emulsifying, or dispersing the active ingredient in an aqueous solution of carrier material, followed by atomization and spraying of the mixture into a hot chamber, the Spray-drying of active agent can commonly be achieved. [8]. During this process a film is formed at the droplet surface, thereby retarding the larger active molecules while the smaller water molecules are evaporated. The active agent in organic solutions like acetone or ethanol can also be spray-dried; however, this is used much less for environmental and safety reasons (which also increase the costs).

Spray-dryers in the food industry are usually atomizing the infeed with a high-pressure nozzle or centrifugal wheel (also called rotary atomizer) and operate with a co-current flow of air and particles to give minimal overheating of the particle. This latter is significant if there are heat sensitive contents or to some extent volatile (like that of the case with aromas). The particles prepared in the counter-current mode are less porous while as

the co-currently dried particles are likely to be more porous. The various factors that determine the atomizing droplets size include the viscosity and surface tension of the liquid, velocity of the spray and pressure drop across the nozzle. The drying time and particle size is also determined by the size of the atomizing droplets. Under standard spray-drying conditions, the wet bulb temperature is of the order of 50°C. If the spray-dryer is larger, there will be longer residence time of the particle in the dryer (typically 5–100 s) and for this reason the larger the maximum size of the droplets that can be dried. Atomizing nozzles can also be mounted to spray upward just like a fountain, which allows fairly larger droplets to be dried due to larger droplet residence time. However atomizing nozzles are usually mounted to spray downward.

A film is formed at the surface of the droplet during the drying process and the ingredient concentration increases in the drying droplet. Finally, a porous, dry particle is formed. There are certain characteristics that a carrier material should possess, which include high solubility in water, protection of active material, diffusibility, crystallinity, good emulsifying properties, good film forming properties and low costs [9]. There are many examples which include proteins (soy proteins, dairy proteins, gelatin, etc.), lipids (waxes, emulsifiers), carbohydrates (maltodextrins and cellulose derivatives) and/or natural gums (gum arabic, alginates, carrageenans, etc.). Upon addition to water, the active agent from conventional spray-dried encapsulates gets released immediately (which may also depend on the particle porosity). However, a more gradual release upon dilution in water is provided by more hydrophobic and/or cross-linked carrier materials. Examples of these are denatured proteins, cross-linked proteins or cross-linked biopolymers.

1.3 Spray-Cooling or Spray-Chilling

The lipid-coated active agent can also be produced by another process called as Spray-chilling or spray-cooling [10, 11, 12]. The active agent might be present as dry particles or aqueous emulsions, or soluble in the lipids. The molten lipid(s) droplets are atomized into a chilled chamber (e.g., passing through nozzle, spinning disk or (centrifugal) co extrusion), the outcome of which is solidification of the lipids and their recovery as fine particles. The primary set-up of spray cooling is relatively analogous to spray drying, with a difference that evaporation of water does not occur here. The particles in the spray-chilling technique are kept at a low temperature in a set-up like that of fluidized bed spray granulation, on which molten lipid droplets may adhere to already hard lipid particles before solidification. For spray-chilling, the melting point of the lipid used is in the range of 34–42°C, while as in the higher range for spray-cooling in general.

1.4. Coacervation

A liquid–liquid phase separation mechanism of an aqueous solution into a polymer-rich phase (known as coacervate) and a polymer-poor phase results in the formation of coacervates. The process of coacervation can be recognized as (simple) coacervation in which only one type of polymer is involved or complex coacervation in which two or more types of polymers of opposite ionic charges are present, depending on the number of polymer type(s) present. Mostly the complex type of coacervates are used to encapsulate the active agent. Gum arabic and gelatin generally compose their shell. An o/w emulsion with gelatin and gum arabic at a 1:1 w/w ratio and at a 2–4% w/w of each polymer dissolved in the water phase via adjusting the pH from neutral to about

4 under, turbulent conditions in a stirred vessel at >35°C, a temperature above the gelation temperature of gelatin, is mainly used to prepare complex coecervates [12, 13]. This results in the formation of three immiscible phases i.e. oil, polymer-rich and polymer-poor phase, and due to the interfacial sorption, the polymer rich phase droplets deposit on the emulsion surfaces. Complex coacervation on the other hand can be induced by dilution instead of pH adjustment in which oil is emulsified in 8–11% (w/w) gelatin solution, followed by adding gum arabic and dilution water [14]. On cooling well below 35°C [13], the deposited gelatin and thus the shell will solidify. There are various factors that affect the preparation process which include pH, temperature, ionic strength, polymer concentrations, emulsion size and turbulence of the system. The shell can be crosslinked after cooling with, e.g., glutaraldehyde (not permitted in Europe for food applications) or transglutaminase [14]. The coacervates are finally isolated and washed (if needed) by means of filtration or sedimentation (if the density of coacervates is higher than the density of water, which depends on the relative amount of shell compared to the oil core) and may be dried by fluid bed drying or spray-drying. Other negatively charged molecules like pectin, carrageenan, carboxymethyl cellulose, polyphosphate or alginate and alginate derivatives can replace gum arabic [15], or whey proteins can replace gelatin [16]. Mostly gelatin has a beef or pork origin, but as a Halal or Kosher alternative fish gelatin may be used. Every combination of polymers operates at unique conditions in terms of ionic strength, pH, polymer levels, temperature, charge density, molecular weight, cooling rate, etc. The shape of Complex coacervates is often a very typical, oval.

1.5. Lyophilization

The process used for the dehydration of almost all heat sensitive materials and aromas is known as Lyophilization, or freeze-drying. Water-soluble essences and natural aromas as well as drugs are being encapsulated using this process. Except for the long dehydration period required (commonly 20 h), freeze-drying is a simple technique, which is particularly suitable for the encapsulation of aromatic materials. The chemical nature of the system determines the retention of volatile compounds during the lyophilization [17].

II CONCLUSION

The use of microencapsulated food ingredients for controlled-release applications is a promising alternative to solve the major problem of food ingredient delivery faced by food industries.

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