

Microencapsulation and Spray Drying Technology

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Introduction

Till recent, food was analysed only based on sensory flavor and texture as well as its nutritional value. However, on account of the growing evidence the other bioactive components play in linking food and health, an increased interest has been evident among consumer regarding their health benefits. This has further resulted in accounting for food beyond the basic nutritional benefits to the disease prevention and health enhancing aspects. Nutrients and dietary supplements are major bioactive constituents in functional foods as well as nutraceuticals which make them instrumental in maintaining health, act against various disease conditions and thus promote the quality of life. Bioactive ingredients include proteins, vitamins, minerals, lipids, antioxidants, phytochemicals probiotic bacteria etc. These bioactives are very sensitive and their application in food is a great challenge to the industry without affecting their properties. Microencapsulation technique has proved to be one of the quality preservation techniques for sensitive substances and a method for production of novel food materials with new valuable properties. Spray drying is one of the most commonly used microencapsulation and drying technologies in food and pharmaceutical industries which produces microcapsules in micrometer to millimeter range.

Microencapsulation

Microencapsulation can be defined as a technology wherein solids, liquid or gaseous material (core particle) are compactly packed with thin polymeric coatings (matrix) to form small particles referred to as microcapsules in micrometer to millimeter range (2-5000 μm) (Gibbs et al. 1999). The polymer acts as a protective film, isolating and protecting the core material of interest. On exposure to specific stimulus, this wall membrane dissolves itself facilitating the release of core material at the appropriate place and time for effective utilization. The active agent that is encapsulated is referred to as core material, the active agent, internal phase, or payload phase. The material that is used for encapsulating is called as coating, membrane, shell, carrier material, wall material, external phase or matrix. Generally, the term microcapsule is used for a reservoir-like structure with a well-defined core and envelope/coat. There exist a variety of microcapsules which differ in size, composition, and function. The characteristics of the microcapsules ultimately depend on the final goal of the encapsulated product. In general, there are two forms of encapsulates viz., reservoir type; and matrix type (Fig. 1). In reservoir type, the active agent is surrounded by an inert diffusion 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.

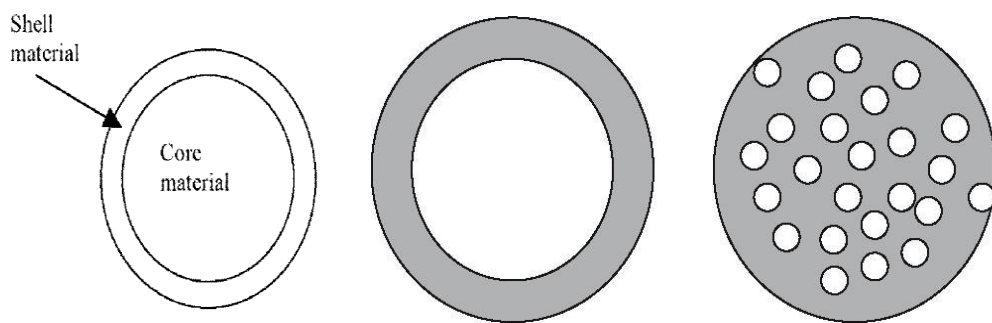


Fig. 1 a) Reservoir type capsule b) Matrix type

Purpose of Microencapsulation

Microencapsulation can be used to achieve a number of objectives, which in general include structural integrity of the material, protection of the enclosed product/core material, and controlled release of the encapsulated contents. Microcapsules can provide structuration to compounds that are normally difficult to administer on account of various factors viz., insolubility of material, volatility, reactivity, hygroscopicity as well as physical state. Microcapsules also facilitate the role of core content protection preventing product degradation due to external environmental factors. Stability of microcapsules should also be ensured during oral administration for therapeutic purposes, due to exposure to harsh conditions in the upper gastrointestinal tract.

In brief, the purpose of microencapsulation includes the following (Desai and Park 2005):

To protect the core material from degradation and to reduce the evaporation rate of the core material to the surrounding environment.

To modify the nature of the original material for easier handling.

To ensure slow, regulated and targeted release of active ingredient

To mask unwanted flavor or taste of the core material.

To reduce nutrient interaction with other ingredients

To ensure uniform mixing due to dilution with the matrix and in powder form

To improve the bioavailability, stability and efficacy of product

MICROENCAPSULATION METHODS

Numerous techniques can be adopted to fabricate microcapsules, depending on the desired characteristics and application of the final product. The method of preparation and the techniques employed for microencapsulation overlap considerably. In general, the various microencapsulation processes can be divided into chemical, physical and physiochemical methods.

Table 1 Methods for microencapsulation

Chemical methods
Solvent evaporation
Interfacial cross-linking
Interfacial polycondensation/interfacial condensation polymerization polymerization
Matrix polymerization
Physical methods
Spray drying
Pan coating
Fluid-bed coating
Centrifugal extrusion
Vibrating nozzle/vibrating-jet
Spinning disk/rotational suspension separation
Physicochemical methods
Ionotropic gelation
Polyelectrolyte complexation
Phase separation/coacervation (simple and complex)
Supercritical fluid technology

Source: Tomaro-Duchesneau et al. (2012)

Spray Drying

Spray drying is one of the most commonly used microencapsulation and drying technologies in food and pharmaceutical industries on being flexible, economical, efficient, easy to scale-up, easily available equipment and produces good quality powder (Desobry et al. 1997). It has been extensively used for decades in the encapsulation of bioactive food ingredients such as proteins, fats, vitamins, enzyme, pigments and flavours. But its use in thermo-sensitive products, such as microorganisms and essential oils is limited because the required high temperature causes volatilization and/or destruction of the product (Gharsallaoui et al. 2007). Microencapsulation by spray drying involves the formation of an emulsion, solution or suspension containing the

core and wall material, followed by nebulization/atomization in a drying chamber with circulating hot air (Fig. 2). The water evaporates instantly in contact with the hot air, and the matrix encapsulates the core material (Laohasongkram et al. [2011](#)).



Fig. 2 Microencapsulation process by spray drying

Preparation of Emulsion: For encapsulation of any bioactive compounds, preparation of stable emulsion is the primary step (Desobry et al. 1997). Emulsion is a mixture of two or more liquids that are normally immiscible. To aid the process, the addition of emulsifiers is required wherein emulsifier stabilizes the emulsion by reducing the interfacial tension between the two phases by forming a rigid interfacial film which serve as mechanical barrier to coalescence. Once the wall or coating material is selected for encapsulation of active ingredient, it must be hydrated. After solubilization of wall material, the active ingredient to be encapsulated viz., flavors, vitamins, minerals, oil etc is added to wall material solution. This is followed by homogenization of the mixture to create small droplets of active ingredient within the wall material or encapsulating solution. A typical ratio of encapsulating agent to core material is 4:1 to 5:1. Emulsion can be prepared either as two layer or multilayer system (Fig. 3) for improved stability (Bortnowska 2015).

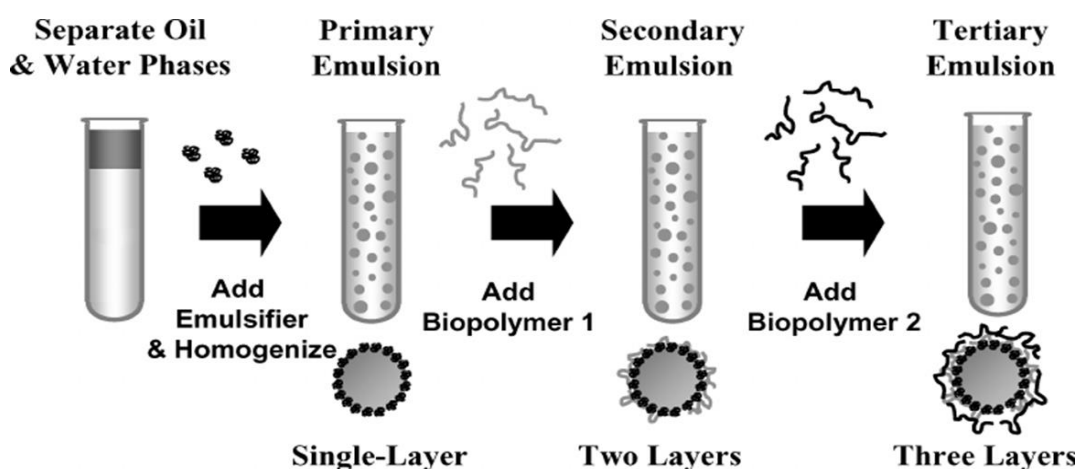


Fig. 3 Preparation of Multilayer emulsion (Source: McClements et al. (2009))

Atomization of the in feed Emulsion: The core- wall material mixture or emulsion is fed into a spray dryer where it is atomized through a nozzle or spinning wheel. The major components of a standard spray dryer include an air heater, atomizer, main spray chamber, blower or fan, cyclone and product collector (Fig. 4).

Dehydration of the atomized particle: When the atomized particle contacts hot air flowing in either a concurrent or countercurrent direction, water in the particle gets evaporated and a dried encapsulated product is produced. Morphology of microencapsulated product obtained by spray drying will be matrix type with the particle size in the range of 10-400 μm .

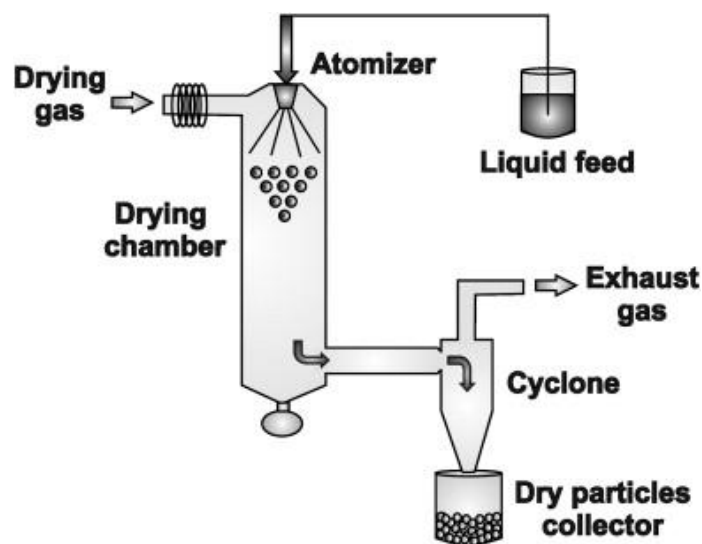


Fig. 4 Schematic diagram of Spray drying (Source: Sosnik and Seremeta (2015))

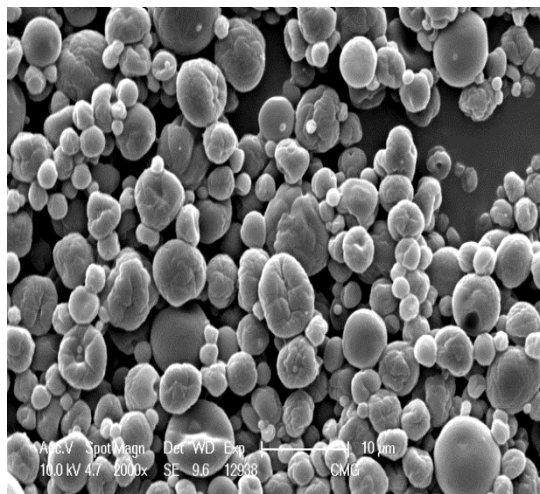


Fig. 5 SEM image of microencapsulated fish oil

Coating/wall materials used for microencapsulation of food ingredients by spray drying

The correct choice of a wall material for microencapsulation of food ingredients by spray-drying is very important to achieve better encapsulation efficiency and microcapsule stability. The ideal wall material should have the following characteristics viz., not reactive with the core; ability to maintain core integrity and stability; lack an unpleasant taste in the case of food applicability and economic viability (Gharsallaoui et al. 2007; Nazzaro et al. 2012). The criteria for selecting a wall material are mainly based

on the physico-chemical properties such as solubility, viscosity, molecular weight, glass/melting transition, film forming, and emulsifying properties etc. Hence, the selection of wall material or encapsulating material according to the desired application is an important task. Most wall materials do not offer all the desired properties and hence to fulfill all the requirements, generally a combination of wall materials is employed. Wall materials can be selected from a wide variety of natural and synthetic polymers, including the following: Carbohydrates: starch, modified starches, dextrans, sucrose, cellulose etc.; Gums viz., gum Arabic, alginate and carrageenan; Lipids: wax, paraffin, monoglycerides and diglycerides, etc.; Inorganic materials including calcium sulfate and silicates; Proteins viz., gluten, casein, gelatin and albumin. Wall materials used for microencapsulation of various food ingredients by spray drying are given in Table 2.

Table 2 Wall materials used for microencapsulation of food ingredients by Spray drying

Food ingredients	Coating material used
Fish oil	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
Poly phenols: Black carrot extracts (anthocyanins), procyanidins, olive leaf extract, <i>Hibiscus sabdariffa</i> L. extract (anthocyanins), soybean extract, grape seed extract, apple polyphenol extract, olive leaf extract, oregano essential oil, mint oil, cardamom oleoresin, black pepper oleo resin, cumin oleo resin, turmeric oleo resin	Maltodextrin, gum arabic, chitosan, citrus fruit fiber, colloidal silicon dioxide, maltodextrin and starch, sodium caseinate, soy lecithin, skimmed milk powder, whey protein concentrate, gelatin
Vitamin C, vitamin A	Tripolyphosphate, cross-linked chitosan, starch, β -cyclodextrin, maltodextrin, gum arabic,
β-Galactosidase, lipase from <i>Y. lipolytica</i>	Chitosan, modified chitosan (water soluble), alginate, calcium alginate and arabic gum, α -amylase, gum, α -amylase,
Hydrolysate and peptide	Soy protein isolate, gelatin, whey protein concentrate, alginate, maltodextrin, gum Arabic, carboxymethylated gum

(Source: Shahidi and Han 1993; Desobry 1997; Schrooyen et al. 2001; Desai and Park 2005; Jeyakumari et al. 2014; Bortnowska 2015; Mohan et al. 2015)

Advantages and Disadvantages of Spray Drying Process

Advantages

- ✓ Relatively simple, fast and easy to scale-up, equipment is readily available
- ✓ The cost of spray-drying method is 30–50 times cheaper than other encapsulation method with low process cost and reduced storage and transportation costs
- ✓ Possibility of employing a wide variety of encapsulating agents viz., both hydrophilic and hydrophobic polymer
- ✓ Ideal for production of sterile materials
- ✓ Rapid solubility of the capsules
- ✓ It increases stability and shelf-life of food product
- ✓ It improves handling of the viscous and sticky food materials.

Disadvantages

- Considerable amounts of the material can be lost during the process due to sticking of the microparticles to the wall of the drying chamber.
- Process variables that should be optimized for encapsulation
- Non uniformity of microcapsule size
- Limitation in the choice of coating material
- Produce very fine powder which needs further processing
- Not good for heat sensitive material

Challenges

Microencapsulation has been applied widely in a variety of food and pharmaceutical products. Studies have shown its enormous potential to provide superiorly featured core, resulting in advanced quality products applicable in the food and pharmaceutical industry. It provides an effective protection for active agent against oxidation, evaporation or migration in food as well as facilitate conversion of liquids to powders. In spite of recent developments of spray drying technique, the process remains far from completely being controlled for microencapsulation of active food ingredients. Spray drying technology is yet to become a conventional tool for food and pharmaceutical industry to produce encapsulated ingredients. To produce effective encapsulated products, the appropriate selection of coating material is a great challenge which can be achieved by multidisciplinary based research approach and consideration of industrial requirements and constraints.

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