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Study of ultrasound-assisted emulsions on microencapsulation of ginger essential oil by spray drying

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ABSTRACT

This study aimed to evaluate the influence of the encapsulating matrix on producing spray-dried ginger essential oil powders using blends of gum Arabic (GA), maltodextrin (MD) and inulin (IN) as wall materials. The effects of emulsification process assisted by ultrasonication on kinetic stabilization of emulsions used as the feeding liquid in the spray drying were evaluated. The emulsions obtained by using ultrasound were more stable and presented smaller droplets ($\leq 2.03 \pm 0.01$ μm). The use of MD and IN together with GA improved the wettability of the powders (245 ± 21 s). GA:MD powders adsorbed less water vapour than other treatments under the same storage conditions. The partial replacement of GA by MD affected considerably the encapsulation efficiency showing the higher value for this parameter (93.0 ± 0.8%). Larger microparticles were observed in the powders prepared with GA (15.44 ± 0.13 μm) or a mixture of GA and MD (15.83 ± 0.14 μm). The physical and chemical properties of the microparticles were substantially modified by using IN or MD together with GA. Based on the studied properties, the microparticles produced with GA and MD were considered to present the better characteristics for wettability, encapsulation efficiency and higroscopicity.

1. Introduction

Synthetic flavourings, essential oils, and natural oleoresins are the main aromatic components used by the food industry. Ginger (*Zingiber officinale*) is a plant that belongs to the *Zingiberaceae* family with antioxidant and antimicrobial activities, being considered important for the treatment of various diseases and disorders (Nile and Park, 2015). This product is widely used in food production such as beverages, jams and bakery products (Mesomo et al., 2013) and it is valued for its pungency (Kumar et al., 2014). The essential oil produced by *Zingiber officinale* rhizomes varies in colour from pale yellow to light-amber and can be extracted with yields ranging approximately from 1.5% to 3.0% depending on the quality of the crop (Bellik, 2014).

Essential oils are unstable in the presence of oxygen, light, heat, moisture and metals. Therefore, the evaluation of stabilization processes of these substances are extensively performed by several industrial segments. Encapsulation is one of the techniques most applied to stabilization of essential oils (Osorio-Tobón et al., 2016). In this sense, the encapsulation technique by emulsification using biopolymers combined with the spray-drying of emulsions obtained is a promising alternative for preservation and availability of bioactive and functional compounds found in essential oils.

The emulsification process requires an energy input to blend two immiscible fluids when a proper emulsifier is not added to mixture. In order to overcome this limitation, ultrasound emulsification provide major advantages over other techniques, primarily due to the energy-efficiency, low production cost, ease of system manipulation and better control over formulation variables of ultrasound (Silva et al., 2015a).

Spray drying belongs to the rather complex multiphase convective-drying processes which involve the atomization of droplets of emulsions, particle transport, evaporation of droplets

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Table 1
Composition of the feed emulsions and emulsion processes used in the experiments.

Feed emulsion (g 100 g^{-1})				Emulsion step	
GA	MD	IN	Ginger essential oil	Homogenization (H)	Ultrasonication (U)
20	–	–	5	x	
20	–	–	5	x	x
10	10	–	5	x	
10	10	–	5	x	x
10	–	10	5	x	
10	–	10	5	x	x

GA: gum Arabic; MD: maltodextrin; IN: inulin.

as well as the interaction between particles and/or droplets and/or dryer walls (Blei and Sommerfeld, 2011; Schmitz-Schug et al., 2016). Different parameters can be controlled during the spray drying process in order to obtain desired characteristics in the final product. The wall material system is commonly used in order to avoid these technological problems and the choice of the appropriate carrier depends on the desired physicochemical properties and the final application of the powdered product (Daza et al., 2016). It is necessary to choose the wall materials with high efficiency for microencapsulation by spray-drying because they are playing an important role in encapsulation efficiency and microcapsule stability (Bakry et al., 2016). Gum Arabic, which it is one of the most common wall materials used in microencapsulation by spray drying, is the most commonly used biopolymer emulsifier in flavour emulsions (Niu et al., 2016). Maltodextrin is produced by partial hydrolysis of starch and is commonly used as secondary wall material in microencapsulation by spray drying, offering advantages such as relatively low cost, neutral aroma and taste, low viscosity at high solids concentrations and good protection against oxidation (Otálora et al., 2015). However, the greatest limitation of this wall material is its low emulsifying capacity, so it is generally mixed with other materials. All the commercial inulin types present very high purity and different powder characteristics and carbohydrate compositions (Botrel et al., 2014). Inulin is a natural fructan composed by a linear chain of fructose monomers with a terminal glucose unit. It has a degree of polymerization that ranges from 10 to 60, and the lengths of its molecular chains are associated with its technological properties (Silva and Meireles, 2015). As well as maltodextrin, inulin can provide protection to encapsulated core materials, although these carbohydrates lack any emulsifying properties and need the addition of other encapsulants. Moreover, the use of inulin in foods, at certain levels, provide benefits to consumer health.

There are few published works reporting the effect of different types of homogenization process and the use of wall materials, particularly inulin, on the encapsulation efficiency and the particle properties of microencapsulated ginger essential oil. This study evaluated the effects of the ultrasound-assisted emulsions of ginger essential oil on the physical and chemical characteristics of the microparticles obtained from spray drying using gum Arabic, maltodextrin and inulin as wall materials.

2. Materials and methods

2.1. Materials

Ginger (*Zingiber officinale* L.) essential oil was purchased from Ferquima (Vargem Grande Paulista, Brazil). Gum Arabic was obtained from Colloides Naturels Brasil (São Paulo, Brazil), inulin (degree of polymerisation >10) Orafti®GR from BENEO-Orafti (Tienen, Belgium) and maltodextrin from Maltogil DE 10 Gargil (São Paulo, Brazil).

2.2. Preparation of ginger essential oil emulsions

The volume of each emulsion was set at 400 mL. The ratio between the ginger essential oil and each biopolymer was 1:4 (w/w). Each polysaccharide suspension, gum Arabic (GA), gum Arabic + maltodextrin (1:1; w/w) (GA:MD) and gum Arabic + inulin (1:1; w/w) (GA:IN), was prepared by dissolving the material at 20% (w/w) in distilled water. The solutions were prepared the day before emulsification and stored at room temperature for 12 h to ensure complete saturation of the molecules of the materials.

The ginger essential oil was slowly incorporated into each polysaccharide suspension by mechanical stirring at 1000 rpm for 5 min, using a rotor-stator blender (Ultra-Turrax IKA T18 basic, Wilmington, USA), to form emulsions (H). For the treatments where the ultrasound was applied (H/U), after the homogenization process by mechanical stirring, the samples were submitted to ultrasonication at 160 W of nominal power (Branson Digital Sonifier®, Model S-450D, Branson Ultrasonics Corporation, Danbury, USA), 20 kHz, for 2 min. The height contact between the ultrasonic probe and the emulsions was standardized to 30 mm. The experiment was conducted according to Table 1 with three replicates.

2.3. Characterisation of the emulsions

2.3.1. Emulsions viscosity

Rheological measurements were analysed according Botrel et al. (2014).

2.3.2. Emulsion droplet size

The droplet size distribution of the emulsions was determined by light scattering using laser diffraction (Mastersizer 2000 Malvern Instruments Ltd., Malvern, UK) according to the method described by Silva and Meireles (2015). The surface mean diameter (d_{32}), the volume surface mean diameter (d_{43}) and the polydispersity index (PDI) were calculated.

2.3.3. Optical microscopy

Optical microscopy of the emulsions was performed immediately after their preparation. The samples were poured onto microscopes slides, covered with glass cover slips and observed using a Carl Zeiss Model MF-AKS 24 × 36 Expomet optical microscope (Zeiss, Germany).

2.3.4. Creaming stability

The creaming index (CI) of the ginger essential oil emulsions was analyzed as described by Silva and Meireles (2015).

2.4. Microencapsulation by spray drying

The spray drying process was conducted for all the emulsions obtained in 2.2 section. The feed emulsions were dried using a spray-dryer (model MSD 1.0; Labmaq do Brasil, Ribeirão Preto,