

Food Microencapsulation

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ABSTRACT

Nutraceuticals like antioxidants, vitamins, minerals, fatty acids, probiotics and other dietary supplements have various functional properties and there is sufficient scientific evidence to support their beneficial effects on health. The bioactive compound responsible for functionality of nutraceuticals may be naturally present in the product but appropriate technologies are required for their formulation to optimize the desired benefits. Appropriate transport, release, biological barrier interaction, improved loading and stability can all be possible by suitable microencapsulation of the bioactive compound. In the food industry encapsulation can ensure stabilization of core material, controlled release, masking flavour, colours or odours, extended shelf life and minimize nutritional loss.

Key words: Bioactive compound, Nutraceuticals, Release, Transport.

1. 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]. Encapsulates may either be in the form of solid particles or droplets of liquids. Because of the limited understanding of bioavailability and delivery systems in nutritional science, dietary supplements might be taken in excessive amounts or delivered to unwanted sites. Currently, processing technologies have to focus on two aspects [3]:

1. Formulation of the product such that all the bioactivity is retained during processing and storage.
2. Delivering the desired bioactive compounds to the target sites in the body.

Microencapsulation provides more efficient delivery because it increases the ability of the core substances to interact with the body. The active ingredients like probiotics, Omega-Fatty acids, anthocyanins, carotenoids, flavours are encapsulated into a particle that may be as small as of one micron. The greatest feature of microencapsulation is the control provided by the choice of coating. The choice of coating imparts microencapsulation the controlled release feature. Coatings that allow release at specific site or area of the body may be developed. A microcapsule can be designed such that acid-labile core materials which needs to be consumed by gastrointestinal fluids will not be fractured while passage through the stomach [4]. The encapsulating and coating materials selected for a particular application would depend on the physical and chemical properties of the core materials as well as the method used for capsule formation. These materials must be non-reactive with the core materials, biocompatible and biodegradable. Microcapsule coating materials which are film formers, can be selected based on the core to be encapsulated and attributes required in the final product. Wide variety of natural as well as synthetic polymers are available as coating materials [5]. The choice of coating material is based on the functionality of microcapsule and the desired characteristics for a particular ingredient. 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 [6]. 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) [7]. The properties of microcapsule that can be altered for specific ingredient use include composition, fracture mechanism, size of particle and physical state. Purpose of encapsulation has to be clear before considering attributes of encapsulated product [5]. In designing the encapsulation process, the following things should be taken into consideration:

- Functionality provide by encapsulated ingredients to the final products

- selection of specific food grade coating materials needed for particular purposes
- processing conditions the active ingredient must survive before release
- encapsulated ingredients economics
- mechanism of release of core substances from the microcapsule
- particle size, density and stability requirements

2. Morphology of microcapsule

The core material and deposition process of the shell determine the morphology of microcapsule.

- **Mononuclear:** microcapsules containing the shell around core
- **Polynuclear capsules:** capsules having many cores enclosed in a single shell
- **Matrix encapsulation:** homogeneous distribution of core material in the shell

Besides these three basic morphologies, there can be mononuclear microcapsules with multiple shells or microcapsules with multiple shells or they might be having cluster of microcapsules.

3. Shell material for microencapsulation

The most commonly used shell materials for microencapsulation are carbohydrates such as starches, maltodextrins and corn syrup solids. Carbohydrate based shell materials however provide poor interfacial properties and need to be chemically modified in order to improve surface activity. In contrast, amphiphilic properties of proteins offer characteristics required for encapsulating hydrophobic core materials.

3.1 Carbohydrates

Carbohydrates due to their lower viscosity are considered as good shell materials but their microencapsulation efficiency is low due to lack of interfacial properties as are generally associated with encapsulating materials such as proteins or gums [8]. Chemical modification of carbohydrates is done to improve their microencapsulation efficiency for example, modified starches with surface activity are widely used for microencapsulation. Hydrophilic compounds such hydrolyzed starch products, having little affinity for flavours can be modified by linkage with hydrophobic side chains [9].

3.2 Pectin

The protein residues present within the pectin chain and higher content of acetyl groups are responsible for emulsifying properties of pectin [10]. A stable emulsion is possible with a pectin content of 1-2%. Lipophilic food ingredients can be encapsulated by sugar beet pectin. A wall system containing sugar beet pectin as shell material and glucose syrup as bulk one has been successfully used for encapsulation of fish oil [11]. Most of functional properties of pectin are not influenced by spray drying. For microencapsulation of bioactive compounds with pectin as shell material spray drying is suitable.

3.3 Gums

Film forming and emulsion stabilization properties of gums make them a suitable microencapsulation agent. Acacia gum, generally known as gum arabic, is mostly used gum due to its excellent emulsifying properties. The constituent of gum Arabic are D-glucuronic acid, L-rhamnose, D-galactose, and L-arabinose, with approximately 2% protein. This protein fraction is responsible for emulsifying properties of gum arabic [12].

Gum arabic has been found to be a better wall material for encapsulation of cardamom oleoresin than maltodextrins and modified starch, the resulting microcapsules exhibit a free-flowing character [13]. It has shown good properties as wall material for encapsulation of cumin oleoresin by spray-drying [14]. Gum arabic is usually preferred because it produces stable emulsions with most oils over a wide pH range and also forms a visible film at the oil interface. Because of this emulsifying efficiency, gum arabic has been usually used to encapsulate lipids. Typically, the ratio of oil/wall material, when gum arabic is used, is lower than 0.15. Gum Arabic is ideally suitable for the microencapsulation of lipids because of both its surface activity and its film forming properties.

3.4 Proteins

Proteins possess excellent functional properties that are responsible for their good coating behavior during microencapsulation by spray-drying. Milk proteins and gelatin are most commonly used for microencapsulation of food ingredients. Proteins have excellent binding properties for the flavor compounds. Because they possess functional properties required for microcapsule wall material, they have been successfully used as a wall system to encapsulate anhydrous milk fat by spray-drying with encapsulation yield greater than 90%. According to some authors, microencapsulation efficiency can be improved by partial (50%) replacement of whey proteins by lactose. In fact, the incorporation of lactose in the whey protein-based wall system can limit the diffusion of polar substances through this wall. Lactose

in its amorphous state acts as a hydrophilic sealant that significantly limits diffusion of the hydrophobic core through the wall and thus leads to high microencapsulation efficiency values. Encapsulation of essential oils in a wall system consisting of milk protein to provide protection against oxidation has been found efficient [15].

4. Microencapsulation of flavours

Many flavours being volatile need to be encapsulated for better retention in the food. Protection of core material that is sensitive to oxygen during processing and storage, controlled or delayed release can be achieved by microencapsulation. The carrier material for microencapsulation of flavours can be gums, carbohydrates, lipids and proteins. The most common method for microencapsulation of flavours is spray drying [16]. Despite the high temperature of processing during spray drying most of the volatiles of flavours are still retained. The sensory attributes of dairy products are most important as they are sold based on appearance, flavour and taste. Sensory characteristics of dairy products are best preserved by microencapsulation. Flavour is one of the most important sensory attribute. Flavours being highly volatile are easily lost from the food matrix on processing and storage. Microencapsulation was developed to prevent flavour loss and to retain them inside the food matrix on processing and storage.

Flavour-flavour interaction can be minimized by microencapsulation. Ideal spray-drying carrier need to be highly soluble, must have limited viscosity of solution at 35–45% solids content, must be a good emulsifier, have good drying properties, nonhygroscopic character, bland taste, nonreactivity, and low cost. Three classes of starches widely used for flavour encapsulation include hydrolyzed starches, modified starches and gum Arabic [17]. Native starches and starch hydrolysis products are hydrophilic in nature, thus having little affinity for hydrophobic flavour oils. Esterification with hydrophobic groups or negatively charged groups has been done to change their hydrophilic nature.

5. Microencapsulation of probiotics

Probiotics are defined as live microorganisms which, when administered in adequate amounts confer a health benefit to the consumers. Growing evidence suggests that protection against gastrointestinal (GI) disorders including gastrointestinal infections and bowel diseases can be provided by healthy gut microflora. Mitigation of lactose maldigestion, higher resistance from gut invasion of pathogenic bacteria species, immune system stimulation and colon cancer protection are some of the claimed benefits of probiotics based on which they are in the market [18]. Probiotics are meant to alter the gastrointestinal microflora such that bactericidal activities advantageous to host are stimulated and ones adverse to health of host are suppressed. The site of action of probiotics is mostly small intestines[19].

A probiotic can benefit human health only if it fulfills certain criteria. It should not lose viability and functionality or create unpleasant flavours or textures. It must be functional in the gut environment, for that it should pass safely through the upper gastrointestinal tract to be alive at the site of action. Probiotic dosage needs to be high for effective action. Storage temperature, pH, oxygen levels, inhibitors, competition from other microbes determine viability of a probiotic in food matrix [20]. Therefore, probiotic cells are to be protected against adverse environmental and gastrointestinal tract conditions. To improve bacterial cultures including probiotics in food and intestinal tract microencapsulation is used. The bacterial cultures are encapsulated and converted into powdered form by various techniques such as spray drying, freeze drying, fluidized bed drying. However, there is complete release of bacteria encapsulated by these techniques in the product. The cultures thus are not protected from environment or provided safe passage through stomach or intestinal tract in this case. Hydrocolloid beads entrap or immobilize the cells within the bead matrix on encapsulation providing protection from environment [21].

6. Microencapsulation of carotenoids

Microorganisms and plants synthesize natural pigment carotenoids. There are more than 600 naturally occurring carotenoids. These are 3-13 conjugated double bond constituting polyenes. Fruits, vegetables, leaves, peppers, and certain types of fishes, sea foods, and birds are the main sources of carotenoids. They act as light absorbers during photosynthesis and may function as cell protectors against photosensitization. The destructive effect of reactive oxygen species can be inhibited by carotenoids.

Many studies based on the antioxidant activity of carotenoids against cardiovascular diseases and certain types of cancers, as well as other degenerative illnesses, have been carried out [22,23]. Carotenoid rich diet may also provide photoprotection against UV radiation. Bone formation and mineralization stimulation have been related to carotenoids such as b-cryptoxanthin and lycopene by some studies. Thus, carotenoids have been related to osteoporosis prevention [24]. Unsaturated chemical structure of carotenoids makes them very sensitive to heat, oxidation, and light. The nature existence of carotenoids as crystals or protein

bound complexes has shown to be responsible for only minor absorption of carotenoids from raw fruits or vegetables. The bioavailability of carotenoids however increases when dissolved in vegetable oils as they are almost insoluble in water and only slightly soluble in oil at room temperature. Solubility increases as the temperature of oil increases. Carotenoids having antioxidant activity can be microencapsulated to improve solubility, stability, and bioavailability [25].

7. Conclusion

The number of uses and types of microencapsulated ingredients available to the food industry is growing rapidly. Advances in the development of new wall materials and microencapsulation methods have paved the way for value-added ingredients of higher quality, consistency, enhanced performance and improved prices.

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