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Effect of carriers on physicochemical properties, antioxidant activities and biological components of spray-dried purple sweet potato flours

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ABSTRACT

This work focuses on the impact of carriers on the physicochemical properties, antioxidant capacities and biological components of spray-dried purple sweet potato flours. The optimal carrier addition of maltodextrin (MD), β-cyclodextrin (β-CD) and their combination (MD/β-CD, 5/1) were 30, 10 and 24 g/100 g in terms of flour yield. Compared to the flour without carrier, flours with carriers had higher values in L^*, fluidity, water solubility index, glass transition temperature, lower values in chroma, water absorption index and water holding capacity. The influence intensity of carriers on the physicochemical properties of flours followed the sequence of MD > MD/β-CD>β-CD. The flours with carriers were more dispersive and had smoother surface than flour without carrier. The addition of carrier had little effects on flours' sorption isotherm and the Halsey model presents the best goodness-of-fit to all flours. The flour with MD had higher retention rate of anthocyanins, flavonoids and total phenolics than flours without and with other carriers. The flour with MD has higher antioxidant activity (DPPH test) than flours with MD/β-CD or β-CD.

1. Introduction

Purple sweet potatoes (*Ipomoea batatas*) have high nutritional value. They are particularly rich in anthocyanins, which gives the sweet potatoes the strong purple color (Ahmed, Akter, Lee, & Eun, 2010). The purple sweet potato has received increasing attention from researchers in recent times. The anthocyanins of purple sweet potatoes not only show great potential in terms of natural colorants but also provide various nutraceutical properties such as free-radical scavenging activity (Oki et al., 2002). Storage of fresh sweet potatoes requires nicely controlled temperature (13–15 °C) (Reesa et al., 2003) and relative humidity (85–95%) (Mortleyl, Bonsi, Loretan, Hill, & Morris, 1994; Padda & Picha, 2008), which could be fulfilled with advanced and expensive equipments. It is also manpower consuming. In developing countries, a large amount of sweet potatoes decayed when they stored in unsuitable conditions. To avoid the above-mentioned loss, sweet potatoes could be sliced and dried or converted to flour before storage. Dried sweet potato flours have longer shelf life and are ready for use. The unique purple color, flavor and supplemented nutrients as well as the thickness of purple sweet potato flour make it an ideal additive to soups, sauces, baby foods and bakery products (Ahmed, Akter, Lee, et al., 2010).

Flours can be derived from various fruits and vegetables through different drying methods such as hot-air-drying, freeze-drying, microwave-drying and spray-drying. Spray-drying has been widely applied on account of its ability to produce dry particles of good quality with readily available equipment (Fang & Bhandari, 2011; Yang, Chen, Zhao, & Mao, 2010). However, when the puree of starchy vegetables such as sweet potato is fed, the drier is easily blocked. Moreover, the high sticky nature of the feed will result in deposition of the powder on the dryer wall and conveying system (Bhandari & Howes, 2005; Hennings, Kockel, & Langrish, 2001). Recently, the addition of carriers has proved to be an effective way to ease this technological problem (Desai & Park, 2005). The carriers can be classified into three categories, namely, polysaccharides (maltroxtrin, gum, starch), proteins (whey, gelatin, casein, soy protein) and lipids (stearic acid) (Saénz, Tapia, Chávez, & Robert, 2009).

Abbreviations: β-CD, β-cyclodextrin; DE, dextrose equivalent; DPPH, 1,1-diphenyl-2-picrylhydrazyl; EMC, Equilibrium moisture content; LPI, Lipid peroxidation inhibition; MD, Maltodextrin; Tg, Glass transition temperature; WAI, Water absorption index; WHC, Water holding capacity; WSI, Water solubility index.

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Maltodextrin (MD) and cyclodextrin (CD) are the most commonly used carriers in spray-drying and possess high water solubility and low viscosity at a low cost. On the other hand, they have proved to improve the stability of bioactive components and increase the yield and physicochemical properties of spray-dried flours (Ahmed, Akter, Lee, et al., 2010; Del Valle, 2004; Goula & Adamopoulos, 2010; Grabowski, Truong, & Daubert, 2006; Kalogeropoulos, Yannakopoulou, Gioxari, Chiou, & Makris, 2010; Quek, Chok, & Swedlund, 2007). It was evident that the effects of the carriers were highly depended on the properties of matrices to be dried and the carriers themselves. In this context, it is of industrial importance to comparatively study the effects of different carriers on the spray-dried purple sweet potato flours. Unfortunately, information related to this is scant.

The aim of this research was to investigate the effects of the MD, β-CD and their combination on the bioactive components, physicochemical properties and antioxidant capacity of spray-dried purple sweet potato flours.

2. Material and methods

2.1. Materials

Purple sweet potatoes (Wanzi 56 variety) were supplied by the Experimental Farm of Southwest University, Chongqing, China. After harvesting, they were cleaned, stewed (water/sweet potato ratio of 1:6 (w/w), cooking temperature 100 °C and cooking time 25 min) and manually peeled. They were homogenized with the aid of a household blender to produce purple sweet potato puree. The contents of anthocyanins, flavonoids and total phenolics, on dry basis in puree were 44.28 mg/100 g, 1.217 g/100 g and 2.504 g/100 g respectively. The obtained puree was packed in polyethylene bags and stored at −18 °C prior to use. MD (dextrose equivalence 20) was sourced from Xiwang Food Co. (Shangdong, China) and β-CD was purchased from Kelong Chemical Reagent Co. (Chengdu, China). All other chemicals and reagents were of analytical grade.

2.2. Spray-drying

The frozen puree was thawed at room temperature (approximately 25 °C) and ground after adding water to it using a colloidal mill (JMS-50, Xiangtong jixie Co., Hebei, China) to produce purple sweet potato suspension. Carriers (MD of 0–20 g/100 g, β-CD of 0–40 g/100 g and MD/β-CD of 20–26.7 g/100 g) were incorporated into the suspension on dry basis of the puree. The solid content of the suspension was normalized to 16.7 g/100 g by adding water. It was later homogenized using a GYB-60-63 (Donghua, Shanghai, China) experimental homogenizer operating at 30 MPa to prepare the feed. The spray-drying was conducted using a spray dryer YC-015 (Yacheng, Shanghai, China) with inlet and outlet temperatures of 200 °C and 100 °C. The reference flour was prepared in the same way but without the carrier. Moisture contents of the puree and flours were measured using the AOAC method (AOAC, 1984).

2.3. Hunter color values

The color parameters of the flours, including Hunter L^*, a^*, b^*, hue angle (the property of the color) and chroma (the color intensity or saturation) were determined as described by the method of Grabowski et al. (2006) by using an UltraSan PRO HunterLab (Xinlian, Shanghai, China). The color of flours expressed as L^*, a^* and b^* values, where L^*, a^*, and b^* stands for brightness, redness, and yellowness, respectively. The colorimeter of the puree was as the standard sample ($L_0 = 27.87$, $a_0 = 4.09$, $b_0 = -6.86$). The total color change (ΔE) of samples was calculated as Eq.: $\Delta E = ((L - L_0) + (a - a_0) + (b - b_0))^{1/2}$ where L_0, a_0 and b_0 were the L, a, and b values of the standard sample, which here is the puree. Hue angle (H) was calculated from arctan (b^*/a^*) and chroma from $(a^{*2} + b^{*2})^{1/2}$.

2.4. Determination of angles of repose and slide

The angle of repose (θ) was measured according to the method reported by Zhao, Yang, Gai, and Yang (2009) and the slide angle was determined according to the procedure reported by Zhou and Ileleji (2008).

2.5. Hydration properties of the flours

The water holding capacity (WHC) of flour was determined according to the method described previously (Zhao et al., 2009). The starch dispersion was incubated in a water bath for 40 min with varying temperature from 20 °C to 80 °C or at 60 °C with varying time from 10 min to 60 min. Water solubility index (WSI) and water absorption index (WAI) were determined according to the method described by Ahmed, Akter, Lee, et al. (2010). Moisture sorption isotherm was determined according to the method reported by Lee and Lee (2007) with minor modifications. The equilibrium moisture content (EMC g/100 g, dry weight basis) of flour was determined using a gravimetric technique. Saturated salt solutions of NaOH (a_w, 0.070), $MgCl_2$ (a_w, 0.33), $Mg(NO_3)_2$ (a_w, 0.528), NaCl (a_w, 0.752), KBr (a_w, 0.807), KCl (a_w, 0.842), $BaCl_2$ (a_w, 0.901) and $K_2Cr_2O_7$ (a_w, 0.986) were used to obtain flours with different a_w values by equilibrium. Experiment was done at room temperature (25 ± 1 °C). The isotherm models, including Henderson, Kuhn, Oswin, Bradley, Halsey and Chung-Pfost were used to fit the experimental moisture sorption data of a_w and EMC%.

2.6. Analysis of bioactive components

The content of anthocyanins in flour was measured according to the method reported by Hosseinian, Li, and Beta (2008). The extraction of flavonoids from flour was performed according to the method of Andarwulan, Batari, Sandrasari, Bolling, and Wijaya (2010) with slight modifications. The flour (1.0 g) was extracted at 60 °C for 3 h with 30 mL aqueous methanol (methanol/water ratio of 95:5 (v/v)). Following centrifugation at 8000 rpm for 15 min, aliquot of supernatant was reserved and allowed to cool. Then the supernatant was made up to 100 mL with methanol (methanol/water ratio of 95:5 (v/v)). The content of flavonoids in flour was measured using the method of Ahmed, Akter, Lee, et al. (2010). The content of total phenolics in flour was analyzed, using Folin–Ciocalteu method as described by Yang et al. (2010) with minor modifications. The flour (1.0 g) was repeatedly extracted at 80 °C for 10 min with 8 mL aqueous methanol (methanol/water ratio of 80:20 (v/v)). The supernatants obtained by centrifugation at 2150 g for 15 min were combined and diluted to 50 mL with methanol (methanol/water ratio of 80:20 (v/v)). The aliquots of extract solution were packaged in amber bottles and stored at −18 °C prior to the test for total phenolic content and antioxidant activity. The total phenolic content was calculated on the basis of calibration curves of gallic acid and expressed as g GAE (gallic acid equivalent)/100 g on dry weight basis.

2.7. Determination of antioxidant activities

The measurement of DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging activity was performed according to the procedure reported by Huang, Chang, and Shao (2006). The reducing power was measured using the method of the ferric reducing