8. MICROENCAPSULATION TECHNIQUES: PRINCIPLES AND APPLICATION

Jeyakumari A.
Senior scientist, Fish Processing division,
ICAR- Central Institute of Fisheries Technology, Cochin-29

Now-a-days the demand for healthy and nutritional food products is increasing worldwide. Today foods are intended not only to fulfill the hunger and to provide necessary nutrients for humans. It also intended to prevent nutrition-related diseases and improve physical and mental health. In this regard, functional foods play an outstanding role. Functional foods are foods that enriched with functional ingredients to offer health benefits or to reduce the risk of chronic diseases beyond their basic nutritional functions. Bioactive in food are physiologically active components that provide health benefits beyond their nutritional role. Bioactive ingredients include proteins, vitamins, minerals, lipids, antioxidants, phytochemicals and probiotic bacteria. These bioactives are very sensitive and their application in food is a great challenge to the industry without affecting their properties. Encapsulation technology has proven to be an excellent method to protect the sensitive food ingredients and to develop the novel foods formulations with improved properties.

Encapsulation defined as a process of coating small particles of solids, liquids, or gaseous components, with protective coating material. Based on particle size they are categorized into

i) Microcapsule: Particle size ranged from 0.2-5000 µm
ii) Macrocapsules: Particle size larger than 5000 µm
iii) Nano capsules/ nanoparticles/ nanospheres: Particle size smaller than 0.2 µm (200nm).

Purpose of Encapsulation

In the food industry, the encapsulation process can be applied for a various purpose such as (i) to protect the core material from degradation and to reduce the evaporation rate of the core material to the surrounding environment; (ii) to modify the nature of the original material for easier handling; (iii) to release the core material slowly over time at the constant rate; iv) to prevent unwanted flavor or taste of the core material; v) to separate the components of the mixture that would react one another.

Overview of Encapsulation Technologies

The material that is encapsulated is called as core material, the active agent, internal phase, or payload phase. The substance or material that is encapsulating the core is called as wall material, coating material, membrane, shell, carrier material, external phase or matrix. Two main types of encapsulates are reservoir type and matrix type. In reservoir type, the active agents form a core surrounded by an inert barrier. It is also called single-core or mono-core or core-shell type. In matrix type, the active agent is dispersed or dissolved in an inert polymer. Coated matrix type is a combination of first two (Fig.1).

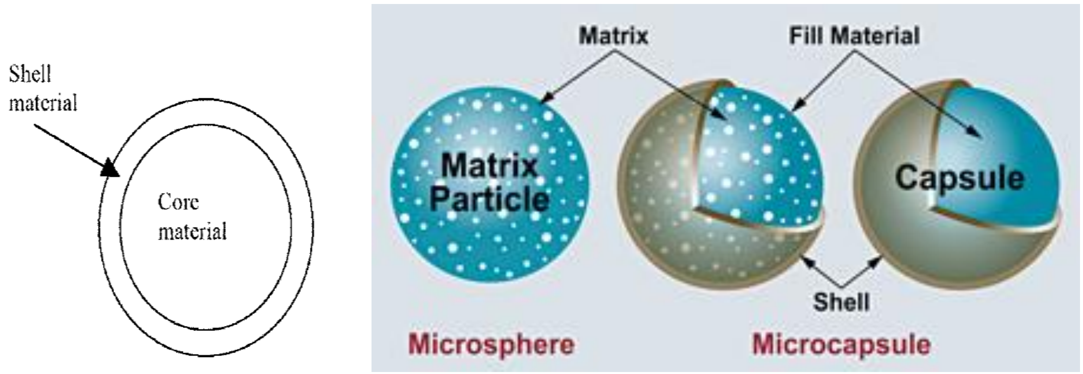

Fig. 1.Morphology of microcapsule

The microcapsules are prepared by a variety of methods. The encapsulation process can be divided into physical and chemical process. Physical process includes spray drying, spray chilling, rotary disk atomization, fluid bed coating, coextrusion and pan coating. The chemical process includes simple and complex coacervation, interfacial polymerization and phase separation.

Nanoparticles can be prepared by two basic approaches: either by a ‘‘top-down’’ approach, in which nanoparticles are produced by means of physical processing of several materials, or alternatively by a ‘‘bottom-up’’ approach, in which nanoparticles are produced via self-assembly and self-organization of smaller molecules

Spray drying: The general process of spray drying involves dispersion of a core material into a polymer solution, forming an emulsion or dispersion, pumping of the feed solution/emulsion, atomization of the mixture and dehydration of the atomized droplets to produce microcapsules. Depending on the feeding solution and operating conditions, the size of the microcapsules vary from 10–50 μm or large size particles of 2–3 mm with active load of 5–50%.

Freeze drying: In this method, the emulsion is frozen at temperature between −90°C and −40 °C and then dried by sublimation under low pressure. In general, less than 40 % of active load can be achieved by this method. Encapsulates made by freeze drying have particle size ranging from 1 to 100 µm. Advantages are Product with good resistance to oxidation Maintain the shape of microcapsule. Disadvantages are i) High energy use, the long processing time and the open porous structure obtained ii) Compared to spray-drying, freeze-drying is upto 30–50 times more expensive.

Coacervation: In simple coacervation, the oil component is usually dispersed in gelatin solution and then a pH adjustment causes the gelatin to coacervate and form a coating over oil droplets. The subsequent cooling step hardens the coating and encapsulates the oil. Complex coacervation uses two oppositely charged polymers and is one of the most promising technologies for stabilization of omega-3 oils by encapsulation delivering highest pay load of 40–90%. In this method, the isolated coacervates might be dried by spray drying or fluid bed drying. Encapsulates made by coacervation have particle sizes ranging from 10 to 800 µm.

Fluid bed coating : In this method, process includes i) Preparation of coating solution **,** ii) Fluidization of core particles iii) Coating of core particle iv) Dehydrate or cool. Encapsulates made this method have particle size ranging from 5 - 5000 µm. Advantage of this method is uniform layer of shell material onto solid particles. Disadvantages are i) Control of air stream and air temperature is a critical factor ii) To achieve uniform coating droplets must be significantly smaller than core.

Extrusion : Process includes i) Preparation of molten coating solution Dispersion of core into molten polymer ii) Cooling or passing of core-coat mixture through dehydrating liquid. Particle size ranging from 200 - 5000 µm. Advantage is product shelf life is long (eg.5 years for extruded flavor oils) . Disadvantages are i) Large particles formed by extrusion ii) Very limited range of shell material is available.

Liposome Entrapment: Major process involved are **i)** Microfluidization ii) Ultrasonication iii) Reverse-phase evaporation. Encapsulates made this method have particle size ranging from 10 - 1000 µm. Advantages are Liposomes are mainly studied and used as advanced, pharmaceutical drug carriers and their use in foods. Disadvantages are i) Limited due to its chemical and physical instability ii) Low encapsulation yield

I. Encapsulation of bioactive ingredients

A. Encapsulation of omega-3 fatty acids

Omega-3 fatty acids are belongs to the family of polyunsaturated fatty acids that the body cannot synthesize, but are essential for multiple function in human health. Biochemically, omega-3 fatty acids which have their first double bond (unsaturated) in the third carbon from the methyl end. The most important omega-3 fatty acids are alpha linolenic acid (ALA, 18:3 n-3), eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaneoic acid (DHA, 22:6n-3). Due to its unsaturated nature, they are susceptible to oxidation and also produce hydroperoxides and off-flavours which are objectionable by consumers. To overcome the above mentioned problems, the utilization of encapsulation technique has been studied by various researchers.

Methods and wall material used for encapsulation of omega-3 fatty acids

Methods: Spray drying, Freeze-drying, coacervation, Electrospraying, Spray granulation and fluid bed film coating etc.

Wall material: Gelatin, maltodextrin, casein, lactose, sodium caseinate, dextrose equivalence, highly branched cyclic dextrin, methylcellulose, hydroxypropyl methylcellulose, n-octenylsuccinate, derivatized starch/glucose syrup or trehalose, sugar beet pectin, gum arabic, corn syrup solids, egg white powder etc.

B. Encapsulation of polyphenols/flavors

Flavor plays an important role in food products which influences further consumption of foods and provide consumer satisfaction. Commercially available food flavors in liquid forms are difficult to handle or incorporate into food systems. However, many flavor constituents are very sensitive to oxygen, light, and heat. These problems can be solved by encapsulation. Several essential oils such as ginger, garlic, cinnamon, coriander, clove, peppermint, citrus peel, oregano, thyme, rosemary basil, eucalyptus and have been demonstrated various biological properties activities, including antioxidant, antimicrobial, antiviral and anti-inflammatory functions. Several researchers reported that plant polyphenols can slow the progression of cancers, diabetes, osteoporosis and reduce the risks of cardiovascular disease . Due their instability and unpleasant taste (astringency) which needs to be protected or masked before incorporation into food products.

Methods, wall material used for encapsulation of polyphenols

Methods**:** Spray Drying, Coacervation, Co-crystallization, Freeze drying, Molecular encapsulation, Extrusion, Electrostatic extrusion

Wall material**:** Maltodextrin, gum arabic, chitosan, citrus fruit fiber, colloidal silicon dioxide, maltodextrin and starch, sodium caseinate-soy lecithin, skimmed milk powder, whey protein concentrate, gelatin, Calcium alginate , chitosan, ϰ-carrageenan, etc.

C. *Encapsulation of vitamins and minerals*

Fat-soluble (e.g. A, D, E, K) and water-soluble (e.g. ascorbic acid) vitamins can be encapsulated. Iron is one of the most important elements and plays a major role in human health and its inadequate consumption leads to iron deficiency. One of the ways to prevent this problem is fortification of food with iron. But, the bioavailability of iron is affected by interactions of iron with the food ingredients such as tannins, phytates and polyphenols. Encapsulation can be used to prevent these reactions.

Methods and wall material used for encapsulation of vitamins and minerals

Methods**:** Spray drying, Spray cooling and spray chilling, Liposome entrapment, Extrusion, Fluidised bed coating, Coacervation, Molecular inclusion, Liposome entrapment

Wall materials**:** Tripolyphosphate, cross-linked chitosan, starch, β-cyclodextrin, malto dextrin, gum arabic, Waxes, fatty acids, water-soluble polymers and water-insoluble monomers, soy lecithin, Maltodextrin (DE 7–10), lactose, fructo-oligosaccharide, Polymethacrylate, ethylcellulose, waxes, hydrogenated vegetable oil, stearin, fatty acids, emulsifiers, gums and maltodextrins etc.

D. *Encapsulation of calcium*

Soya milk contains much less calcium (12mg/100 g) than cow's milk (120mg/100 g), which is undesirable from a nutritional point of view. By encapsulating the Ca salt (calcium lactate) in a lecithin liposome, provides possible to fortify 100g soya milk with calcium up to 110 mg for obtaining calcium levels equivalent to those in normal cow's milk .

E. *Encapsulation of enzymes*

Enzymes are biomacromolecules or in other words complex protein molecules with specific catalytic functions and they regulate the chemical reactions needed for the human body. Because of their enormous catalytic power in aqueous solution at normal temperatures and pressures, enzymes are of great commercial and industrial importance. During encapsulation process, the enzyme is entrapped within a semipermeable membrane so that the activity of an enzyme is not affected (Table 5). But the movement of the substrate to the active site may be restricted by the diffusional limitations especially when large molecules like starch and proteins are used, which can have an adverse effect on the enzyme kinetics.

Methods and wall material used for encapsulation of enzymes

Methods **:** Liposome, Complex coacervation, Spray drying, Liposome entrapment

Wall materials **:** Alginate, Chitosan/Cacl2 polyelectrolyte beads, Sodium alginate and starch, Chitosan, modified chitosan (water soluble), alginate, calcium alginate and arabic gum, α-amalase, Alginate, carrageenan etc.

F. *Encapsulation of protein hydrolysate and peptide*

Food protein hydrolysates and peptides are considered as a promising functional food ingredients. However, food application of protein hydrolysates and peptides can be inhibited by their bitter taste, hygroscopicity and interaction with the food matrix. These problems can be solved by encapsulation.

Methods and wall material used for *encapsulation* of protein hydrolysate an peptide

***Methods*:** Spray drying, Coacervation, Liposome entrapment

***Wall materials*:** Soy protein isolate, gelatin, whey protein concentrate, alginate, maltodextrin, gum Arabic, carboxymethylated gum, pectin, Phosphatidyl choline, phosphatidyl glycine, lecithin, stearic acid and cupuacu butter

II. Application of encapsulated bioactive ingredients in food and pharmaceutical industry

Bioactive ingredients from aquatic secondary raw material has wide food and nutraceutical application. Details are given below.

Bioactive ingredients from aquatic secondary raw material: Fish protein hydrolysate, Fish protein Isolate and Fish protein concentrate, Fish gelatin, Enzymes, Fish collagen, Collagen peptide, Astaxanthin, Fish oil, Chitin, Chitosan and its derivatives

***Food Application*:** Functional ingredient in cereal products, simulated fish and meat products, beverages, soups, gravies, breads, cakes, Mayonnaise, stabilizer, thickener, or texturizer in foods, ingredient for the production of functional fishery products etc.

***Nutraceutical applications*:** Used as capsules, slow release matrices, sponges, scaffolds and "smart" hydrogels for treating obesity, cancer, blood glucose stabilization, weight management. and antihypertension etc.

III. Challenges and future prospects

Currently, the demand for nutraceutical product from marine source are increasing day by day. Apart from marine oil and protein, several bioactive ingredients from process discards have entered beverage market as functional and medicinal supplements. The successful seafood waste utilization and management is a great challenge for the seafood Industry and it requires appropriate eco-friendly reprocessing technologies that can convert all the valuable components present in the waste into valuable products. The major issues related to processing of secondary raw material is that lack of awareness in bioactive and nutraceutical ingredients from seafood waste, lack of cost-effective process to convert waste to value added products, finally inappropriate cold chain management from the source of generation to the point of conversion to valuable product. Hence, improved utilization of fish processing discards reduces bioactive ingredient loss and can help reduce the pressure on the environmental pollution.