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Application of maltodextrin and gum Arabic in microencapsulation of saffron petal's anthocyanins and evaluating their storage stability and color

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ABSTRACT

In this work, anthocyanin stability and color of encapsulated freeze-dried saffron petal's extract with various matrices consisting gum Arabic (AG) and maltodextrin (M7 and M20) were studied. Total anthocyanins of powders and color parameters (a^*, b^*, L^*, C, H° and TCD) were measured immediately after production and during storage up to 10 weeks by pH differential method and computer vision, respectively. Different compounds of wall materials did not show any significant differences in terms of stabilizing anthocyanins ($P < 0.01$) and no significant decrease in anthocyanin content of the powders was observed after storage. The efficiency order of wall materials considering total color differences (TCD) was AG > M20 > M7. By evaluating 3D surface and Cox trace plots it was revealed that wall formulas which had the lowest amount of AG and highest amounts of M20 and M7 showed the lowest total color differences after storage ($P < 0.05$). To conclude, microencapsulation by freeze drying could be recommended as a suitable method for stabilizing anthocyanins of saffron petal's extract.

1. Introduction

The first property that the consumer observes in every food product is its visual color, which is an indicator of pigment concentration that is measurable immediately. Color can be changed during heat processing based on different reactions of pigments such as pigment degradation, browning reactions like Millard reactions, enzymatic browning and oxidation of ascorbic acid (Maskan, 2006). Most of the synthetic colors which are used in the food industry have chemical sources with harmful health effects. Since the anticancer and antioxidant properties of natural colorants are proven, today there are more tendencies to use natural colorants instead of synthetic ones (Andersen, Jordheim, Lew, & Hung-Wen, 2010).

Anthocyanins as natural pigments are found in roots, leaves, fruits and flowers of plants. Attractive color and functional properties (like prevention of neuronal and cardiovascular, cancer and diabetes illnesses) of anthocyanins make them a good substitute for synthetic pigments in the food industry (Castaoveda-Ovando, Pacheco-Hernondez, Priez-Hernandez, Rodriguez, & Galoan-Vidal, 2009). These natural soluble water colorants are rather unstable and influenced by final processing temperature, storage temperature, pH, chemical structure and concentration of anthocyanin, light, oxygen, enzymes, proteins and metallic ions (Patras, Brunton, O'Donnell, & Tiwari, 2010).

Saffron (*Crocus sativus*) which is produced largely in Iran, with more than 90% of total annual saffron production in the world (Kafi, 2006), has cyanic color flowers with major colorant of anthocyanins (Nørbæk, Brandt, Nielsen, Ergaard, & Jacobsen, 2002). The existence of anthocyanins in saffron's petal had been proven before by Williams, Harborne, and Goldblatt (1986) and Nørbæk et al. (2002) too. Since nearly 86.4% wet base or 96.36% dry base of total weight of saffron flowers is related to the petals (Hemmati, 2001) and a large scale of saffron flowers is disposed to the nature after picking stigmas annually; anthocyanins of petal extract can be used as a natural resource of colorants in the food industry adding to its other medicinal/industrial applications (Kafi, 2006).

Microencapsulation is a technique to package materials (like natural colorants) in the form of micro- and nano-particles. Microencapsulation can protect sensitive materials from moisture, heat, light or oxidation (Jafari, Assadpoor, He, & Bhandari, 2008). There are different methods for encapsulation in the food industry. Freeze drying which has a long dehydration period has been used as a simple technique in encapsulating water-soluble essences and natural aromas or drugs. During this procedure, core materials and matrix solutions are homogenized and then co-lyophilized to make dried materials (Fang & Bhandari, 2011).

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In various experiments on encapsulation of anthocyanins, different materials and compounds have been used in spray drying (Akhavan, Jafari, Ghorbani, & Assadpoor, 2013) or freeze drying techniques such as glucan gel (Xiong, Melton, Easteal, & Siew, 2006), maltodextrins with different DEs (Ersus & Yurdagel, 2007; Fang & Bhandari, 2011; Saenz, Tapia, Chavez, & Robert, 2009), maltodextrin and inulin (Bakowska-Barczak & Kolodziejczyk, 2010), pectin, caffeine, shellac (Berg, Bretz, Hubbermann, & Schwarz, 2012), maltodextrin, ascorbic acid (Ahmed, Akter, Lee, & Eun, 2011), mesquit gum (Kandansamy & Somasundaram, 2012), maltodextrin, kappa-carraginan (Krishnaiah, Sarbatly, & Nithyanandam, 2012) and maltodextrin, Arabic gum, and tapioca starch (Tonon, Brabet, & Hubinger, 2010).

Also, there have been some efforts on encapsulating of saffron extract and its individual ingredients (Cormier, Dufresne, & Dorion, 1995; Dufresne et al., 1999; Nair, Salomi, Varghese, Panikkar, & Panikkar, 1992; Selim, Tsimidou, & Biliaderis, 2000) but, encapsulation of saffron petal's extract as mentioned before, which is known as a good and huge source of anthocyanins has not been investigated. Therefore, encapsulation of saffron petal's anthocyanins with freeze drying technique through wall materials of maltodextrins and Arabic gum and then, evaluating stability of anthocyanin and color of encapsulated powders during storage could be an initial step to produce natural colorants with high stability.

2. Materials and methods

Saffron flowers were collected before sunlight from a farm near Torbat-E-Heydariyeh (Iran) in November, 2012. After removing stigmas and anther, the petals were dried in a dark and warm room (35 °C, 24 h) in front of a fan. Dried petals were crashed and sieved (1 mm meshes) and were kept in air-tight bags within a cold store.

In order to choose the best drying method of saffron petals, some primary experiments were done based on three different methods consisting oven drying (60 °C ± 1, 6 h), vacuum oven drying (45 °C, 500 mbar, 24 h) and drying in a dark warm room (35 °C, 24 h) in front of a fan. Results showed (data not given) that a lower temperature in drying procedure (drying in warm room) resulted in the least anthocyanin degradation during process.

Arabic gum (AG) was provided by Samchun Chemicals Company (Korea). Maltodextrin DE = 16–20 (M20) and DE = 4–7 (M7) was purchased from Sigma–Aldrich (Castle Hill, NSW, Australia). Analytical grade hydrochloric acid (HCL) and ethanol were purchased from Merck (Darmstadt, Germany). Distilled water was used for preparation of all solutions. All general chemicals used in this study were of analytical grade.

2.1. Saffron petal analysis

Some physicochemical properties of saffron's petal were analyzed including moisture content (AOAC, 2006), lipids (AOAC, 2006), proteins (AOAC, 2006), total ash (AOAC, 2006), total dietary fiber (AOAC, 2006), total reducing sugar (Fehling test) and total monomeric anthocyanins content by pH differential method (Lee et al., 2005).

2.2. Extraction and concentration of anthocyanins

For extraction of anthocyanins from saffron petals, the procedure of Srivastava and Vankar (2010) was adopted by some modifications. In every experiment, 12 g of dried saffron petals were mixed with 240 ml 50% ethanol (it was acidified with 2 N HCl up to pH = 2) in a dark colored bottle. After 24 h in 25 ± 1 °C, samples were filtered through a filter paper (Whatman no. 1). The ethanol content of permeate was removed under reduced pressure by a rotary evaporator (BÜchi 461, Switzerland) keeping the water bath temperature below 40 °C through 20 min until a level of 10 ± 0.5% soluble solids was reached.

Table 1
Physicochemical properties of saffron's petal and total monomeric anthocyanin content of its extract.

Constituents	Data	Ref. method
Proteins (g/100 g)	1.64 ± 0.09	AOAC (2006)
Lipids (g/100 g)	0.32 ± 0.01	AOAC (2006)
Total ash (g/100 g)	0.74 ± 0.01	AOAC (2006)
Fiber (g/100 g)	8.25 ± 0.04	AOAC (2006)
Total sugar (g/100 g)	1.67 ± 0.02	AOAC (2006)
Moisture (g/100 g)	87.11 ± 0.04	AOAC (2006)
Anthocyanins (mg/l extract)	1712.19 ± 60.24	Lee et al. (2005)

2.3. Preparation of microencapsulated powders

Wall materials including AG, M20 and M7 were mixed based on Response Surface Methodology (RSM) experiment design (Table 1) and dissolved in distilled water at ambient temperature (25 ± 1 °C) to obtain 40% total solids concentration. The solution was kept in refrigerator for complete hydration in 24 h. Then, extract of anthocyanins from saffron petal and wall materials were mixed in a weight ratio (w/w) of 1:5 (extract:wall material). The pH of mixtures was decreased to pH = 2 with HCl (1.5 N) to stabilize anthocyanins (Berg et al., 2012), then mixed with a rotor-stator (120 rpm, 10 min). Total anthocyanins of samples were measured through differential pH method (Lee et al., 2005) before drying. The solutions were dried in a freeze drier (Operon-Korea) for 42 h (−86 °C, 5 mbar). Dried materials were ground using a pestle and mortar and passed through a 0.71 mm mesh and stored in brown glass bottles with screwed caps in a freezer (−18 °C) until usage. In Fig. 1 the schematic procedure of the microencapsulation of saffron petal's extract by freeze drying technique has been depicted.

For preparation of blank sample, the concentrated extract (10 ± 0.5% soluble solids) without wall materials was acidified with HCl 1.5 N up to pH = 2 and then freeze-dried in similar conditions with other samples (−86 °C, 5 mbar) in 42 h.

2.4. Determination of physical properties of the powders

The moisture content of the powders was determined by vacuum drying (Schutzart, Germany) at 70 °C and 500 mbar for 24 h, followed by cooling to room temperature in desiccators, in the presence of excess amount of silica gel (Fang & Bhandari, 2011). Hygroscopic moisture of every 2 g powder samples was measured under saturated solutions of Na_2SO_4. After 1 week, hygroscopic

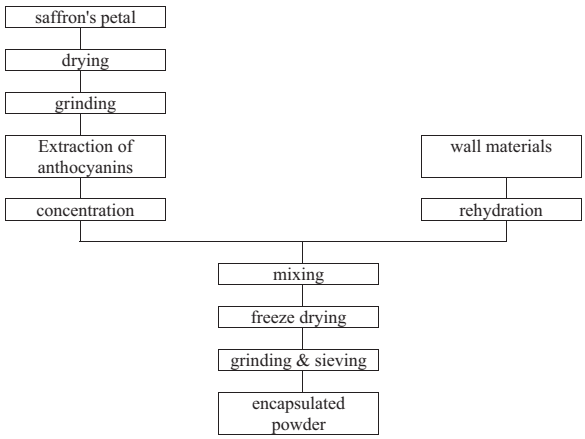

Fig. 1. Schematic description of the microencapsulation of saffron petal's extract by freeze drying technique.