Spray Drying Technology in The Food Industry

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Abstract

Microencapsulation is defined as the process of engulfing entities within a continuous polymeric matrix at the microscopic level. The method thus provides erect stability and protection to the sensitive components of food by encapsulating liquids, solids, or gaseous materials with diameters between 1 and 1000 µm. Spray drying has been included as one of the most effective and versatile methods among all the developed methods for microencapsulation. It discusses the mechanism of spray drying and the benefits concerning preserving flavors, oils, vitamins, and other active elements. Spray drying enhances any food significantly, as it reduces losses in nutrition, improves stability, and controls the release of encapsulated ingredients. This technique is very promising in the food industry, catering to increasing demands for stable and fortified food products, because it produces particles of controlled size and can accommodate a variety of materials for both the core and shell.

Introduction

One defines microcapsules as the microscopic, continuous film of the encapsulating material, normally a polymer, that encases the active material. The process is referred to as microencapsulation. Materials, upon encapsulation into microcapsules, may be liquid, solid, or gaseous. These various forms may have different sizes, measuring between 1-1000 µm, depending on the applied microencapsulation technology (Ozkan et al., 2019). Encapsulations less than 1 to 1000 nm, usually between 100 and 500 nm, are called nanocapsules (Pathak et al., 2018). Microencapsulation is still a more common practice in the food industry, although nanoencapsulation is gaining interest because it holds several advantages over microencapsulation. The safety aspect of the food substances encapsulated in nanoparticles is also a matter of investigation (Katouzian & Jafari, 2016).

As far as microencapsulation is concerned, the material to be contained is often referred to as the active, encapsulate, or core, while the polymer controlling the active is referred to as the shell, wall, matrix, or coating (Arenas-Jal et al., 2020). The common constituents of the shell are gums, proteins, lipids, or synthetic polymers based on the application (Desai & Park, 2005). Normally, the shell would be insoluble and non-reactive with the core. The matrix or shell should be able to form outstanding films and barriers to oxygen, water, pressure, heat, and/or light to employ enrobing with the core material. This is usually actually accomplished by applying the matrix or shell as a liquid, solution, suspension, or molten substance (Shishir et al., 2018). It is a novel technique applied in tastes, acids, oils, vitamins, microbes, pharmaceutical, and agrochemical industries, not forgetting the food sector. Proper selection of the wall material, core release shape, and encapsulation technique has contributed to the success of this technology (da Silva et al., 2014). This review article will concentrate on analyzing the spray drying microencapsulation method and the uses and applications of this method in the food industry. It will throw more light on the benefits and real-life implications that the spray drying process has in enhancing foodstuffs.

Types of microencapsulation techniques

The several microencapsulation procedures can be classified based on the microparticle formation process. Each methodology is a different way of generating encapsulates and has its own set of advantages and disadvantages that produce particles with a specific spectrum of materials, particle sizes, core loading, morphologies, and related prices (Carvalho et al., 2016). Generally, the perfect form of the microcapsules may be spherical, with smooth surfaces, indicating that the carriers have completely covered the core, hence a high core load and high encapsulation efficiency (Shamaei et al., 2017). Since the stiff microcapsule wall allows hardly any entry of gases, moisture, and microbes, it is generally advantageous for long-term storage. This results in the protection of the active ingredient and avoids particle degradation, thereby enhancing stability (Huang et al., 2019). There are three categories into which microencapsulation techniques apply. Fisical procedures: these are processes that rely on physical changes in the shell material alone, like gelling, freezing, or drying, to form microparticles. The physical methods that give rise to microspheres are lyophilization, extrusion and emulsion-based procedures, spray coating, fluid bed, atomization, spray-drying, spray-chilling, and lyophilization (Gouin, 2004). On the other hand, microcapsules are generally the product of the chemical processes like coacervation, interfacial polymerization, solvent evaporation, nano-encapsulation, and liposomes. Although, some methods are considered to form a third group of classification, which is the physico-chemical methods, as they lie somewhere in between the two groups (Ozkan et al., 2019).

Spray drying process

Spray drying shall be used for whenever a heat-sensitive chemical or active substance needs protection. Although considered to be a dehydration process, it is in most instances applied as an encapsulating technique (Estevinho et al., 2013). By definition, spray drying is a process in which an atomized feed is sprayed into a hot drying gas for it to transform from a fluid condition, like an emulsion, dispersion, or solution, directly into powder. The liquid formulation is fed in either the form of an emulsion, suspension, or solution (aqueous or organic). Afterwards, the liquid is pumped and atomized at the entrance of the drying chamber where it is converted into spray of tiny drops. This is done through a commercially available spray nozzle available in three types: centrifugal disk atomizer, pneumatic, and pressure nozzles, which transform the feeding solution into relatively small droplets. The centrifugal disk atomizer is recommended for high-capacity processes because of flexibility and easiness of handling, with low maintenance. The pneumatic nozzles are used for small-size processes since they are less effective, while the use of compressed air increases the operating cost of running them. Pressure nozzles were found useful in the drying of high viscosity solutions. This is so because the size of the drops is small, and hence they will expose a larger surface area to the hot gas stream whereby mass transfer and heat transfer processes make the droplets evaporate. Upon entering the drying chamber, these droplets will make contact with the inlet gas that can either be heated ambient air or an inert gas in a case that the drying product is oxygen-sensitive or a liquid phase that is flammable. Particle development follows the sequence of nucleation and growth, then agglomeration and coalescence of the individual particles. Particles then expand and follow a helical pattern towards the bottom or dryer exit. The separation methodology is based on the principle of centrifugal force imparted on the particles by the gas stream and the resulting impingement of the particles on a cylindrical blanket surface that collects them. At the bottom of the drying chamber, solid particles are collected inside the cylinder after filtration from the gas stream, and the gas is released to the outside of the cylinder (Piñón-Balderrama et al., 2020). Figure 1 shows the procedure.

The particle sizes for powders produced by conventional spray drying can be characterized and classified into three categories: small, ranging between 1–5 μm; medium, ranging between 5–25 μm; and large, ranging between 10–60 μm. The main part of the apparatus affecting particle size is the atomization system. Droplet size corresponds well with particle size, simply meaning that the larger the droplet size, the larger the size of the particles. Nowadays, the spray drying process may be carried out, to a certain extent, under some control with respect to particle size because different classes of atomizers are available. However, the final size still depends on proper adjustment of the conditions of atomization, as (Vicente et al., 2013) have pointed out.

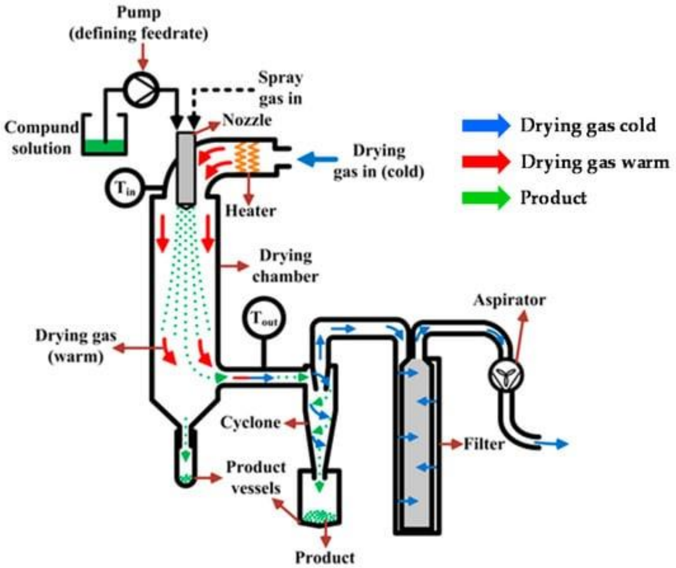

Fig.1: Schematic representation of the conventional spray-drying process (Piñón-Balderrama et al., 2020)

Microencapsulation of food active ingredients

Only some of the advantages of encapsulating food active ingredients are the preservations of labile food components against degradation during storage, reducing nutritional loss, or even adding nutritious nutrients after processing. Added to this, by masking odors and flavors, maintaining volatile ingredients, increasing the antibacterial activity, and providing more flexibility in the production of nutrient-rich foods, microencapsulation can be used to introduce new or sustained-release mechanisms into formulation. The potential payloads that can be encapsulated include flavors, oils, lipids, acidulants, antioxidants, vitamins, and minerals, among other food constituents, colorants, sweeteners, preservatives, enzymes, peptides, polyphenols, and probiotics. Encapsulation helps the core material retain its characteristics and hence would significantly improve the final result on processing, flavor, aroma, flowability, and hydrophobicity or hydrophilicity, for instance (Rezvankhah et al., 2020). Hydrophobic substances which do not show any solubility in water or other hydrophilic systems, like oils and lipids, can be solubilized. In addition, due to the large versatility given by the encapsulation process, entrapping agents can ensure delivery of the bioactive dietary ingredients into the human body to specific locations in a controlled manner (Saavedra-Leos et al., 2014).

Applications in food industry

Discussions on the encapsulation of flavors, lipids, and carotenoids, among others, are actually linked with various interests. More recently, blends of proteins, gums, and carbohydrates have been the focus of research since it is impossible for an encapsulating agent to possess, a single one, all of the qualities desired of a wall material (Gharsallaoui et al., 2007).

Most of the flavoring substances responsible for the typical smell of food are very volatile in water. Thus, they become readily lost during the process of spray-drying. Several techniques of microencapsulation of flavors have been documented; however, the process of spray drying is the most common. Different researches have been conducted on operation conditions and compositions of wall materials affecting controlled release and micro-encapsulation of encapsulated flavors (Madene et al., 2006). L-menthol is a cyclic terpene alcohol, typically having a melting point of 41 to 43 degrees Celsius and always 'in crystal or granule form' (Soottitantawat et al., 2005). L-menthol possesses high volatility and whisker formation characteristics. It was found that high retention of L-menthol was detected only in a wall system with maltodextrin and gum arabic at high solid content. Spray-drying microencapsulation resolved these two problems that restrict its use and shelf-life storage. Results indicated that the feed emulsion with high taste retention and very minimal flavor residue left on the surface had an ideal L-menthol concentration of 1/4 in L-menthol/wall materials (Gharsallaoui et al., 2007).

Volatile aromatic compounds will be hydrophobic molecules dissolved in lipids when using them as solvents. Five advantages of lipid encapsulation, according to (Visser et al., 1990): are that it can protect dissolved chemicals from enzyme hydrolysis, delay auto-oxidation, enhance stability, regulate the release of lipid-soluble flavor, and mask the bitter taste of lipid-soluble substances. Spray-drying works quite well when encapsulating oils and oleoresins. Information on the spray-drying process for the microencapsulation of cardamom oleoresin with gum arabic, maltodextrin, and modified starch as wall materials already exists (Krishnan et al., 2005). This study demonstrated that the content of gum Arabic decreased in the blends with modified starch and maltodextrin, considerably reducing the stability of the cardamom oleoresin. Hence, the mix in a ratio of 4/6 : 1/6 : 1/6 for gum arabic, modified starch, and maltodextrin was considered appropriate. Hogan et al. used mixes of sodium caseinate and carbohydrates to encapsulate soy oil through spray-drying and showed an enhancing effect of higher dextrose equivalency of the carbohydrates on microencapsulation efficiency (Hogan et al., 2001). Studies in spray-dried powders with 50% butteroil encapsulated in sucrose and double encapsulated in a matrix of vegetable waxes suggest that the double-encapsulation process may improve capsule resistance to moisture sorption, although this was at the expense of powder flow characteristics, as reported by (Onwulata et al., 1998).

(Oneda & Ré, n.d.) used spray drying to obtain calcium microparticles with polymethacrylic acid and cellulose derivatives as wall systems. It was shown that the size and shape of spray-dried microparticles depended on the type of polymer used and its initial concentration. Lycopene was microencapsulated through its spray-drying with sucrose and gelatin as a wall system. According to (Shu et al., 2006), the ratios for the ideal ratios for gelatin and sucrose were 3/7 and core and wall material respectively. In spite of being a chemical susceptible to heat, lycopene was found to be more than 52% pure in this work with feed and intake temperatures of 55 and 190 degrees Celsius respectively with a homogenization pressure of 40 MPa. According to (Diosady et al., n.d.), however, spray-drying was also considered as the most efficient process to encapsulate iodine, and dextrin worked best among all.

Conclusion

Microencapsulation has become very interesting in the food business; in particular, methods of spray drying do not only distribute but also provide protection to the active chemicals. The technique offers very many benefits that enlarge storage stability, nutritional value, and preserve easily damaged components of food. Evidence of its versatility can clearly be drawn from its ability to encapsulate quite a general range of compounds, such as flavors, oils, vitamins, and antioxidants. As much as spray drying is versatile and successful, it still remains the method of choice in producing regulated particle sizes and good encapsulation. Food quality and functionality will further be enhanced through microencapsulation, much of which comes with state-of-the-art methods like spray drying, as the market for stabilized and fortified foods increases.

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