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Microencapsulation Methods and Food Applications: A Mini review

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ABSTRACT

Microencapsulation techniques have been widely used in the food and pharmaceutical industries to increase the stability of compounds, to reduce the size of particles, to mask the undesirable taste and improve the quality of compounds. The active material is encapsulated by the core materials which are either polymeric or no polymeric like cellulose and gelatin. There are several techniques used for microencapsulation such as spray drying, freeze drying, extrusion and coacervation. Many factors affect the quality and efficiency of microencapsulation techniques like types of core and wall materials and preparation techniques. In this article the applications of microencapsulation in the food industries and factors that affect the whole process of microencapsulation are discussed.

Keywords: Microencapsulation, Food Industry, Spray Drying, Freezing Drying

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Introduction

The shelf life and quality of food is affected by different aspects mainly microbial and chemical agents resulting in a significant decline in consumer choices. Plant based bioactive components have antioxidant, antimicrobial and anti-browning properties that inhibits the spoilage in foods [1]. Main causes of food spoilage and loss of bioactive components is poor packaging and interaction of foods with environments by chemical and physical reactions. It is possible to delay the process of food spoilage and browning in food by addition of different bioactive ingredients, good packaging and by the technique of microencapsulation that provides the protection to active ingredients [2]. Microencapsulation is an innovative technique which provides the protection to bioactive compounds in foods and enhances the shelf life by decreasing the microbial activity. Microencapsulation is the process where various food ingredients are stored in a microscopic size coating for protection and to avoid exposure with environmental factors such as light, heat, water, oxygen and improve shelf-life of food [3].

Microcapsules have two phases including external and internal phase coating, shell or wall is external phase and core is internal phase. Shell wall or coating material are composed of gums, proteins, lipids, waxes, polymers and carbohydrates, the core material should be of liquid or solid nature. Microencapsulation technique classified into three categories; mono nuclear (single core), poly nuclear (multiple core) and matrix [4]. There are many novel and conventional process of encapsulation to combine shell and core material into microcapsules. General types of techniques are spray drying, freeze drying, extrusion, spray chilling and coacervation. These techniques has different and unique method of forming an encapsulated product with different advantages and disadvantages. Each technique produce the different size and shape of the products on the bases of physical and chemical changes. The size of microcapsules varies from 1-1000 um depends on the techniques and core materials, coating materials. When the size of microcapsules lower than 1um they are known as nano capsules [1]. Selection of encapsulation process is a challenging task because multiple factors are considered during selection like shell material, core material, particle size, particle morphology, production quantity, quality and availability of process. Cost of operating process also varies depending on, formulation, quantities of products, and type of techniques. Mostly the cost of encapsulation production tends to be higher as the particle size decrease and morphology complexity increase [5]. Microencapsulation method protects the activities of beneficial compounds like essential oils, microorganisms, and probiotics in functional foods and fermentation. These compounds are sensitive to high temperatures, light, and oxygen, making them susceptible to oxidation. Encapsulation controls the delivery and release of active compounds and vitamins in the body, depending on the coating materials used. For example, gum coatings release active ingredients and flavors during chewing process. Microencapsulation can also mask undesirable flavor and aroma of bioactive compounds, such as fish oil aroma and bitter flavor of isoflavones is masked by using insulin and starch as coating materials (Figure 1). This review promotes knowledge about microencapsulation and its application in the food industry [6].

Components of Microcapsules

Core materials: The core material can be liquid or solid in nature. The composition of the materials can be varied such as the liquid core includes dissolved or dispersed materials, providing define flexibility and stability [7].

Coating/wall materials: Wall materials or coating material is important part of microencapsulate technique and it have some define properties such as stability, provide strength to the capsules, non-reactive with core, tasteless, impermeability and develop a cohesive film on the core [7].

Techniques used in Microencapsulation Process

Microencapsulation is a process of packing liquid and solid materials with coatings to form capsules in micrometer to millimeter sizes. Technique includes different methods spray drying, molecular inclusion complexion, coacervation, emulsification, and liposomes [7].

Spray drying

Spray drying is a microencapsulation technique related to atomization of a liquid into dry powder by injector using hot drying steam or gas. This technique works in three stages firstly, atomization (homogenization of liquid by an atomizer), then droplet conversion to dry particles (drying of solution by hot gas or steam and evaporation of the solvent), lastly, collection of particles (collection of dry particle by filter or a cyclone) [7].

Freeze drying

Drying through freeze drying technique occurs in three stages including pre-freezing (water is frozen), primary drying (water removal by sublimation) and secondary drying (desorption of water). During quick or pre freezing water is converted (free water) into solid state which is helpful in minimizing denaturation and avoid frothing during vacuum drying stage. In sublimation stage frozen moisture is heated and causes the conversion of solid into vapour (through sublimation), 90-95% of food moisture is removed in this stage. The residual moisture is removed by desorption at high temperature under pressure but range of temperature is controlled to avoid the denaturation of product ingredients [8].

Complex coacervation

This process involves four steps: a) preparation of an aqueous solution of two or more polymers, b) mixing hydrophobic into an aqueous solution, followed by homogenizing the mixture to develop an emulsion, c) separation phase by change of pH and temperature to certain level to induce coacervation, d) hardening of the polymer matrices using different temperature ranges via desolvation agents. Principle of this process is homogenous colloidal solution separation into two immiscible liquid phases. Complex coacervation in microencapsulation covers the active compound and oppositely charged polyelectrolytes interact with each other in solution. Proteins and polysaccharides are used as wall materials in this process [9].

Emulsification

In emulsion microencapsulation based on the dispersion of core substances in organic solvents, the wall material is dissolved in the organic solvent. Then, the dispersion is emulsified in water or oil containing an emulsion stabilizer. Organic solvents are removed by evaporation, which is aided by stirring, thus producing closely packed polymer globules encapsulating the core. The method gained favor because of its simplicity concerning all stages of particle production and selection of components for formulation and preparation conditions. Other substances that have been encapsulated through emulsification include mainly enzymes, minerals, vitamins, and microorganisms [10].

Characterization of Microcapsules

Particle size

Particle size of microcapsule depends on techniques which are used to form capsules like particle size in spray drying process is 5-5000 um [11].

Morphology of microcapsule

Shape of microcapsule either internally as well as externally depends on which type of core and wall material is used [11].

Surface hydrophobicity

Hydrophobicity property of microcapsules depends on the type of core materials mainly, because core materials have huge impact on the hydrophobicity of the microcapsules [11].

Flow property

It depends on the size, shape and water content of microcapsule, flow property of microencapsulated powder and density important for the storage and packaging process [11].

Application of Microencapsulation

Microencapsulation technology is widely applied in different industries, especially food and pharmaceutical industries because of its ability to improve solubility, enhance stability, and control the slow release of compounds like essential oils, antioxidants, enzymes, drugs, etc. (Table 1) [12].

Table 1: Microencapsulation techniques and their advantages and Limitations

Coating material type	Source	Properties	Technique used	Process	Working conditions	Advantages	Limitations	Reference
Gums	Arabic gum, Carrageenan	Poor tensile Strength, elastic gels, hydrocolloidal	Spray drying	Drying particles in emulsion or suspension by hot air	150 oC temperature, 7ml/mint feed flow, 40 m3/h airflow	Low cost, short time process, efficacy and production rate high, handling of products easy	Not good for thermolabile compound, particles made in nonuniform way	[3]
Carbohydrates	Sucrose, Starch, Dextran	Higher tensile and hydro colloidal strength	Freeze drying	Lyophilization, desorption and freezing	-85 oC for 20 hr	Good for temperature sensitive compounds	Slow process, high in cost	[8]
Proteins	Albumin, Gelatin	Gelation, Emulsification, Water-binding capacity	Extrusion	Material extrusion through a nozzle	Inner nozzles 150 um, outer nozzles 300 um, pressure 600 mbar, voltage 1.5kv	No need of high temperature and specific pH, cost effective process	Nonuniform products, not suitable for viscous solutions	[10]
Lipids	Phospholipids, Bees wax, Stearic acids	Good barrier to vapor and gases, Good Plasticizer	Spray chilling	Microcapsule material using lipids which s atomized in cold chamber and solid particles are leaving in the end	Temperature 38 oC, compressed air at 0.3 bar, aspiration rate 20 m3/h	Good for heat sensitive compounds and low operation cost	Scale up every parameter (cooling temperature, melting, pressure and feed flow), nonuniform particles	[7]
Cellulose	Plant cells	Ability of film hydrophilic forming	Coacervation	Combination of polymers at specific pH and proportion	pH 4, oil/water emulsion, temperature 50 oC	Heat resistant properties and make products in stable form	Expensive, encapsulation efficiency depends on coating materials	[11]

Applications in the food industry

Food industry is using functional ingredients as food additives to enhance their flavor, color, and texture properties and to improve their shelf life. Besides it, functional health ingredients such as antioxidants and probiotics have gained significant interest as well. Most of these ingredients possess low stability due to environmental factors and are easily decomposed by them. Therefore, it is essential to manufacture highly stable products of bioactive compounds. One of the solutions for these problems is microencapsulation. Extensive research has been conducted all over the world recently in designing highly efficient microcapsules and their applications in food industry [3].

Thus, microencapsulation has been utilized with several classes of compounds in the food sector. Quantifying them until 2013; most of the publications in the food sector are related to: 19% probiotics, 12% flavors, 10% lipids, 8% antioxidants, 7% vitamins, 7% enzymes, 3% dyes, and 1% stabilizers, among others. All these compounds have significance in the food industry. The recent example is the inclusion of probiotics in food products, which is defined by World Health Organization as "live microorganisms which, when administered in adequate amounts, confer a health benefit on the host" [12].

Microencapsulation protects the probiotics which can be used to enhance the viability during the food processing, and also for the targeted delivery in gastrointestinal tract, avoiding contact with the extreme conditions of stomach. Other examples include flavors that have a wider spectrum of applications in the food industry; however, they are extremely sensitive to ambient or industrial processes conditions. However, flavor loss during the storage process of foods is frequent, thus making microencapsulation important for protecting and storing flavor in the best conditions to be ingested [13].

Challenges of Microencapsulation Process

Microencapsulation posing great opportunity for food industry (preservation to packaging) but also facing many challenges during processing. Different factors mainly such as selection of core materials, selection of wall materials, cost of process and selection of microencapsulation techniques. The selection of wall and core materials are main challenge due to different categories of food groups and consumer choices toward vegan movement and vegetarian diet. So it’s necessary to use same ingredients used in wall and core materials if food which are capsulated are vegan wall material should be from vegan source. Selection of technique depends on the food materials which are encapsulated, cost, efficiency and need of consumer. Some techniques work efficiently but are costly while other techniques are traditional but they are not safe anymore [6, 8].

Future Trends

Microencapsulation itself is a novel technique which is widespread across different industries from food to cosmetic industry. Future trends of microencapsulation research direction include application of encapsulation for enzymes and spray form microencapsulation and microencapsulation of biosensors [5].

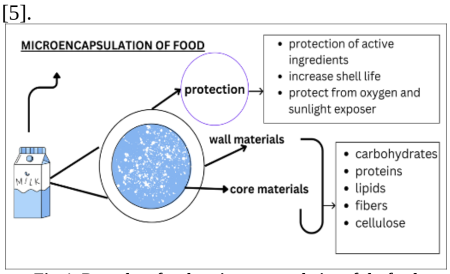

Fig. 1: Procedure for the microencapsulation of the food

Conclusion

Food spoilage and quality are influenced by microbial and chemical factors, leading to a decline in consumer choices. Plant-based bioactive components can delay spoilage and browning by adding antioxidant, antimicrobial, and anti-browning properties. Microencapsulation techniques store food ingredients in microscopic coatings to protect them from environmental factors. Encapsulation processes are challenging due to factors like core material, particle size, morphology, production quantity, and quality etc. Future trends include developing innovative techniques for various industries.

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