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Microencapsulation techniques used for bioactive food ingredients: An overview

Soumya, SB Swami, AA Sawant and YP Khandetod

Abstract
Microencapsulation is a process of coating of small particles of solid or liquid material (core) with protective coating material (matrix) to produce microcapsules in the micrometer to millimeter range. It is one of the methods of protecting sensitive substances and producing active ingredients with improved properties. Many different active materials like lipids, proteins, vitamins and minerals, enzymes and flavours have been successfully encapsulated. A variety of encapsulation techniques are used in the food and pharmaceutical industry. These techniques include spray drying, spray chilling and cooling, coacervation, fluidized bed coating, liposome entrapment, rotational suspension separation, extrusion and inclusion complexation. This chapter will provide an overview of these techniques. Encapsulation is used to protect ingredients, to convert liquid components into solid particles and to provide a means for controlled release. Research is continuing to improve the methods used and to find new applications. This review paper highlighted the various microencapsulation methods and microencapsulation of bioactive food ingredients.

Keywords: Microencapsulation techniques, bioactive food ingredients

Introduction
Encapsulation is a process by which one material or mixture of materials is coated with or entrapped within another material or system. The material that is coated or entrapped is most often a liquid but could be a solid particle or gas and is referred to by various names such as core material, payload, actives, fill or internal phase. The material that forms the coating is referred to as the wall material, carrier, membrane, shell or coating shown in fig1.
Encapsulation is used in a number of different industries with a wide variety of techniques or processes available i.e., spray drying, spray chilling/cooling, fludized bed coating, spinning disc automization and extrusion. Food ingredient encapsulation was once thought of as a formulator's choice of last resort, i.e., rather high priced and custom route to solving unique problems. Today however, higher production volumes and well-developed technologies have made a number of encapsulated products like natural colour (anthocyanin), supply encapsulated versions of such nutritional substances as vitamin C, vitamin B's, ferrous sulfate, ferrous fumarate, sodium ascorbate, potassium chloride, and a variety of vitamin/mineral premixes. Specifically, fat coatings prevent reaction between ascorbic acid and iron containing ingredients in multi-vitamin tablets and powdered infant formula. Encapsulating ferrous fumarate and ferrous sulfate also improves their flowability and compressibility, as well as reducing their dustiness compared standard items, are available at cost effective prices (DeZarn, 1995) [17].
These bioactive compounds i.e., anthocyanin, omega 3 fatty acids, polyphenols/flavours, calcium, lipids 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. (Jeya Kumari *et al*., 2016) [31] Microencapsulation defined as a process of coating small particles of solids, liquids, or gaseous components, with protective coating material typical wall materials include proteins (sodium caseinate, whey proteins, soy proteins, and gelatin) and hydrocolloids (modified starch and Arabic gum). Hydrolysed starches (glucose, lactose, corn syrup solids, and maltodextrin) are generally added as a secondary wall material to improve drying properties are very sensitive and their application in food is a great challenge to the industry without affecting their properties. (Calvo *et al.*, 2011) [10]
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. Microencapsulation defined as a process of coating small particles of solids, liquids, or gaseous components, with protective coating material (Jeyakumari *et al*., 2016) [31].

Encapsulation involves the incorporation of food ingredients, enzymes, cells or other materials in small capsules. Applications for this technique have increased in the food industry since the encapsulated materials can be protected from moisture, heat or other extreme conditions, thus enhancing their stability and maintaining viability (Gibbs *et al*., 1999). [24]

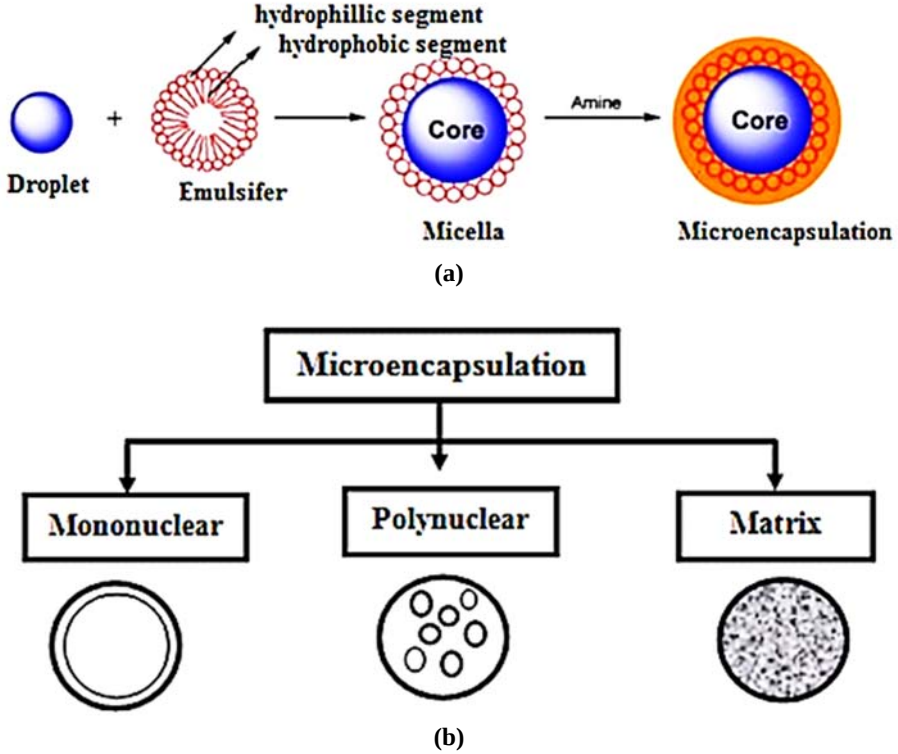


Fig 1: (a) Structure of microencapsulation (Su *et al*., 2015) **(b)** Types of microencapsulation (Tyagi *et al*., 2011)

Microencapsulation 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 (Zuidam and Shimoni., 2010) [70].

Microencapsulation techniques used in the food industry. However, there is a need to discuss the different carriers and methods with a particular focus on encapsulating bioactive food ingredients. The microencapsulation technologies in a three perspectives. First, it focuses on theoretical aspects of different types of microencapsulation techniques and criteria required for encapsulating agents Next, it discusses microencapsulation of various bioactive food ingredients such as omega-3 fatty acids, polyphenols, enzymes, protein hydrolysate and peptides, microorganisms, vitamins and minerals and its applications. The third section summarizes controlled release mechanisms of microcapsules. (Jeya Kumari *et al*., 2016) [31].

The microcapsules are prepared by a variety of methods. The microencapsulation process can be divided into physical and chemical process. Physical process includes spray drying, spray chilling, spinning disk atomization, fluid bed coating and extrusion. The chemical process includes simple and complex coacervation, interfacial polymerization and phase separation (Zuidam and Heinrich. 2010) [70].

Spray drying

Since spray drying is an economical, effective method for protecting materials and specialized equipment is not required, it is most widely employed technique, particularly used for flavours. It is also used for dehydration of materials such as powdered milk. For encapsulation purposes, modified starch, maltodextrin, gum or others are hydrated to be used as the carrier or wall material. The major steps involved in spray drying is shown in table 1. The material for encapsulation is homogenized with the carrier material usually at a ratio of 1:4. The mixture is then fed into a spray dryer and atomized with a nozzle or spinning wheel. Water is evaporated by the hotair contacting the atomized material. The capsules are then collected after they fall to the bottom of the drier. Recent developments have been in the use of new carrier materials and a newly designed spray dryer (Fig.2 (a)). Colloids', Naturals (Thevenet, 1995) [68] and TIC Gums (Reineccius *et al.*, 1995) [52] have developed new combinations of gum arabic starches to increase the retention of volatiles and shelf-life of the microcapsules. In particular, (Risch and Reineccius, 1988) [55] enhanced the retention of orange oil and decreased oxidation by using gum arabic. (Bhandari *et al.,* 1992) reported that a new type of dryer called the spray dryer, which uses a high air velocity with a temperature of 300 to 400 ºC, was effective for encapsulating citrus and linalyl acetate without degradation. A disadvantage is that a separate agglomeration step is required to prevent separation or to

render the obtained powder soluble. A chief advantage is that this technique can be used for heat-labile materials (Gibbs *et al*., 1999) [24]

Spray chilling/cooling

In general, the spray chilling process can be divided into two steps. The first step consists of adding the bioactive compound (anthocyanin, omega 3 fatty acids, polyphenols/flavours, calcium, lipids) to the carrier material, which is usually a lipophilic compound, to be encapsulated. The major steps involved in spray chilling/ coolin is shown in Table 1. This incorporation process can be performed by dissolving or mechanically dispersing the material into the encapsulating matrix (the latter is the most widely applied method). The use of an emulsion is also a method to incorporate some hydrophilic bioactive agents (Pedroso *et al*., 2012; Ribeiro *et al*., 2012) [48, 54]. The second step consists of atomisation of the molten material, which is typically carried out by a heated atomising nozzle to maintain a proper temperature, thus avoiding solidification of the feeding material. When this material is atomised in contact with a refrigerated chamber (due to the injection of cold air or liquid N_2), a heat transfer occurs between the molten material and the cold air, thus leading to solidification of the carrier and the formation of particles (Killeen *et al*., 1993) [35].

The residence time of droplets in the spray cooling chamber is relatively short (only a few seconds). The particlesare collected in a container located below the cooling chamber, and fine particles are transported by air into a cyclone where they are collected in another container (Fig. 2(b)).

The preparation of particles using this method has been applied in various sectors, including pharmaceutical, cosmetic, agricultural, veterinary and food industry (Chambi *et al*., 2008) [12]. The application of spray chilling encapsulation process has also been reported for the production of both food ingredients and several drugs (Gibbs *et al*., 1999) [24]. Numerous applications of solid lipid microparticles obtained by spray chilling have been investigated, such as odour and taste masking (Akiyama *et al*., 1993; Yajima *et al*., 1999) [1, 73]; protection of the active ingredient against detrimental conditions, such as pH, enzyme activity, moisture, oxygen and light; optimisation of the dissolution of poorly soluble drugs; modulating the release kinetics of active compounds; and improvement of flow properties, handling, appearance and other purposes (Ilic *et al*., 2009) [30].

If lipids are used as the carrier material, the final product is insoluble in water and there is usually controlled release of its contents by utilising the melting point of the carrier (Barbosa-Cánovas *et al*., 2008) [4] or by digestion of the carrier in the intestine. The proper selection of the carrier is crucial because the encapsulation process can modify its properties, such as reduce its hygroscopicity and/or increase its chemical/physical stability (Akiyama *et al.,* 1993) [1].

The atomisation of the molten mixture (carrier plus active ingredient) and the solidification process are considered critical steps. The atomisation process is related to the disintegration of the molten mixture into small particles (Liu *et al.,* 2001) [38], and the solidification process is associated with the processing of the molten material into a solid (obtained by cooling). From the operational standpoint, insufficient cooling leads to agglomeration of the droplets and/or adhesion of these droplets on the surface of the chamber, thus negatively affecting the morphology, process and other properties of the microparticles (Kiyomi *et al*., 2013) [36].

Spinning disc atomization

Spinning disc atomization is a less common alternative to the standard atomization techniques associated with spray drying or spray chilling. Emerging in the 1960s, spinning disc atomization was developed to both generate particles and overcoat particles (Johnson *et al.*, 1965) [33]. Images of the spinning disc are shown in Fig. 2(c). The major steps for Spinning disk atomization is shown in Table 1. The microsphere forming mixture is extruded onto the surface of the spinning disc. The liquid wets the surface of the disc as it is centrifugally pulled to the periphery, where it breaks into individual jets. The inherent instabilities of the jet result in breakup of the liquid into discrete droplets for drying, chilling, or congealing (Senuma *et al*., 1999) [59].

Spinning disc atomization offers some unique advantages for spray chilling. First, slurries are more easily processed due to the lack of restricting orifices. Pressure nozzles, two-fl uid nozzles, and other common atomization systems are susceptible to clogging when pumping and atomizing slurries if the dispersed particulates are initially too large or agglomerate to form particles that are too large to pass through the nozzle system. A spinning

disc can be fed with large orifices often over 1 cm in diameter. Therefore, slurries with large particles or agglomerates can be processed with little concern for clogging. A second advantage is particle size (Hilborn,1994).

When the flow rate, disc speed, and fluid properties are properly controlled, jet formationcan result in very uniform particles with D90/D10 commonly less than 1.8, where D90/D10 is the ratio of the 90 and 10th percentile particle size values for a cumulative particle size distribution. Finally, spinning disc offers a wide range of potential particle sizes coupled with high throughput. On average, spray chilling with a spinning disc can achieve particle sizes down to 50 or 60 μm. Larger sizes may be made up to at least 2 mm and possibly larger if necessary. Depending on the formulation and desired particle size, production rates over tons per hour may be achieved (Senuma *et al*., 1999) [59].

Fluid bed coating

Fluid bed technology is generally used for encapsulating solid materials with hot melt or solvent-based coatings. The major steps for Spinning fluid bed coating is shown in Table 1. Fluid bed encapsulation is accomplished by suspending solid particles in an upward-moving stream of air, which is temperature and humidity controlled. Once this moving, "fluid" bed of particles has reached the prescribed temperature and is moving uniformly, it is sprayed from the top with a finely atomized, liquid coating whose droplets are of smaller size than the substrate being coated. In the case of hot melts, the coating is hardened by solidification in cool air. In the case of solvent-based coatings, the coating is hardened by evaporation of the solvent in hot air (De Zarn, 1995) [17]. Fig 2(d) shows the fluid bed coating process.

The working zone of a top spray fluid bed encapsulation unit is also known as the spray region. During the encapsulation process, each particle is gradually covered with a film of coating by making numerous passes into the spray region. Above the spray region resides the filter housing. There the upward-moving stream of fluidizing air passes through porous filter material which effectively traps very small particles

entrained in the air and returns these particles to the process for further application of coating (De Zarn, 1995) [17].

Extrusion

Encapsulation by extrusion involves dispersion of the core material in a molten carbohydrate mass. This mixture is forced through a die into a dehydrating liquid which hardens the coating to trap the core material. The major steps for extrusion is shown in Table 1.The most common liquid used for the dehydration and hardening process is isopropyl alcohol. The strands or filaments of hardened material are broken into small pieces, separated and dried. This method was firtst patented in 1957 (Schultz *et al*., 1957) [58] with another patent issued (Swisher, 1962) [64]. The work which led to this development was accomplished by (Schultz *et al*., 1956) of the United States Department of Agriculture. They mixed orange oil into a molten carbohydrate mass and allowed it to cool on a stainless steel sheet. When solidified, the material was pulverized (Swisher, 1962) [64]. Further developed this idea by extruding the material instead of just pouring it onto a sheet, as revealed in his patents (Swisher, 1957; Swisher, 1962) [64]. A lower temperature process is developed, in which a mass of potato starch, glycerol and water is processed and gelatinized in a twin screw extruder at about 100°C. The mass is then cooled down and the bioactive formulation is injected in the last barrel, where the temperature should approximately be 50°C. The extruded ropes are cut into pieces and dried (Zasypkin and Porzio, 2004) [74].

Shelf lives of up to 5 years have been reported for extruded flavor oils, compared to typically 1 year for spray dried flavors and a few months for un encapsulated citrus oils. Carbohydrate matrices in the glassy states have very good barrier properties and extrusion is a convenient process enabling the encapsulation of flavors in such matrices (Zasypkin and Porzio, 2004) [74].

Table 1: Microencapsulation techniques and its major steps

Sl. No	Microencapsulation technique	Major steps in encapsulation
1	Spray-drying	a. Preparation of the dispersion
		b. Homogenization of the dispersion
		c. Atomization of the infeed dispersiond.
		Dehydration of the atomized particles
2	Spray-chilling	a. Preparation of the dispersion
		b. Homogenization of the dispersion
		c. Atomization of the infeed dispersion
3	Extrusion	a. Preparation of molten coating solution
		b. Dispersion of core into molten polymer
		c. Cooling or passing of core-coat mixture through dehydrating liquid
4	Fluidized-bed coating	a. Preparation of coating solution
		b. Fluidization of core particles.
		c. Coating of core particles
5	Spinning disc atomization	a. Mixing of core in a coating material separation
		b. Pour the mixture over a rotating disc to obtain encapsulated tiny particles
		c. Drying

(Poshadri and Arna, 2010) [49]

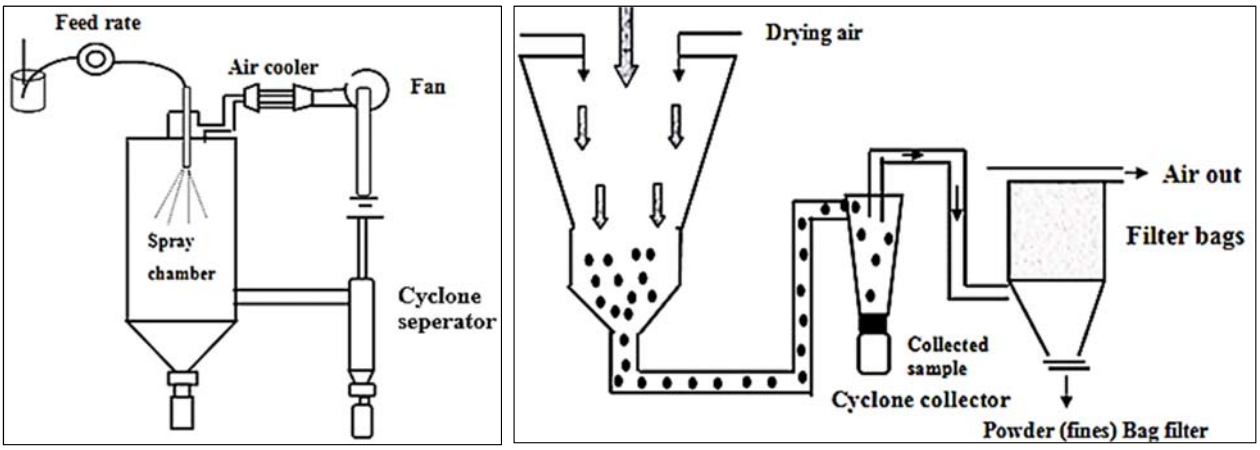
Coating Material Characteristics

When evaluating a coating material for its feasibility in fluid bed encapsulation, a number of factors must be considered. A coating's viscosity, thermal stability and film-forming ability are critical. Table 2. shows the overview of the various coating materials used for bio active ingredients. In the case of aqueous-based coatings, the acceptable viscosity will itself limit the solids concentration allowed in the coating solution. Coatings must typically withstand processing temperatures ranging from 15 to 75°C.Finally, since encapsulation is accomplished by the continual formation of a film on each particle, all coating materials must be able to spread over the particle surface. Materials which are ideally suited for hot melt coating are hydrogenated vegetable oils, or stearines, such as soybean, cottonseed, palm, and canola (low erucic acid rapeseed); fatty acids; various emulsifiers; and waxes, such as beeswax and carnauba wax (De Zarn, 1995) [17].

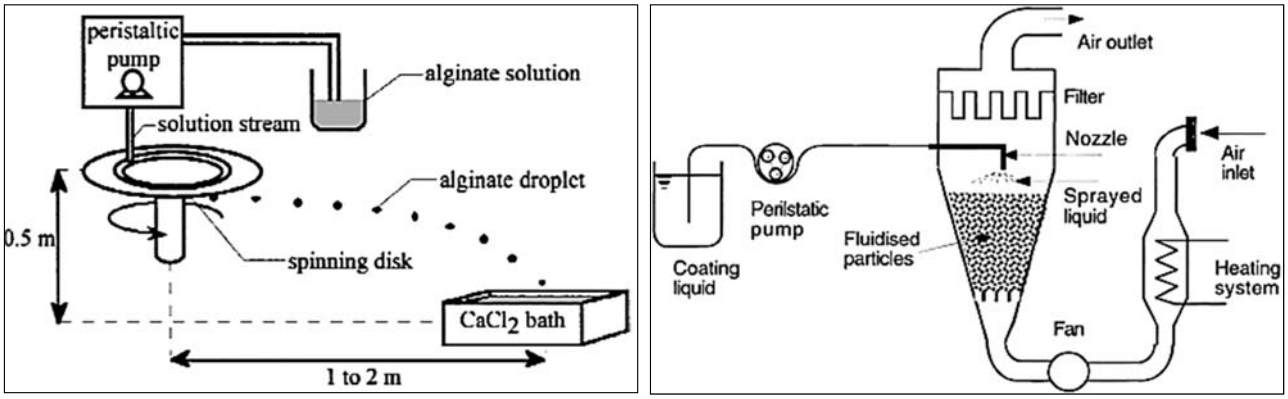
Table 2: Overview of microencapsulating material for bio active ingredients

Sl. No	Origin	Carbohydrate polymer	Protein	Lipid	References
1	Plant	Starch	1) Gluten (corn)	Fatty acids/alcohols	Wandrey *et al.* 2010 [70]; Murugesan and and Valérie Orsat, 2012 [39]
		– Derivatives Cellulose	2) Isolates(pea, soy)	Glycerides	
		– Derivatives		Waxes	
		Plant exudates		Phospholipids	
		– Gum arabic			
		– Gum karaya			
		– Mesquite gum			
		Plant extracts			
		– Galactomannans			
		– Soluble soybean			
2	Marine	Polysaccharides			
		Carrageenan			
		Alginate			

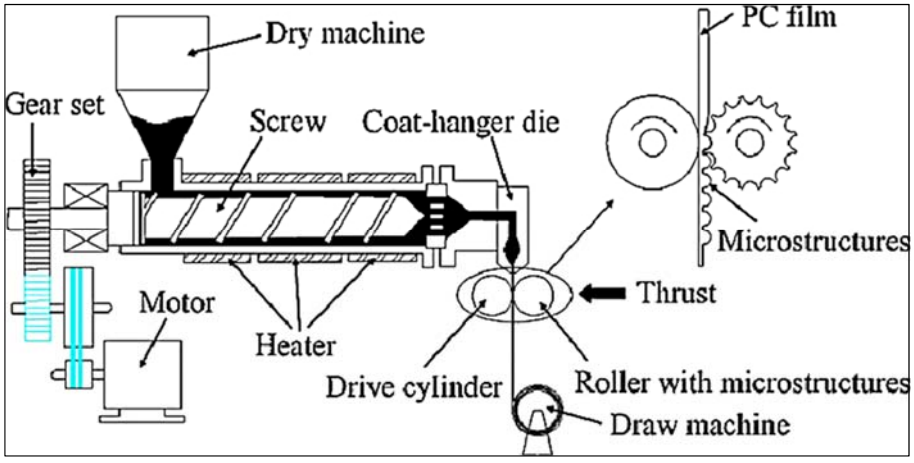
3	Microbial/animal	Xanthan	1) Caseins	Fatty acids/alcohol	
		Gellan	2) Whey proteins	Glycerides	
		Dextran	3) Gelatin	Waxes	
		Chitosan		Phospholipids	



(a) **(b)**



(c) **(b)**



(d)

Fig 2: (a) Schematic diagram of spray drying (Kiyomi *et al*., 2013) [36] **(b)** Spray chilling/cooling (Oxley, 2012) [47] **(c)** Spinning disk atomization (Senuma *et al.,* 1999) [59] **(d)** Fluid bed coating (Teunon and Poncelet 2002) [66] **(e)** Extrusion coating (Jiang *et al*., 2008)

The microcapsules are prepared by a variety of methods. i.e., spray drying, spray chilling, spinning disk atomization, fluid bed coating and extrusion different types of microencapsulation for various plant parts, surfaces and some of the bio-active ingredients are summarised in Table 3 and 4.

Table 3: Overview of process conditions used in various microencapsulation methods

Sl. No	Method	Plant parts/surfaces/Bio-Active ingredient	Temperature	References
1	Spray drying	Jaboticaba peel	Inlet air temperature of 180 ºC	Silva *et al*., 2013 [62]
2	Spray drying	Yoghurt	Inlet air temperature of 160 ºC	Claudia *et al*.,2014[14]
	Fludized bed drying	b-carotene	Inlet air temperature of 80 ºC	Claudia *et al*.,2014 [14]
3	Spray drying	Banana passion fruit	Inlet air temperature of 180 ºC	Gil *et al*., 2013 [25]
4	Spray drying	Cranberry	Inlet air temperature of 160 ºC	Clydesdale *et al*., 1979 [15]
5	Spray drying	Culinary banana bract(anthocyanin)	Inlet air temperature of 170 ºC	Begum and deka, 2017 [6]
6	Spray drying	Roselle calyces	Inlet air temperature of 170 ºC	Shruthi *et al*., 2016 [61]
7	Spray drying	Pomegranate juice	Inlet air temperature of 171 ºC	Muzaffar *et al*., 2016
8	Spray drying	Red amaranthus	Inlet air temperature of 110 ºC	Narayana *et al*., 2018
9	Spray drying	Andes berry (*Rubus glaucus*) and Tamarillo (*Solanum betaceum*)	Inlet air temperature of 150 ºC	Olaya *et al*., 2009
10	Spray drying	*Clitoria Ternatea* (Blue Pea Flower)	Inlet air temperature of 170 ºC	Sapiee.,2013

Table 4: Overview of bioactive ingredients considering various techniques

Sl. No	Category	Coating materials	Widely used methods	References
1	Carbohydrate	Starch, maltodextrins, corn syrup solids, modified starch, dextran, cyclodextrins	Spray- and freeze-drying, extrusion coating	(Reineccius and Coulter, 1989)
2	Cellulose	Carboxymethyl, cellulose, methyl, cellulose, ethylcellulose, celluloseacetatephthalate, celluloseacetate butylate- phthalate	Spraydrying	(Greener and Fennema 1989);
3	Gum	Gum acacia, agar, sodium alginate, carrageenan	Spraydrying,	(Dziezak, 1991)
4	Lipids	Wax, paraffin, beeswax, diacylglyerols, oils, fats	Extrusion coating	(Kamper and Fennema, 1984);
5	Protein	Gluten, casein, gelatin, albumin, peptides	Spray-drying	(Ono, 1980)

Microencapsulation of Bio Active Ingredients

There are numerous methods are used for microencapsulation of bioactive ingredients. Microencapsulation methods used for various bioactive ingredients are discussed below:

Anthocyanin

Anthocyanins are chemically classified as flavonoids, and they form a group of pigments responsible for most of the red to purple colors of flowers, fruits, leaves, stems and roots of plants (Castaneda-Ovando *et al*., 2009). The natural anthocyanin dye is commercially used in candy, bakery products, juice powders and gelatins, and it is generally used in food with lower pH values (pH values up to 3.5) because it has greater stability in acidic conditions (Barros and Stringheta, 2006) [5].

Anthocyanins are a flavonoid group of phytochemicals, widely distributed among fruits, berries, and flower and provide attractive colours such as orange, red, and blue. These pigments are water-soluble and this property facilitates their incorporation into numerous aqueous food systems. They have been used for various food preparations such as jelly dessert, milk dessert, soft ice cream, hard icecream, and yogurt (Shi *et al*.,2003) [60]. In addition to their colourant characteristics, anthocyanins possess biological, pharmacological, anti-inflammatory, antioxidant, and chemoprotective properties (De *et al*., 2007) [16].

During storage of encapsulated anthocyanin at 25 °C and 4 °C with maltodextrin (DE

20–21), the higher storage temperature (25°C) led to higher anthocyanin loss (from 600 mg/100 g to 400 mg/100 g approximately) as compared to the lower temperature (4 °C) with minimal loss from 600 mg/100 g to 500 mg/100 g approximately (Ersus and Yurdagel 2007) [22]. Watermelon juice with 3% and 5% maltodextrin was spray dried at different inlettemperatures of 145 °C, 155 °C, 165 °C and 175 °C in a study conducted by (Quek *et al*. 2007) [50]. Bayberries juice was spray dried and micro encapsulated using maltodextrin (DE 12 and 19), with the inlet and outlet temperature ranges of 140-160 °C and 65-85 °C (Gong *et al.* 2008). The juice powder quality indicated the importance that the inlet temperature played in the colour of the final product (Gong *et al*. 2008). Red–purple food colourant from Opuntia stricta fruits was produced by spray drying (Obon *et al*. 2009).

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, eicosapentaenoic acid and docosahexaneoic acid. Due to its unsaturated nature, they are susceptible to oxidation and also produce hydro peroxides and off-flavours which are objectionable by consumers (Jeyakumari *et al*., 2016) [31].

Fish oil is rich in many nutrients, especially omega-3 fatty acids. Consumption of fish oil has proven to help reduce several risk factors of cardiovascular disease (Nestel, 2000). Fish oil was encapsulated using alginate and starch blends (Tan *et al*., 2009).

Polyphenols/Flavors

Flavor plays an important role in food products which influences further consumption of foods and provide consumer satisfaction. The market for flavors is focused in using aromatic materials coming from natural sources to replace the use of synthetic flavors in the food products(Teixeira *et al*., 2004) [67] These aroma compounds are not only delicate and volatile, but also very expensive(Atmane *et al*.,2006) [3].

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. Encapsulation provides an effective method to protect flavor

compounds from degradation, oxidation and migration from food. Essential oils (Eos) are volatile, complex mixtures of compounds characterized by a strong odor, and they are formed by aromatic plants as secondary metabolites. 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 function(Bennick, 2002; Quideau and Feldman, 1996) [51].
Several researchers have reported that plant polyphenols can slow the progression of cancers, diabetes, and osteoporosis and reduce the risks of cardiovascular disease (Arts and Hollman, 2005; Scalbert *et al*., 2005).
More than 90% of the flavours available in the market are produced or encapsulated by spray drying. Oleoresins which are good antioxidants (Singh *et al*. 2005) are the substances responsible for most of the spice flavours. They are very reactive and unstable in light, temperature and oxygen. Their sensitivity can be overcomed by effective encapsulation. Gum arabic, maltodextrin and modified starch have been used as encapsulating materials to encapsulate cardamom oleoresins (Krishnan *et al*. 2005).

Vitamins and Minerals
Fat-soluble (e.g. A, D, E, K) and water-soluble (e.g. ascorbic acid) vitamins can be encapsulated by microencapsulation. 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. The bioavailability of iron is affected by interactions of iron with the food ingredients such as tannins, phytates and polyphenols. Moreover, iron catalyses oxidative processes in fatty acids, vitamins and amino acids, which results in loss of sensory features and decrease in nutritional value of the food. Microencapsulation can be used to prevent these reactions(Wilson and Shah, 2007) [72]
Ascorbic acid losses begin with harvesting and continue through storage (Erdman and Klein 1982). Vitamin C encapsulation was investigated by (Esposito *et al*., 2002) with the assistance of methacrylate copolymers in drugs. The results showed that methacrylate is effective in encapsulating vitamin C. The encapsulation efficiency was around 98% to 100% with good morphology and size distribution, but it showed poor controlled release of vitamin C. Similar research was conducted with different encapsulating materials by (Desai and Park, 2005)

Calcium
Soya milk contains much less calcium (12mg/100g) than cow's milk (120mg/100g), 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 110mg for obtaining calcium levels equivalent to those in normal cow's milk (Hirotsuka *et al*., 1984).
Calcium micro particles were successfully encapsulated by spray drying with the help of derivatives of cellulose and neutral polymethacrylate (Oneda and Re, 2003). The spray dryer was set at inlet air temperature 120-128 °C, outlet air temperature 91-95 °C and a flow rate of 3 mL/min. The encapsulated final product was evaluated for its calciumcontent, size distribution, and morphology and release profiles. The results showed that the final product properties vary with the polymer concentration and its type (Oneda and Re, 2003).

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. In the microencapsulation method, the enzyme is entrapped within a semi permeable membrane so that the activity of an enzyme is not affected. 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 (Cisem, 2011).

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. Proteins, polysaccharides and lipids based carrier systems used for protein hydrolysates and peptide encapsulation. The protein and polysaccharide based carrier used for masking the bitter taste and reducing the hygroscopicity of protein hydrolysates, whereas the lipid-based carriers are intended for enhancing the bioavailability and biostability of encapsulated peptides (Erdmann *et al*., 2008).
Caraway (Carum carvi L.) essential oil was encapsulated by spray drying. Whey protein concentrate, skimmed milk powder and waxy corn starch were used in combination with maltodextrin as encapsulating materials in the experiment. The inlet and outlet temperatures of 180±5 °C and 90±5 °C were used in the spray drying process. The combination of whey protein concentrate+ maltodextrin/waxy maize starch (9:1) gave higher encapsulation efficiency of 85.88%, with highest total oil retention of 87.85% (Bylaite *et al*. 2001).

Conclusion
Microencapsulation process provides an effective protection for active agent against oxidation, evaporation or migration in food. It plays a major role in development high quality functional food ingredients with improved physical and functional properties in order to make superior products. To produce effective encapsulated products, the choice of coating material and method of microencapsulation process are most important. New markets will be developed as advances in encapsulation. Coacervation seems to be particularly promising since the cost can be reduced due to the requirement for lower levels of food ingredients. The microencapsulation technology is yet to become a conventional tool for food industry to develop the healthy and novel food products which can be achieved by multidisciplinary based research approach and consideration of industrial requirements and constraints.

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