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Encapsulation Applications and Production Techniques in the Food Industry

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Abstract

The encapsulation method is a process applied to increase the shelf life of the active food components, ensure their stability, perform their controlled release and improve their functional properties. Active particles such as fatty acids, peptides, vitamins and probiotics are coated with coating materials such as starch derivatives, gelatin, gum arabic to eliminate external effects. Encapsulation methods commonly used in the food industry; Since it is cheap and effective, it is primarily spray drying followed by fluid bed coating and extrusion respectively. It is thought that the chemical, physical and functional properties of food products will be improved and control will increase during the process with the future studies. The aim of this study is to examine encapsulation techniques applied to foods. These encapsulation techniques include spray drying, spray cooling and spray freezing, extrusion coating, fluid bed coating, liposome compression, coacervation, inclusion complex and centrifugal extrusion.

Keywords: Encapsulation; Encapsulation Techniques; Active İngredients; Coating Materials

Introduction

Encapsulation is a useful method to improve the transportation of bioactive molecules (antioxidants, minerals, vitamins, phytosterols, lutein, fatty acids, lycopene, etc.) and living cells (probiotics, etc.) to foods by keeping the active agents in a carrier material [1,2]. Microencapsulation is a technology that increases nutrient consumption and food retention throughout the intestine and ensures controlled release of it at a certain time [3]. The sizes of microcapsules vary between 1 µm and nm, depending on their size and morphology. Microcapsules are called microparticles or microspheres between 3 and 8 µm. If the particles are larger than 1000 µm, they are called macroparticles [4]. In the food industry, microencapsulation can be applied for a variety of purposes. Some of these purposes are to protect the core material against deterioration and reduce the evaporation rate of the environ ment around the core material [5,6]. Many of the liquid food flavors are volatile and chemically stable against air, oxygen, moisture and high temperature. Microencapsulation method provides a stable and free flowing powder property of liquid flavoring agents, providing ease of use in powdered foods [7-9]. Figure 1 shows microencapculation application in the food industry. Most of the materials used for microencapsulation in the food industry are biomolecules. In addition to carbohydrates/polymers/polysaccharides, proteins and lipids are also biomolecules suitable for microcapsulation in the food industry [10-12].

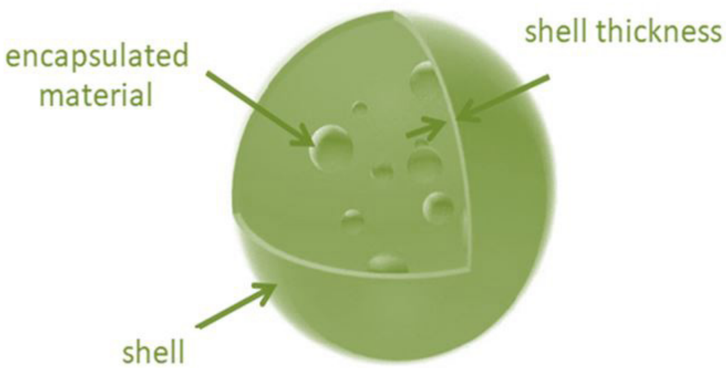

Figure 1: Microencapculation application in the food industry

The purpose of this review is to examine the encapsulation techniques applied to foods according to recent studies, and to determine the advantages and disadvantages of the methods. These encapsulation techniques include spray drying, spray cooling and spray freezing, extrusion coating, fluid bed coating, liposome compression, coacervation, inclusion complex and centrifugal extrusion [13].

Encapsulation Techniques

Spray Drying

The most common and economical method of encapsulating food ingredients is spray drying [13]. Spray drying solution, emulsion or suspension is a method in which the atomization process is applied in the hot gas stream in order to obtain powder from a product. The gas used is air, or nitrogen, an inert gas more rarely used [14]. The first stage of the spray drying method is to hydrate the carrier or coating material (such as maltodextrin, modified starch, chewing gum or combination etc.). The flavor or ingredient to be encapsulated is added to the carrier and homogenized or thoroughly mixed into the system using a similar technique. The ratio of the carrier to the core material is generally 4/1, but in some applications, higher flavor loads can be used. The mixture is homogenized to create small flavor or ingredient droplets in the carrier solution [15]. The encapsulation material should be selected for its high solubility, effective emulsification and film forming, efficient drying and low viscosity even in high concentrate solution [16]. As a result of encapsulation with Capsul-CAP material by applying spray drying method, a yield of 100% for vitamin A and 48% for vitamin E was achieved [17]. Figure 2 shows microencapculation examples in the foods.

Figure 2: Microencapculation examples in the foods

Spray Cooling and Spray Freezing

Spray cooling, also known as spray-freezing, is a microencapsulation method that allows the use of oils or waxes as wall material [18]. The core material is dissolved or dispersed in a molten carrier, and the resulting preparation is fed to an atomizing nozzle, and sprayed into a cooling chamber. Molten droplets that come into contact with the cooled air solidify. Thus, it leads to the formation of microparticles in which the core material is evenly distributed [19,20]. In studies conducted, models of simulating fermented and non-fermented beverages examined the immobilization of bifidobacteria (B. longum) in a lipid matrix of cocoa butter. According to the results of the study, it was observed that the bacteria can survive during the shelf life, as the lipid matrix protects the microorganism against water and H+ ions [21]. Vitamin E, known for its antioxidant properties, is sensitive to environmental factors such as pH, oxygen, high temperature [22]. According to the literature, encapsulation was carried out using spray freeze method tocopherol acetate, stearyl alcohol, carnauba wax and low melting polymers. As a result of the study, close to 95% efficiency was obtained [23].

Extrusion Coating

Extrusion encapsulation technique provides economic and environmental benefits. Examples include not using organic solvents and high temperatures, saving energy and water [24]. In this respect, it is another widely used method for encapsulation of probiotics [25]. This method is based on a polysaccharide gel that immobilizes the nucleus when in contact with a multivalent ion [26]. Extrusion involves the inclusion of the core in a sodium alginate solution. It then involves incorporating the drop-extruded mixture into a curing solution, such as calcium chloride, through a reduced-caliber pipette or syringe [27]. The main advantage of the extrusion method is the stability of the aromas against oxidation. Glassy carbohydrate matrices have very good barrier properties, and extrusion is a convenient process to encapsulate flavors in such matrices [28]. As the carrier material, it may consist of multiple components such as sucrose, maltodextrin, glucose syrup, glycerin and glucose [26]. In this way, excellent stability against oxidation is provided and shelf life is extended. The product shelf life can be stored for 1-2 years without significant quality deterioration.

Fluid Bed Coating

The coating method is one of the processes used for the coating and encapsulation of additives and food ingredients [29]. The specific feature of the technique is that it allows coating of solid dry particles (powder products) [30]. Fluid bed coating technique is not a commonly preferred technique in encapsulation of food products, as it is more costly than spray drying technique. However, with the emergence and development of continuous fluidized bed systems, production costs have decreased and have been an alternative for encapsulation of food products. The mechanism of the fluid bed coating process is based on the formation of layer-shaped capsules as a result of spraying the coating liquid on the particles in the bed by means of the spray head [31,32]. In particular, in the meat industry, various food acids are encapsulated using the fluid bed technique to improve flavor and color [33].

Liposome Compression

Liposomes can be defined as spherical lipid sacs consisting of two-layer polar lipids, used in the pharmaceutical, chemical, personal care and food industry, to encapsulate both hydrophilic and hydrophobic materials. It is formed by dispersing polar lipids in a polar environment such as water. The most common sources of polar lipids in nature are soy, sunflower lecithin and egg [34,35]. For liposome production, mechanical methods such as High Intensity Ultrasonication, High Pressure Homogenization, Extrusion Homogenization and non-mechanical methods such as Reverse Phase Evaporation, Freeze Drying-Reconstitution are used [36].

It has been observed that the components encapsulated with liposomes, which are encapsulated antioxidants, antimicrobials, vitamins, are more stable in processes such as drying, pasteurization, frying, and cooking [37]. The most distinctive feature of liposome encapsulation technique that distinguishes it from other encapsulation materials is that it is structurally similar to the cell membrane. Thanks to this, it has been observed that the bioactive components can be transported to the specified areas in the body and controlled controlled release, and the aftif components increase the bioavailability [38]. It was observed that the toxic effect of vitamin A consumed in large quantities was eliminated when it was encapsulated [39]. In addition, since they are not polymer based, they do not alter the rheological properties of the system in which they are used compared to other encapsulation components. Because liposomes are fragile, they may lose or leak the materials they encapsulate due to physical instability [40,41]. In addition, liposomes are at low energy levels. For this reason, small liposome spheres combine, causing an increase in particle sizes, forming precipitate and ending dispersion.

Coacervation

Coacervation technique is the process of keeping the coating agent separated from a polymeric solution in a homogeneous layer around the suspended core particles of the liquid phase [42,43]. For the process to be successful, the particles must be compatible with the polymer and must not dissolve in the coacervation system.

Coacervation (phase separation) process is divided into two as simple and complex coacervation. In simple coacervation technique, only one type of polymer is used, while in complex coacervation technique two or more types of polymers are used. The complex coacervation technique is based on the electrostatic interaction between two counter charged polymers. Complex coacervation technique is applied by bonds between cationic (chitosan, gelatin and plant proteins) and biopolymers such as anionic (alginate, pectin, gum arabic) [44]. Gelatin / gum arabic system is the most preferred coating material in microencapsulation with coacervation technique [45]. Compared to other encapsulation methods, the complex coacervation method is advantageous because it offers stability in conditions such as high coating activity (99%), high humidity and temperature, and controlled release in gastrointestinal systems (bile salt pH, and enzymatic activity). The Coacervation method is not a widely used technique in the food industry due to the high cost and complexity of the process [46].

Inclusion Complex

Also known as the molecular complexing method, the inclusion complex is formed by the enzymes acting on the starch molecule in order to obtain cyclodextrins [47]. Cyclodextrins are crystalline, water-soluble, non-reducing starch derivatives. Their main characteristics are chemical stability, water resistance enhancer, edible, homogeneous, pure, non-hygroscopic and non-toxic [48,49]. Since the inclusion technique is a concentration-dependent method, particles in the solution can form precipitate when bound to other parts of the cyclodextrin surface [50,51]. In the food industry, the inclusion complex technique increases the shelf life of foodstuffs by protecting the stability of hydrophobic food compounds such as vitamins, flavors, color matter and unsaturated fats from heat-based deterioration reactions, vapor losses and microbial contaminations [52].

Centrifugal Extrusion Method

This technique is generally used by vitamin manufacturers, especially in the production of vitamin A acetate. The technique is a liquid extrusion method and a rotary extrusion head with concentric nozzles is used. The particles and coating materials are fed from the concentric feed tube to the nozzles located opposite each other [53]. For the technique to be successful, the particles must be pumpable, and the coating material must have liquid and good suspension properties at room temperature [54]. Table 1 shows some examples of encapsulation applied in food industry.

The Aim of the Study	Encapsulation Method	Purpose of Usage	References
Encapsulation of soy phosphatidylcholine liposomes in food waste compounds	Freeze drying	Packaging stability and	[15]
Encapsulation of cinnamon oil in cyclodextrin nanospongs	Freeze drying	Antimicrobial food packaging	[55]
Encapsulation of 2-acetyl-1-pyrroline zinc chloride using hydrophobic materials	Spray cooling	Packaging stability and flavor application in foods	[56]
Fish oil	Electro spray	Food enrichment	[57]
Encapsulation of -epigallocatekin-3-gallate (EGCG) in solid lipid nanoparticles (-)	coacervation	Foods enriched with EGCG products	[58]
Encapsulation of cinnamon oil	coacervation	Food packaging films	[59]
Soy protein isolate and inulin Fish oil	coacervation	Food enrichment	[60]

Table 1: Some examples of encapsulation applied in food industry

Conclusion

As a result, the most common preferred micro-encapsulation method of food is spray drying method with low production cost and cheap method. Solvent is not used in spray drying method. In addition to being an expensive method, freeze drying process has advantages such as the reconstitution properties of the product obtained is very good, the loss of aroma is very low and the losses are minimal due to the movement of the solutes in the food. Since fluid bed coating is a very expensive method, it is not a preferred method. Extrusion is a new technology, but it is a method generally used in coating flavoring substances. Oxidation resistant capsules are developed with this method.

In many areas, encapsulation methods are used to protect the products from the external environment, to extend their shelf life, stabilize them, perform controlled oscillations and improve their functional properties. With the developing techniques in recent years, it has been used more widely and in areas with formulations and cost reductionIn encapsulation method, coating materials generally consist of protective materials such as pullulan, starch, sucrose, glucose, maltose, lactose, gelatin gum arabic and casein. These preservatives, active ingredients such as fatty acids, lipids, peptides, vitamins, antioxidants, probiotics, color materials and minerals are protected. In the food industry, the spray drying method has been the most widely used technique because it is convenient and cheap to use in the encapsulation of food particles. In addition, methods such as fluidised bed coating, spray cooling, extrusion and coacervation are also preferred. Encapsulation techniques are used in the food industry to increase digestibility of products, increase nutritional value, ensure controlled release of functional products, shorten maturation time and most importantly, extend shelf life. With the new techniques developed, it is hoped that the control will increase during the process and the functional, physical and chemical properties of the food components will be improved.

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