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Physical and chemical characteristics of encapsulated goldenberry (*Physalis peruviana* L.) juice powder

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ABSTRACT

Goldenberry (*Physalis peruviana* L.) is an exotic fruit that is valued due to its high antioxidant activity and phenolic content. In order to preserve the bioactive contents, microencapsulation is a proper method to extend its shelf life. The aim of this study was to encapsulate goldenberry juice using maltodextrin mixed with gum arabic, alginate and pectin to enhance its stability at simulated digestion fluids. Different maltodextrin/gum arabic, alginate, pectin ratios (10:0, 9:1, 8:2) and core to coating ratios (3:10) were used and homogenized before freeze-drying for 48 h to obtain the microcapsules. The microcapsules were characterized through particle morphology, particle size distribution, phenolic contents, encapsulation efficiency, antioxidant activity, digestion behavior in the gastric-intestinal fluids, chromatographic and colorimetric analysis. The microcapsules prepared with maltodextrin and pectin had greater volume mean diameter (43.1 μm) compared to those containing gum arabic and alginate. Goldenberry juice microcapsules, prepared by freeze-drying method, was shown to retain more than 75% phenolic compounds for all gum types. In vitro digestion studies showed that the release of phenolic compounds from microcapsules was higher in the simulated intestinal fluid than in gastric medium.

1. Introduction

The goldenberry (*Physalis peruviana* L.) is an herbaceous, semi-shrub, perennial in tropical zones and its size varies between 0.6 and 0.9 m (Erkaya, Dağ;demir, & Sengül, 2012; Ramadan, 2011). Also known as caped gooseberry, it is a tropical seedy fruit with tomato-like in flavor and succulent golden appearance that is encapsulated in an inflated, accrescent calyx with a brilliant yellow peel (Gutierrez, Trinchero, Cerri, Vilella, & Sozzi, 2008; Jéssica et al., 2013). The color change of the fruit from green to orange-yellow is due to chlorophyll breakdown and β-carotene accumulation through the maturity process (Gutierrez et al., 2008). The goldenberry has received growing interest worldwide due to its nutritional composition and bioactive compounds that provide several health benefits and reduce the risks of certain diseases such as cancer, malaria, asthma, hepatitis, dermatitis and rheumatism (Izli, Yildiz, Ünal, Işik, & Uylaşer, 2014; Ramadan, 2011).

Even though the bioactive compounds provide the health status to improve, most of them are unstable and heat sensitive so a protection mechanism could prolong their shelf life. Microencapsulation could avoid the core material from chemical and physical reactions and help to maintain the biological, functional, physicochemical properties of core material by placing a barrier between the core and the wall on a micrometer scale (Bakry et al., 2016; Çam, Içyer, & Erdoğan, 2014; Ray, Raychaudhuri, & Chakraborty, 2015). Maltodextrin commonly used in microencapsulation as wall material is a hydrolyzed starch that provides low cost, good barrier, neutral aroma and taste. However, due to its low emulsifying capacity the combination of maltodextrin with other surface active biopolymers is beneficial to obtain an effective encapsulation process (Carneiro, Tonon, Grosso, & Hubinger, 2013).

Although numerous techniques are available for microencapsulation of food components, many of them are based on drying techniques since encapsulating food components are usually in a liquid form (Gibbs, Kermasha, Alli, & Mulligan, 1999). Among the techniques, freeze drying, also known as lyophilization, is the most proper technology for long-term preservation of heat sensitive food components like polyphenols, antioxidants, as it is based on the phenomena of sublimation (Ceballos, Giraldo, & Orrego, 2012;

Abbreviations: DPPH, 2-diphenyl-1-picrylhydrazyl; SEM, scanning electron microscopy; GAE, gallic acid equivalent; SGF, simulated gastric fluid; SIF, simulated intestinal fluid; ΔE, total color change; C, chroma; H°, hue angle; MD, maltodextrin; GA, gum arabic; ALG, alginate; PEC, pectin.

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Sanchez, Baeza, Galmarini, Zamora, & Chirife, 2013).

In literature, the physical and chemical characterization of goldenberry including nutritional values have been shown in several studies (Jéssica et al., 2013; Ramadan, 2011; Yildiz, Izli, Unal, & Uylaser, 2015). In the study of Ramadan and Moersel (2004), the nutritional profile of goldenberry was determined as 0.05–0.3% protein, 0.15–0.2% lipid, 19.6% carbohydrate, 4.9% fibre and 1% ash. Izli et al. (2014) examined the effect of the convective, microwave and microwave–convective drying methods on total phenolic and antioxidant content with drying characteristics. In their study, the decrease in antioxidant activity (65–75%) and total phenolic content (64–75%) of goldenberry due to heat treatment during drying methods was reported. Epidemiological studies on health benefits of goldenberry were also shown against, degenerative diseases (Ramadan, 2011). In another study, Erkaya, Dağdemir, and Sengül (2012) examined the chemical and sensory characteristics of goldenberry added ice cream as a functional food. Although the chemical and physical characterization of goldenberry were previously investigated by several studies mentioned above there is still lack of studies about encapsulation of goldenberry to prevent and/or postpone the degradation of its bioactive compounds (Ramadan, 2011). Furthermore, there is no study demonstrating the digestibility behavior at simulated gastric and intestinal fluid of goldenberry phenols. Thus, the aim of this study was to encapsulate goldenberry juice with maltodextrin, gum arabic, alginate and pectin using freeze-drying to extend the shelf life of phenolics in goldenberry juice so that powders could be used in for different food applications. The obtained goldenberry powders were then characterized in terms of moisture content, particle morphology, size distribution, total and surface phenolic content, encapsulation efficiency, antioxidant activity, color, in vitro digestion in gastric and intestinal mediums, and chromatographic analysis by LC-MS/MS.

2. Materials and methods

2.1. Chemicals

Goldenberry was provided from Bursa, Turkey. Ethanol, methanol, sodium hydroxide, hydrochloric acid, acetic acid, gallic acid, caffeic acid, *p*-coumaric acid, ferulic acid, quercetin, kaempferol, myricetin, chlorogenic acid, Folin-Ciocalteau reagent, 2,2-diphenyl-1-picrylhydrazyl radical (DPPH), potassium phosphate, monobasic potassium phosphate, gum arabic, pectin, pepsin from porcine gastric mucosa and pancreatin from porcine pancreas were purchased from Sigma Chemical Co. (St Louis, MO, USA). Sodium carbonate was obtained from J.T. Baker (Holland). Maltodextrin (Dextrose equivalent: 4–7) was obtained from Avebe Food (Veendam, Netherland), alginate from FMC Italy S.R.L.

2.2. Microencapsulation

2.2.1. Preparation of mixtures

Goldenberry fruit was blended for 5 min and centrifuged at 1833 × g (MF-80, Hanil Science Industrial Co. Ltd., South Korea) for 5 min. The supernatant was collected and stored at −10 °C. Maltodextrin was mixed with gum arabic, alginate and pectin at 8:2 and 9:1 ratios in 100 ml distilled water and was stirred overnight at 300 rpm. Afterwards, the supernatant and the solution containing coating materials were mixed to obtain 3:10 core to coating ratio. The mixture was pre-homogenized by an UltraTurrax (WiseTis Homogenizer, Witeg Labortechnik GmbH, Germany) at 1500 rpm for 1 min and then pre-homogenized solution was subjected to a homogenizer (Silentcrusher S, Heidolph Co. Ltd., Schwabach, Germany) at 75,000 rpm for 6 min. Homogenized solution was stored overnight at −50 °C for freeze-drying.

2.2.2. Encapsulation in freeze dryer

Freeze-drying was carried out using a freeze dryer (LGJ-10, Beijing Songyuan Humxing Tech. Co. Ltd., Beijing, China) that had a condenser at - 50 °C and could drop the internal pressure to 1 Pa. After freeze-drying the encapsulated goldenberry, juice was gently pulverized to powders using a spatula.

2.3. Moisture content

The moisture content of the powders and fresh goldenberry juice were determined by using an infrared moisture analyzer (Radwag Mac 50, Radom, Poland). The measurement was performed in triplicates immediately after freeze-drying.

2.4. Particle morphology and size distribution

The particle diameter of the microencapsulated powders was measured using a laser light diffraction Malvern Mastersizer 3000 (Malvern Instruments, Worcestershire, UK). The powders were initially blended at 15,000 rpm for 3 min by the particle size instrument to ensure the complete dissolution of powders in distilled water. All results of the measurements were reported as averages of three replicates. The mean diameter of the microcapsules was expressed as the volume mean diameter, D[4,3] (Eqn (1)) and the surface mean diameter, D[3,2] (Eqn (2)). The 'span' values of the microcapsules were calculated by using equation (3).

$$D_{[4,3]} = \sum n_i d_i^4 \Big/ \sum n_i d_i^3 \quad (1)$$

$$D_{[3,2]} = \sum n_i d_i^3 \Big/ \sum n_i d_i^2 \quad (2)$$

$$\text{Span} = d(v,90) - d(v,10)/d(v,50) \quad (3)$$

where n_i is number and d_i denoted the diameter of the particles; d(v,90), d(v,50) and d(v,10) are the diameters at 90, 50 and 10% of cumulative volume, respectively.

Particle morphology of unencapsulated goldenberry juice and microencapsulated powders were analyzed by scanning electron microscopy, JSM-6400 Electron Microscope (JEOL Ltd, Tokyo, Japan) equipped with NORAN System 6 X-ray Microanalysis System. The outer surface of microcapsules was monitored by Semafore Digitizer at 20 kV by coating the samples with gold/palladium under vacuum. SEM images were obtained at 100x-25000× magnification for all samples.

2.5. LC-MS/MS analysis

Chromatographic analysis of freeze-dried goldenberry juice was performed on LC/MS/MS system at METU Central Laboratory, Molecular Biology-Biotechnology Research and Development Center; Mass Spectroscopy Laboratory with AGILENT 6460 Triple Quadrupole System (ESI + Agilent Jet Stream) coupled with AGILENT 1200 Series HPLC to quantify the phenolic compounds of goldenberry fruit. Separation of phenolic acids was performed using a Zorbax SB-C18 (2.1 mm × 50 mm x 1.8 μm) column. The flow rate and injection volume were set to 0.5 mL/min and 5 μl and the oven temperature was kept at 35 °C. Mobile phase A was consisted of 0.05 ml formic acid in 100 ml distilled water and 5 mmol/L ammonium formate and phase B was methanol. The operation conditions for the analysis in the negative mode were as followings: Nebulizing gas 310 kPa, sheath gas temperature 350 °C, and