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Microencapsulation of lycopene by spray drying: Characterization, stability and application of microcapsules

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A B S T R A C T

Microencapsulation can be an alternative to minimize lycopene instability. Thus, the aim of this study was to microencapsulate lycopene by spray drying, using a modified starch (Capsul®) as an encapsulating agent, and to assess the functionality of the capsules applying them in cake. The quantity of lycopene was varied at 5, 10 and 15% in a solution containing 30% of solids in order to obtain the microcapsules. These microcapsules were evaluated as to encapsulation efficiency and morphology and then submitted to a stability test and applied in cakes. Encapsulation efficiency values varied between 21 and 29%. The microcapsules had a rounded outer surface with the formation of concavities and they varied in size. The stability test revealed that microencapsulation offered greater protection to lycopene compared to its free form and it was observed that the microcapsules were able to release pigment and color the studied food system in a homogenous manner.

Keywords: Atomization; Modified starch; Morphology; Encapsulation; Cake

1. Introduction

Lycopene is one of the most common carotenoids found in human serum and the predominant one found in plasma (Agarwal and Rao, 2000; Stahl and Sies, 1996). Due to the high number of conjugated double bonds, it is considered to be one of the most potent antioxidants among the carotenoids (Dimascio et al., 1989). The increase in the consumption of tomatoes and other products that contain lycopene has been associated with protection against several types of cancer (Morais, 2001), which accounts for the increasing interest in this carotenoid over recent years. Incorporation of this pigment in foods mainly aims at coloration and conferral of functional characteristics. However, due to its high number of conjugated double bonds, lycopene is susceptible to isomerization and oxidation during the storage process (Matioli and Rodriguez-amaya, 2002). Microencapsulation can be an alternative to increase lycopene stability while enabling its dispersion in an aqueous medium.

The concept of microencapsulation stems from idealization of the cell model, in which the core is wrapped in a semi permeable membrane that protects it from the outer medium while also controlling the entry and exit of substances in the cell. Likewise, the microcapsule consists of a layer of encapsulating material that acts like a protective film, isolating the active substance and avoiding the effects of its improper exposure (Jizomoto et al., 1993; Ré, 2006). Microencapsulation has been used successfully in the food industry to protect substances that are sensitive to temperature, light, oxygen and humidity, to reduce the transfer rate from the core to the medium in which the product is located and to modify the physical characteristics of the material, facilitating handling (Desai and Park, 2005).

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Drying by atomization, or spray drying, refers to the removal of moisture from fluid material (solution, dispersion or paste) by breaking it into small droplets in the presence of hot air to obtain a dry powder. In the spray-drying process, the liquid feed is pumped into the drying chamber through an atomizing system (Al-asheh et al., 2003; Ré, 1998). Microencapsulation using this technique has been around for decades in diverse industrial processes to obtain dehydrated materials in the form of fine powders, and it is the most used method in the food industry (Jackson and Lee, 1991; Ré, 1998; Jafari et al., 2008).

Lycopene has already been encapsulated by the atomization method, using Gum arabic and maltodextrin (Matioli and Rodriguez-amaya, 2002), gelatin and sucrose (Shu et al., 2006) and Gum arabic and sucrose (Nunes and Mercadante, 2007) as encapsulants. However, no publications on the application of lycopene microcapsules are available.

Capsul® is a starch that is chemically modified by incorporating a lipophilic component aimed at conferring emulsifying properties. This modification gives the material excellent capacity for retaining volatiles during atomization in a spray dryer (Marchal et al., 1999; Reineccius, 1991; Shahidi and Han, 1993).

The aim of this study was to microencapsulate lycopene by spray drying, characterize the microcapsules formed, evaluate the stability of the carotenoid during storage, apply the capsules to cakes and evaluate them as to color transfer.

2. Materials and methods

2.1. Material

Lycopene dispersed in oil (10% lycopene) (DSM–lot: UE00603001, Sweden) was used as active material or core and modified food starch—Capsul® (National Starch - lot: MFY-212, USA) as encapsulating agent.

2.2. Methodology

2.2.1. Production of microcapsules

Lycopene was added to the Capsul® previously dissolved in water and an emulsion was obtained in an ultra turrax mixer (IKA T18 basic) at 10,000 rpm for 3 min. The emulsion was continuously mixed in a mechanical mixer with a magnetic bar throughout the drying process, which was conducted with an atomizer (Lab Plant SD-05–Huddersfield, England). Work operating conditions were set at: diameter of atomizer nipple (0.5 mm), liquid flow (10 mL/min), inlet and outlet air temperatures were 180 and 98 ± 2 °C, respectively.

Three emulsions were prepared that differed between each other in relation to core concentration (5, 10 and 15% in relation to total solid content, which was set at 30%). Than, the samples produced were named T1 (5% of core concentration), T2 (10% of core concentration) and T3 (15% of core concentration).

The encapsulation process and all analysis were conducted in triplicate.

2.2.2. Morphology

The particles were evaluated by scanning electron microscopy (SEM), and for such, the samples were attached to metallic adhesive tapes adhered to metallic stubs. The stubs underwent recovering by a fine layer of gold in an evaporator (Balzer SCD50–Lichtenstein, Austria) for 180 s and a current of 40 mA. The observations were made using a scanning electron microscope (Jeol JMS-T300–Tokyo, Japan) and a voltage of 10 kV.

2.2.3. Encapsulation efficiency

The method described in Risch and Reineccius (1988) to calculate encapsulation efficiency was adapted: about 10 mg of the sample were dissolved in 0.5 mL of water in order to break the microcapsules. Ten mL of acetone were then added. After mixing, the tubes remained at rest in the dark for about 2 h for decantation of the encapsulation material. Absorption was read in a spectrophotometer (Beckman DU70–CA, United States) in the visible wavelength 470 nm and using a previously elaborated standard curve it was possible to calculate the concentration of lycopene present in the microcapsules. Encapsulation efficiency was calculated as the quantity of lycopene present in the capsules compared to the lycopene initially used to produce them.

2.2.4. Storage stability at different temperatures

The samples were evaluated as to stability at temperature compared to non encapsulated lycopene. The samples were placed in glass vials covered with aluminum foil with rubber lids, vacuum sealed and stored at temperatures of 10 and 25 °C. Quantification was conducted for 73 days, every 7 days, employing the same methodology used to calculate encapsulation efficiency.

For each day of analysis, a vial of each sample was opened, preserving the other samples from contact with oxygen and light.

2.2.5. Application in the food system

Cake was the model system chosen for microcapsule application. The following cakes were prepared: (A) with free-form lycopene; (B) with microcapsules (T1) and (C) a standard cake (without addition of lycopene).

In order to prepare the standard cake (without the addition of lycopene), 150 g of margarine (Leco–São Paulo, Brazil) and 2 eggs were beaten in a domestic beater. Then, while still beating, 240 g of granulated sugar (União–São Paulo, Brazil) and then 240 g of wheat flour (Sol–Fortaleza, Brazil) and 240 mL of whole milk (Líder–Lobato, Brazil) were added, intercalated. The beater was shut off and then 10 g of baking powder were added (Royal–Jundiaí, Brazil). The mixture was placed in a greased and floured pan and placed in a (pre-heated) oven for approximately 40 min.

The addition of microcapsules to the cake formula (B) occurred by mixing them to the milk at 50 °C. Free-form lycopene (formulation (A)) was added to the batter after adding flour and milk.

2.2.6. Evaluation of the color of the food system

Analysis of the cakes' apparent color was conducted by the Lab system, using objective measures, by direct reflection employing a colorimeter (Hunter Lab - Color Quest II–VA, United States). The reading was conducted with the D65 illuminant, 10° opening for angle of vision and in RSIN mode.

In order to measure each sample of cake, slices were cut of approximately 2 cm in thickness. Five readings were taken for each sample at different random points.