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Microencapsulation optimization of natural anthocyanins with maltodextrin, gum Arabic and gelatin

Sahar Akhavan Mahdavi[a], Seid Mahdi Jafari[b,*], Elham Assadpoor[a,c], Danial Dehnad[a]

[a] Department of Food Materials and Process Design Engineering, University of Agricultural Sciences and Natural Resources, Gorgan, Iran
[b] Cereals Health Research Center, Golestan University of Medical Sciences, Gorgan, Iran
[c] Department of Food Science and Technology, Baharan Institute of Higher Education, Gorgan, Iran

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ABSTRACT

The barberry (*Berberis vulgaris*) extract which is a rich source of anthocyanins was used for spray drying encapsulation with three different wall materials, i.e., combination of maltodextrin and gum Arabic (MD + GA), maltodextrin and gelatin (MD + GE), and maltodextrin (MD). Response Surface Methodology (RSM) was applied for optimization of microencapsulation efficiency and physical properties of encapsulated powders considering wall material type as well as different ratios of core to wall materials as independent variables. Physical characteristics of spray-dried powders were investigated by further analyses of moisture content, hygroscopicity, degree of caking, solubility, bulk and absolute density, porosity, flowability and microstructural evaluation of encapsulated powders. Our results indicated that samples produced with MD + GA as wall materials represented the highest process efficiency and best powder quality; the optimum conditions of microencapsulation process for barberry anthocyanins were found to be the wall material content and anthocyanin load of 24.54% and 13.82%, respectively. Under such conditions, the microencapsulation efficiency (ME) of anthocyanins could be as high as 92.83%.

1. Introduction

There is a worldwide trend toward the use of natural colorants as alternatives to synthetic colors in food applications because of both legislative actions and consumer concerns. Seedless barberry, *Berberis vulgaris*, which is widely cultivated in Iran, is a rich source of anthocyanins and could be used as a good source for producing a brilliant red color for many foods. Anthocyanins (Greek *anthos*, flower and Greek *kyanose*, blue) are generally accepted as the largest and most important group of water-soluble pigments in nature and responsible for color of many fruits, flowers, and other parts of plants [8,23].

The interest in anthocyanin pigments and scientific research have increased in recent years mainly due to their role in nutraceutical and health benefits which is given by natural antioxidants [24]. However, stability of anthocyanins depends on a combination of environment and chemical factors such as pH, metal ions, exposure to light, temperature, oxygen, and enzymatic activities [22,28]. So, due to low stability in environmental conditions during processing and storage, introducing those compounds into foods is challenging [7].

Microencapsulation may be an efficient way to introduce such compounds into those products. Microencapsulation is defined as a process to entrap one substance (active agent) within another substance (wall material) [12,31]. The main objective of encapsulation is to protect the core material from adverse environmental conditions, such as undesirable effects of light, moisture, and oxygen, thereby contributing to an increase in the shelf life of the product, and promoting a controlled liberation of the encapsulate [29,30]. There are many encapsulation techniques; among which some have been successfully applied to anthocyanins [11]. The selection of a microencapsulation method depends upon specific applications and parameters such as required particle size, physicochemical properties of the core and coating materials, release mechanisms, process cost, etc. [26]. Spray-drying is the most commonly used technique, on account of it being a continuous, low cost process that produces dry particles of good quality, and for which the machinery required is readily available. Spray drying encapsulation has been successfully used for a number of anthocyanin rich materials [26].

Different types of wall materials have been used for microencapsulation including polysaccharides (starches, maltodextrins, corn syrups and gum Arabic), lipids (stearic acid, mono- and diglycerides), and proteins (gelatin, casein, milk serum, soy and wheat)

* Corresponding author at: Pishro Food Technology Research Group, Gorgan, Iran.
E-mail address: smjafari@gau.ac.ir (S.M. Jafari).

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[9]. The use of different carrier agents for powder production can result in different physicochemical properties, depending on the structure and the characteristics of each agent. Anthocyanins are hydrophilic colorants and specifically compatible with a water-based gel formulation such as gum, or maltodextrin and starches as coating molecules for polar solid matrices [20]. Maltodextrins of different dextrose equivalent (DE) are commonly used as wall material by its high water solubility, low viscosity, low sugar content and their solutions are colorless. These properties make them as the most commonly used carrier or wall materials in the microencapsulation [32]. Gelatin is also a good choice as wall material especially in spray drying due to its good properties of emulsification, film-formation, water-solubility, high stabilizing activity, and a tendency to form a fine dense network, etc. [37]. Gum Arabic, a natural colorless plant polysaccharide exudate of acacia is a well-known effective wall material used for many years and still a good choice because of its stable emulsion formation and good retention of volatiles [18]. According to Fang and Bhandari [11], a single encapsulating matrix does not possess all required characteristics and efforts to improve encapsulation properties have been done by using mixtures of carbohydrates with proteins and polysaccharides at different proportions. The choosing of polymer blends that could result in higher encapsulating efficiency and lower cost than the individual biopolymers has been object of increasing interest [5,10,14,25,32,33,30].

The objective of this study was to study the influence of different types of wall materials (MD + GA, MD + GE and MD) as well as different ratio of core to wall materials on encapsulation efficiency and to investigate physiochemical properties of the produced encapsulated powders along with optimization of the process.

2. Materials and methods

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

2.1. Extraction of natural anthocyanins

Extraction method was adopted from Sharifi and Hassani [36] using a reflux system. The barberries were first ground by means of a grinder (Black & Decker, USA). They 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 removed from the system and kept in the dark for 2 h. Finally, the obtained solution was filtered in vacuum using Watman filter (grade 1) and the produced extract was concentrated to 15° brix by a rotary evaporator at 40 °C (IKA, Germany). Table 1 presents the physicochemical properties of produced extract.

2.2. Microencapsulation of natural anthocyanins

For encapsulation purposes, MD, MD + GA and MD + GE were evaluated as encapsulating agents (wall materials) and anthocyanin extract as core material. Different proportions of core/wall materials (12, 25, 35 and 50%) were tested. the ratios between MD/GA and MD/GE were selected 3/1 according to the best ratio of these wall materials presented by previous studies [13,19,27,39]. MD and MD + GA solution were dissolved in warm distilled water (70 °C) under constant stirring at 120 rpm for 1 h and were kept overnight at 4 ± 2 °C for rehydration. Gelatin was dissolved in hot distilled water, being stirred, to form an aqueous solution. These wall materials containing different ratios, were combined with the pigment extract (15° Brix) until reaching to 20% final solid content and 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; these conditions have been established in a previous work [34]. Spray dried powders were packaged to prevent light incidence and stored over silica gel in desiccators at room temperature for further experiments.

Table 1
Physicochemical properties of barberry extract subjected to encapsulation process.

Analysis	Mean values	Method
Moisture content (% wet basis)	82.79 ± 0.02	AOAC (2006)
pH	3.5 ± 0.07	pH meter
Titrable acidity (% citric acid)	0.71 ± 0.03	AOAC (2006)
Total soluble solids (° Brix)	15.5 ± 0.02	Refractometer
Anthocyanin content (mg/100 mL extract)	609.25 ± 2.18	AOAC [4]
Color		Lovibond (100CAM, England)
L^*	59.3	
a^*	76.8	
b^*	31.7	

All data are the mean of triplicate measurements ± standard deviation values.

Table 2
Influence of the core/wall ratio for anthocyanin extract on microencapsulation efficiency.

Core/wall ratio (%)	Wall materials	Microencapsulation efficiency (%)
12	MD + AG	94.291 ± 1.01[a]
	MD + GE	93.064 ± 0.4[b]
	MD	89.491 ± 1.0[c]
25	MD + GA	96.215 ± 1.02[d]
	MD + GE	94.972 ± 0.2[a]
	MD	93.087 ± 1.0[b]
35	MD + GA	94.391 ± 0.02[a]
	MD + GE	92.972 ± 0.4[b]
	MD	90.087 ± 0.6[c]
50	MD + GA	89.091 ± 1.02[c]
	MD + GE	87.572 ± 0.1[e]
	MD	86.068 ± 0.7[f]

Different letters within column indicate significance difference at $P < 0.05$.
GA, gum Arabic; GE, gelatin; MD, maltodextrin.

2.3. Encapsulation efficiency

The encapsulation efficiency is an important indicator for microencapsulated particles and refers to the potential of the wall materials to encapsulate or hold the core material inside the microcapsule. In order to evaluate the effectiveness of microencapsulation, total anthocyanin content (TAC) and surface anthocyanins content (SAC) of the microcapsules were determined according to a modified method from Idham et al. [20]. To obtain the TAC, 100 mg of samples was weighed and about 1 mL distilled water was added and then the samples were ground using pestle and mortar to destroy the microcapsule membrane. Then, 10 mL ethanol was added and the samples were extracted for 5 min and then filtered.

The extraction of surface anthocyanins from the capsules was carried out by quickly washing with 10 mL ethanol in a vortex for 10 s, followed by centrifugation at 3000 rpm for 3 min at 20 °C. After