Journal of Food Engineering 181 (2016) 59–66

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Storage stability of encapsulated barberry's anthocyanin and its application in jelly formulation

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ARTICLE INFO

Article history:
Received 6 January 2016
Received in revised form
5 March 2016
Accepted 7 March 2016
Available online 9 March 2016

Keywords:
Natural color
Microencapsulation
Anthocyanin
Stability
Jelly

ABSTRACT

The barberry (*Berberis vulgaris*) extract which is a rich source of anthocyanin was used for encapsulation with three different wall materials i.e., combination of gum Arabic and maltodextrin (GA+MD), combination of maltodextrin and gelatin (MD+GE) and maltodextrin (MD) by spray drying process. In this context, the storage stability of encapsulated pigments was investigated under four storage temperatures (4, 25, 35 and 42 °C), four relative humidities (20, 30, 40 and 50%) and light illumination until 90 days. All wall materials largely increased the half-life of the encapsulated pigments during storage compared with non-encapsulated anthocyanins. MD+GA showed the highest encapsulation efficiency, lower degradation rate in all temperatures and was found as the most effective wall material in stabilizing the pigments. The encapsulated pigments were utilized in coloring jelly powder as an alternative of synthetic color. Sensory evaluation were run to identify best encapsulated natural color concentration in jelly powder formulation according to acceptability by consumers. A jelly with added 7% encapsulated color had higher scores than the commercial jelly containing synthetic color for all the sensory attributes evaluated. Physicochemical properties of produced jelly including moisture content, hygroscopicity, acidity, ash content and texture were not significantly different with control sample while, syneresis and solubility of the samples prepared with encapsulated color was significantly reduced.

1. Introduction

There is currently an increasing trend towards natural food coloring as alternatives to synthetic colors in food applications because of both legislative actions as well as consumer concerns. Seedless barberry, *Berberis vulgaris*, which is widely cultivated in Iran, is a rich source of anthocyanin and could be used as a suitable source for producing a brilliant red color for many foods. Anthocyanins (Greek *anthos*, flower and Greek *kyanose*, blue) are generally accepted as the largest group of water-soluble pigments in nature which are responsible for color of many fruits, flowers, and other parts of plants (Delgado-Vargas et al., 2000). Recently, the interest in anthocyanin pigments and scientific research have increased mainly due to their role in nutraceutical and health benefits which is given by natural antioxidants (Konczak and Zhang, 2004). However, stability of anthocyanins depends on a combination of chemical and environment factors such as pH, temperature, metal ions, oxygen, enzymatic activities and exposure to light. So, because of low stability to environmental conditions during processing and storage, introducing those compounds into foods is challenging (Clifford, 2000).

Microencapsulation could be an efficient way to introduce such compounds into food products. Microencapsulation is a process to entrap one substance (core material or active agent) within another substance (wall material) (Chiou and Langrish, 2007; Jafari et al., 2016). In food industry, it involves the incorporation of ingredients, polyphenols, colors, enzymes, volatile additives and bacteria in small capsules, to stabilize, protect and preserve them against nutritional and health losses (Zuidam and Shimoni, 2010). There are many encapsulation techniques; among which some have been successfully assigned to anthocyanins. The selection of an encapsulation technique depends upon specific applications and parameters such as physicochemical properties of the core and wall materials, required particle size, release mechanisms, process cost, etc. (Mahdavi et al., 2014).

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http://dx.doi.org/10.1016/j.jfoodeng.2016.03.003
0260-8774/

Spray-drying is the most commonly used method, on account of it being a continuous, low cost process that produces dry particles of good quality, and for which the apparatus required is readily available. In this technique, the drying process is very rapid and the core is heated to temperatures generally much lower than 100 °C. So, Spray drying is especially useful for the encapsulation of heat sensitive food ingredients (Yao and Yu, 2004). The selection of wall material is the primary step in spray drying method of encapsulation, which should meet required criteria (compatibility with the food product, mechanical strength, appropriate particle size appropriate thermal or dissolution release, etc.). Most common wall materials are maltodextrin, gum Arabic, emulsifying starches and others, of which gum Arabic is preferred for its encapsulation efficiency and stability. Gum Arabic is an important effective wall material used for many years and still a good choice due to its stable emulsion formation. The carbohydrates such as starches and maltodextrins have properties which are desirable in an encapsulating agent such as good solubility and low viscosity at high solids contents. Moreover, hydrocarbon compounds are also used as a significant component of wall materials, which can act as plasticizers, or some others, promoting the formation of spherical and smooth-surfaced microcapsules, enhancing adhesion force between wall and core materials (Mahdavi et al., 2016). Gelatin also is a good choice as wall material because of its good properties of emulsification, water-solubility, film-formation, edibility and biodegradation, etc (Idham et al., 2012; Shu et al., 2006).

Spray drying encapsulation has been successfully used for a number of anthocyanin rich materials (Khazaei et al., 2016; Mahdavee Khazaei et al., 2014; Mahdavi et al., 2014). Nevertheless, there are only a limited number of studies about applying encapsulated anthocyanin powders for coloring and/or improving the color of food products (Burin et al., 2011; Obón et al., 2009; Selim et al., 2008). Thus, In the present study, after encapsulation of barberry's anthocyanin with three different wall materials (MD+GA, MD+GE and MD), the effect of wall material, temperature, relative humidity and light on the stability of spray-dried barberry anthocyanins as well as its application as a natural food colorant in jelly formulation were evaluated.

2. Materials and methods

Fresh barberry fruits (*B.vulgaris*) were obtained from Birjand located in south Khorasan, Iran and was kept in a freezer at −18 °C till used. Maltodextrin (DE = 18–20) (Foodchem, China), Gum Arabic (Samchon Chemical, Korea) and bovine gelatin bloom value 240 (Foodchem, China) were used as wall materials. Strawberry essence (Magnolia, Iran), sugar and commercial jelly powder purchased from a local supermarket. All other chemicals used in this study were of analytical grade and purchased from chemical suppliers.

2.1. Extraction

Extraction method was adopted from Sharifi and Hassani (2012) using a reflux system. The barberries were first grounded by means of a grinder (Black & Decker, USA) then were put into a solvent flask including acidified ethanol and distilled water (1:3). The flask and the condenser in the Water bath were exposed to a temperature of 50 °C for 2 h. Then, the flask was separated from the system and kept in the dark for 2 h. And finally, the obtained mixture was filtered in a vacuum filter. The produced extract was condensed at 40 °C to 15° brix by a rotary evaporator (IKA, Germany) and finally, the condensed samples were stored in brown bottles.

2.2. Microencapsulation

For encapsulation purposes, combination of maltodextrin and gum Arabic (3:1), maltodextrin and gelatin (3:1) and maltodextrin (MD) were evaluated as wall materials. These wall materials dissolved in hot distilled water, being stirred, to form an aqueous solution and combined with the pigment extract (15° Brix). The ratio between the extract solid content and the wall material was 1:4. Then the mixtures were stirred until all the materials were completely dissolved. The resulting mixtures were subsequently spray dried. 500 ml of feed mixtures were fed into a pilot spray-dryer (Novin industries, Iran) at flow rate 800 ml/h. The inlet and outlet air temperatures were 150 and 100 °C, respectively. Then spray-dried powders packaged to prevent light incidence and stored over silica gel in desiccators at room temperature for further experiments.

2.3. Encapsulation efficiency

Total anthocyanin content (TAC) and surface anthocyanins content (SAC) of the microcapsules were determined according to a method from Idham et al. (2012). Anthocyanins content for TA and SA values was carried out by the differential pH method (AOAC, 2005) using spectrophotometer (PG-instrument-Ltd, UK). Encapsulation efficiency (%EE) was calculated according to Equation (1) using the results from total (TAC) and surface (SAC) anthocyanin contents.

$$\%\,EE = \frac{(TAC - SAC)}{TAC} \times 100 \quad (1)$$

A scanning electron microscope (Philips XL, FEI Co., Eindhoven, the Netherlands) was used for the morphological study of the encapsulated powder which operated at an accelerating voltage of 20 kV. After mounting the powder samples directly onto the aluminum sample stub, a thin (200 nm) coating of gold was applied under vacuum using SPI Sputter coating unit (SPI supplies, division of structure probe Inc., USA) to assess their morphology.

2.4. Storage stability studies

To evaluate the stability, immediately after capsules preparation, the spray-dried encapsulated samples were stored in brown bottles with screw caps and placed at 4, 25, 35 and 42 °C for 90 days for the kinetic studies and effects of temperature and time on the stability of anthocyanin's powders. Degradation parameters including degradation rate constants (k) were obtained from slope of a plot of the natural log of anthocyanins retention and half-life and Q_{10} values were determined at a specific temperature by the Equations (2) and (3), respectively where k_T is the reaction rate constant at temperature T and k_{T-10} is the reaction rate constant at a temperature 10 °C lower (Ferrari et al., 2013).

$$t_{1/2} = \ln(2)/k \quad (2)$$

$$Q_{10} = \frac{k_T}{k_{T-10}} \quad (3)$$

The dependence of the anthocyanins degradation on temperature was determined by calculating the activation energy (Ea) values from the Eq. (4):

$$k = k_0 e^{-Ea/RT} \quad (4)$$

where: k_0 − frequency factor; R −universal gas constant (8.314 J/mol·K); T − absolute temperature.

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