



P-ISSN: 2349-8528

E-ISSN: 2321-4902

www.chemijournal.com

IJCS 2021; 9(1): 1836-1840

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Received: 18-11-2020

Accepted: 24-12-2020

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International Journal of *Chemical Studies*

Review: Flavor encapsulation by spray drying technique

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DOI: <https://doi.org/10.22271/chemi.2021.v9.i1z.11492>

Abstract

Flavors are the most expensive valuable ingredient in the food product as they are very delicate and volatile in nature, thus to preserve them has become a concern to food manufacturers. Microencapsulation is a recent technology used to pack food materials in the form of micro and nanoparticles which helps to protect sensitive food components, reduce nutritional loss and preserve flavors. Encapsulation of flavors is a highly commercialized process which involves various methods such as spray drying, spray cooling, extrusion and freeze drying. Among them spray drying encapsulation technique is commonly used for food products. It depends on high retention of the core materials particularly volatiles and some amount of oil for both volatiles and non-volatiles during the processing. The properties of core and the wall materials will influence the efficiency and retention of core during spray drying process conditions. This article emphasizes on spray drying microencapsulation of food oils, flavours and their encapsulation efficiency during the process.

Keywords: Flavors, microencapsulation, spray drying, efficiency

Introduction

Flavours are the most important attributes for every food product. Flavorings are added to enhance the taste. Flavor is the combination of odors and taste which is produced by mouth feel and senses both taste and smell. In recent times, consumers are moving towards the awareness of good health, well lifestyle and beneficial diet. Microencapsulation of food products became a new challenge task faced by the food product developers due to the reason the ingredients which are incorporated in food systems slowly deteriorate and lose their properties or become hazardous toxic, by propagating oxidation reactions in them and change the organoleptic attributes of the product. In order to overcome these challenges microencapsulation is used whose properties are built by using flavor microcapsules that release a volatile compound continuously throughout the mechanical stress and diffusion.

Microencapsulation is defined as a process in which tiny particles or droplets are surrounded by a coating the matrix, to give small capsules with many useful properties. It is a technique by which liquid droplets, solid particles or gas compounds are entrapped into thin films of a food grade microencapsulating agent by encapsulation techniques. It has become a more attractive approach to convert liquid food flavorings into a dry powder form which is easy to handle and to introduce into a dry system (Madene, A., 2006) [23] and mostly depends on initial formulation, production, processing and temperature.

Microencapsulation is a recent technology which is used for generating small particles that cluster into thin layers as it consists of a hard core which is surrounded by a wall of uniform thickness. The thickness of the coat is (0.2-500.0 nm) and protects against chemical processes. Many encapsulation techniques have been developed by the manufacturer of encapsulated food ingredients. Spray drying is one of the most commonly used and old encapsulation techniques in the food industry used in the preparation of the encapsulated flavours using gum Arabic. Extrusion is also a popular processing technique for the microencapsulation of food flavours and oils. Spray drying is economical, easy for maintenance and readily available (Bhandari 2008) have reported on spray drying microencapsulation.

Materials and methods: Microencapsulation process

Microencapsulation involves three steps:

1. Material to be coated or encapsulated
2. Material in which to be encapsulated or wall matrix material
3. Type of microencapsulation techniques to be employed i.e., spray drying.

Coating materials includes flavours, antimicrobial agents, antioxidants, colours, acids, alkalis, buffers, sweeteners, nutrients, enzymes, cross-linking agents, yeasts, chemical leavening agents, and many more (Lakkis, 2007) [18]. Almost all liquid food flavorings are volatile and unstable in presence of air and light. Volatile products have been successfully microencapsulated by using spray drying (Bhandari, 1992) [6]. Coating materials are the thin film-forming material which may be of natural or synthetic polymers, depends on the material which is to be coated and their properties such as strength, flexibility, Impermeability, optical properties compatible and nonreactive.

Properties of the Core Materials

1. Retention of Volatiles: There is less loss of volatiles flavours during spray drying encapsulation. The retention of volatiles depends on their polarity, as the water solubility of the volatile increases, the volatile losses increase due to the ability of the water fraction to diffuse through the selective membrane, even at late stages of the drying process. For example, retention of partially water soluble esters like (ethyl propionate and butyrate) in gum arabic less than those with lower polarity.

2. Concentration of the core material: Most common term used in the microencapsulation is core-to-wall ratio a representative of flavor concentration. More the core

concentration poorer retention in the microcapsules due to the less wall materials used thus increases the yield and economy.

3. Role of the initial emulsion: Emulsion has very important role in determining the retention of volatiles and surface oil content of encapsulated powder. The significance properties which needed to be considered are total solids concentration, viscosity and stability.

4. Total solids content of the emulsion: Another important factor for determining the retention of volatiles and encapsulation efficiency of food oils and flavours during spray drying is dissolved solids content (Rulkens, W.H.; Thijssen, H.A.C, 1972) [38] according to their study the high solids content emulsion increase retention by reducing the required time to form a semi-permeable membrane at the surface of the drying particle. There are mainly two reasons as mentioned below:

5. Total Solids content of the emulsion: Another important factor for determining the retention of volatiles and encapsulation efficiency of food oils and flavours during spray drying is dissolved solids content according to their study the high solids content emulsion increase retention by reducing the required time to form a semi-permeable membrane at the surface of the drying particle. There are mainly two reasons as mentioned below:

- Some solids content, adds more wall materials that exceeds its solubility and those suspended wall materials cannot provide any effective encapsulating effect and also, leads to poorer flavour retention during the drying process;
- For an optimum in feed solid is related to the viscosity of the initial emulsion which is shown to have an optimum (Figure 1).

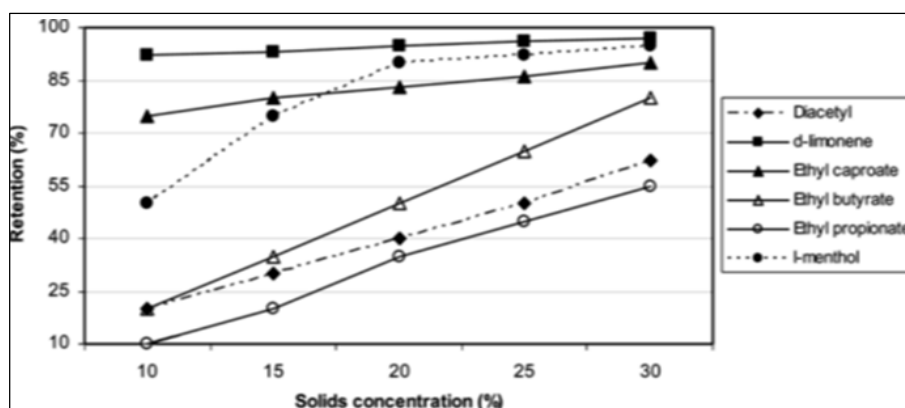


Fig 1: Effect of initial solids concentration on retention of different flavors during spray drying encapsulation (Jafari *et al.*, 2008) [17]

According to Liu, X.D. (2000) [22], study regarding ethylcaproate, found that it was slightly depend on the initial solid concentration they showed that below 25% solids, the retention increased gradually with increase in concentration due to the rapid formation of crust on the surface of droplet, to trap volatiles emerging from the ruptured emulsion. Therefore, it can be concluded that in feed solids concentration has a high influence on those volatiles that are most susceptible to loss.

6. Emulsion Viscosity: An increase in the viscosity than the beyond optimum limit causes a decrease in the retention due to prolong exposure, the slow formation of discrete droplets during atomization and difficult to form droplets. It shows

that a more viscous feed will produce larger droplet sizes and vice-versa. Some researchers have reported that increase in the viscosity of the emulsion is possible without changing its solids content, by addition of thickeners (1% w=w of wall materials concentration) like carboxyl methyl cellulose, gums, sodium alginate. Rosenberg and Silva have monitored the effect of sodium alginate on the retention of ethyl corporate during spray drying encapsulation, they found that the retention of sodium alginate concentration correspond to an emulsion viscosity ranging from 125 to 250 MPa.s for gum Arabic=ethyl caproate emulsions and about 105 MPa.s for maltodextrin=Allylguaiacol emulsions (Figure 2). They claimed that this viscosity was relatively easy to atomize and reasonably spherical particles were formed. Emulsion

viscosity plays significant role in determining volatiles retention, due to its large influence on the control of volatile losses till the surface of the droplet becomes dry, semi-permeable and also it improves retention. Thus, increasing the

viscosity within the limit causes a decrease of the retention, due to a larger exposure during atomization, the slow formation of discrete droplets throughout atomization and difficulties in droplet formation.

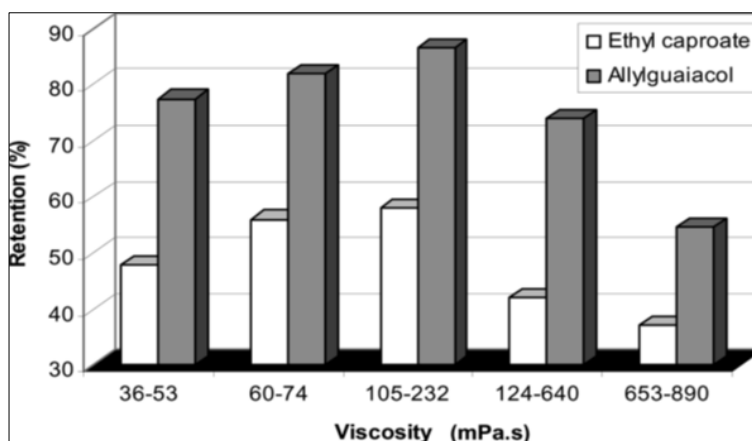


Fig 2: Effect of emulsion viscosity through addition of sodium alginate on the retention of ethyl caproate and Allylguaiacol during spray-drying microencapsulation (Jafari *et al.*, 2008)^[17].

7. Emulsion Stability: The encapsulation efficiency of oils and flavours is influenced by the stability of initial emulsion, better the stability, higher is the efficiency. For example Liu, X.D. (2000)^[22] studied the effect of emulsion stability on the retention of emulsified hydrophobic flavours during drying as a measure of stability and also examined the decreasing rate of emulsion absorbance with increase of emulsion droplet size against the time. Finally, Liu, X.D. (2001)^[40] found that the density of the ester flavours with agents like sucrose acetate and iso-butyrate stability and flavour retention can be improved. However, some other factors such as the molecular weight, volatility and solubility of the flavours possibly influence the retention

8. Emulsion Size: Emulsion size is consider as effect on the encapsulation efficiency of oils and flavours during spray drying microencapsulation. According to some researcher's reports, studies say that the encapsulation efficiency of a specific core material is improved with decreased emulsion droplet size.

One fine study done by they found that retention of volatiles was directly related to the difference between emulsion droplet size and particle size of the spray dried microcapsules (Figure 3). Therefore, it is possible to improve the retention by increasing the difference between emulsion size and powder particle size.

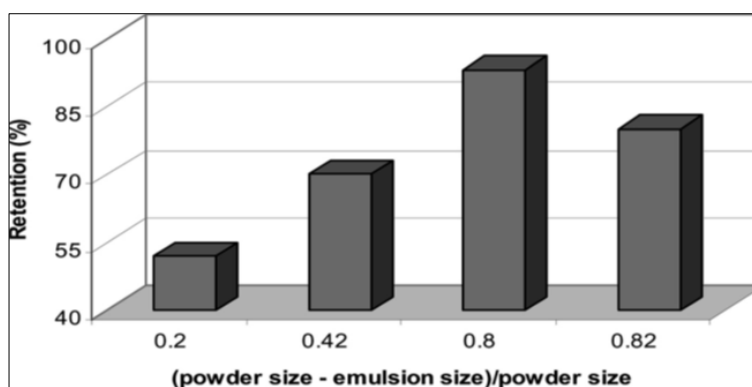


Fig 3: Influence of the difference between the emulsion droplet size and the particle size of dried microcapsules on the volatile retention (Re, M.I.; Liu, Y. J. 1996)^[27].

In this encapsulation technique the coating material must suit the wall material, which forms a continuous thin film and should protect the core material from deterioration. The desired functional properties are high solubility, low hygroscopic, easy release of core material, efficient, added to enhance the viscosity and to stabilise the system. (Lee *et al.*, 2003). Many different materials can be used in developing a microencapsulation: Acacia (Gum Arabic), Ethyl cellulose, Food Starch (Modified), Guar Gum, Hydroxypropyl Cellulose, Hydroxypropyl Methylcellulose, Potassium Alginate, Potassium Citrate, Sodium Alginate, Sodium Carboxymethyl cellulose (CMC), Sodium Citrate, Sodium Polyphosphates (Glassy), Xanthan Gum, etc. (Versic, 2010).

Encapsulation of ingredients in coating materials is involved by several methods such as (physical and chemical) of coating materials and the intended application of it (Desai, 2010; Barbosa., 2005)

After selection of the suitable wall material, an active ingredient is rehydrated with water. This is particularly done for the surface-active polymers to enhance their emulsifying properties during emulsion formation. Then the core material is added to make a coarse emulsion at very high-speed mixing by colloid mills. A concentrated solution of wall material is formed until the desired size of droplets is attained. A 20–25% flavor load based on total solids of the wall solution is traditional in spray drying microencapsulation. The resultant

emulsion is prepared and pumped into the drying chamber of the spray drier. There the water portion is evaporated, yields dried capsules. The capsules are collected through continuous discharge outlet from the drying chamber. This method is used for microencapsulated materials.

The flavor emulsion was spray dried in a co-current spray dryer equipped with atomizer. The process conditions that need to maintain are; air inlet temperatures at 160°C with constant feed rate 28g/min; rotational speed of atomizer 25,000rpm and air flow rate 110kg/h. Temperatures of final powder (<50°C) were measured, the powder was separated by cyclone separator and stored in plastic bags. This process powder yield has the ratio between the total collected powder and theoretical powder quantity from the sprayed emulsion.

Conditions of the spray-drying process

Powder particle size: Particle size of the encapsulated powder is determined by their viscosity and solids concentration and the mechanical process used for atomization. Reineccius, G.A. 2004 [29]. Particle size is influenced by the operating temperatures: high inlet air temperature and low difference between inlet and outlet air temperatures will form large particles and thus, results in slow drying. This is because of the very fast drying particle which does not allow the particles to shrink during drying. Also, the in feed solids shows the same effect in that the particles dry quickly if they are high in solids and do not shrink.

Atomization type: In this atomization step volatiles compounds are lost during early stages of drying. During this period the emulsion is sprayed into a thin sheet with proper mixing. Thus, it is essential to minimize the atomization process for maximum volatile retention. Another reason for volatile retention is the pressure nozzles which are used for the atomization step. According to the recent study done by Finney proved that neither type of atomization or processing temperatures influence on the retention of orange oil or thee with overall excellent flavor retention. Powders are produced by atomization which had high surface oil contents. This depends on the type of the atomization process and the dryer.

Infeed temperature: Sivetz and Foote (1963) [25] studied that cooling the feed (30%coffee solids extract) before drying improve the coffee flavour due to an increase in the feed viscosity which causes affect in the internal circulations and size of the droplets. These influence the particle size of the encapsulated powders on their efficiency during spray drying. Infeed temperature increases at the point of infeed solids which has greater solubility thus, results in better retention of higher solids.

Air flows and humidity in the spray dryer: In this parameter according to Coumans *et al.*, (1994) [11] their study more the heat and mass transfer associated with the drying process thus, more rapid drying of the product. Reineccius, G.A. (1988) [15] reviewed that when powder is sprayed at higher pressure it will improve the air product mixing and enhance the drying rate. Lower air humidity also causes rapid drying and better flavour retention. Disadvantage of this air inlet flow is expensive.

Inlet air temperature: There are various studies done on the inlet and outlet air temperatures of spray dryer, When inlet air temperature is raised up to 160–220°C this leads to formation of the semi-permeable membrane on the droplet surface and

gives optimum flavor retention and causes ballooning effect i.e. excessive bubble growth on the surface that increases loss during spray drying. Ballooning is formed when the steam is passed through the drying droplet due to high inlet air temperatures that causes the droplet to puff, produces a thin-walled hollow particle. The ballooning temperature is up to 280–350°C Liu, Y.J (1995) Liu, X.D *et al.*, 2000 [22] showed that retention of d-limonene was independent of air temperature, while there was a slightly increased in the retention of ethyl caproate thus, the temperature increased from 40 to 100°C. According to the other researcher called Rosenberg *et al.*, (1990) [24] revealed that the influence of inlet air temperature on retention of ethylcaproate was stronger at higher solids concentration. Liu *et al.*, 2000) [22] claimed that for d-limonene or ethyl caproate the emulsion is stable so the retention is high and independent of hot air temperature

Outlet air temperature: The influence of outlet air temperature on the encapsulation efficiency of food flavours and oils is also controversial and unclear. The retention of small soluble volatiles such as diacetyl improves with increasing outlet air temperatures, maybe due to a lower relative humidity at higher outlet air which results in more rapid drying and good flavours retention mainly because of higher solids. Recently, Danviriyakul (2000) [26] proved that surface oil content of milk fat encapsulated powders was not affected by outlet temperature there are some merits and demerits of spray dryer mentioned as below:

Advantages of spray dryer

- Applicable to both heat-sensitive and heat resistant materials
- Applicable to corrosive, abrasive, toxic and explosive materials
- Aseptic drying conditions
- Process is continuous and easy to control

Disadvantages of spray dryer

- High installation cost
- Lower thermal efficiency
- Heat degradation possibility in high-temperature spray drying

Conclusion

Microencapsulation plays an important role that prolongs the shelf-life of the products and produce high quality encapsulated powders which contain active compounds, for this specific appropriate microencapsulation technique and encapsulating material should be selected. There are different properties of the wall, core materials, emulsion characteristics and drying parameters that affects the efficiency of encapsulation. The infeed emulsion and size plays an important role on the retention and the stability of the encapsulated flavors. If the product is not stored at particular conditions then it will quickly deteriorate. As it is recently developed not much known by the consumer, its time for more concern research for scientists and food industries.

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