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Application of simultaneous combination of microwave and steam cooking to improve nutritional quality of cooked purple sweet potatoes and saving time

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ABSTRACT

The influence of simultaneous combination of microwave and steam cooking on contents of specific phytochemicals, carbohydrate and antioxidant activity of purple sweet potatoes (PSPs) was investigated, and compared to those of individual steaming and microwaving. Results showed that the contents of phytochemicals including total phenolics, flavonoids and anthocyanins and phenolic acids except caffeic acid increased after cooking to different extent depending on cooking methods. The PSPs cooked by simultaneous combination of microwave (500 W) and steam (1700 W) for 12 min (M_{500}-S_{1700}-12) contained the highest of total phenolics, flavonoids, phenolic acids and anthocyanins. Simultaneous combination of microwave and steaming resulted in higher content of soluble sugar in PSPs. PSPs cooked by M_{500}-S_{1700}-12 showed the highest antioxidant activity, which was well accordance with higher contents of phytochemicals. The findings suggest that appropriate simultaneous combination of microwave and steaming could better preserve active phytochemicals in PSPs, but significantly shorten cooking time compared with individual steaming.

Industrial relevance: Simultaneous combination of microwave and steam cooking is a new technology for cooking food. However, the information about the effects of simultaneous combination of microwave and steam cooking on quality of food is limited. The present findings showed that the appropriate combination of microwave and steam cooking could significantly decrease the cooking time and improve nutrition value of cooked PSPs. This research is not only of importance for understanding the changes of food composition during different heating process, but also has important practical significance for choosing a scientific cooking methods and developing new type of cooking utensils which can better satisfy current consumers' needs.

1. Introduction

Sweet potato is one of the most widely consumed tuber crop. Purple sweet potatoes (PSPs, *Ipomoea batatas* L.) belong to the member of the sweet potato family. Sweet potatoes are rich in various phytochemicals (phenolic acids, anthocyanins and carotenoids) and also contain abundant carbohydrates, minerals and protein (Cai et al., 2016; Dincer et al., 2011; Kim et al., 2012; Rumbaoa, Cornago, & Geronimo, 2009; Trancoso-Reyes et al., 2016; Wu, Qu, et al., 2015). Extensive research has indicated that these phytochemicals are closely associated with antioxidant activity and play an essential role in the prevention of many chronic disease, such as cancers, diabetes and cardiovascular (Lebot, Michalet, & Legendre, 2016; McGill, Kurilich, & Davignon, 2013; Tian, Chen, Ye, & Chen, 2016; Williams et al., 2013). The sweet potato tubers are commonly cooked before consumption, and the traditional and most popular cooking methods including boiling, frying, steaming, baking and microwaving. It is well known that cooking lead to changes in sensory, nutrition and texture of food. Recently, the influence of domestic cooking on phytochemical and antioxidant activity in PSPs has received increasing interest. Lemos, Aliyu, and Hungerford (2015) reported that steaming and microwaving increase the total phenolic and anthocyanin quantities as well as antioxidant activity of purple majesty potato. In addition, baking, frying and microwaving increase antioxidants as well as the carotenoid and total phenolic content in potato according to Blessington et al. (2010). However, Tian, Chen, Lv, et al. (2016) found that the total phenolics, anthocyanins and antioxidant activity in purple-fleshed potatoes were significantly reduced by a microwave treatment.

Steaming and microwaving are two main household cooking methods with different characteristics. These cooking processes produce a number of changes in the physical characteristics and chemical composition of food (Turkmen, Sari, & Velioglu, 2005). Although steaming cooks PSPs over a long time period, its advantages include uniform heat distribution and an enhanced water-retaining capacity after

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cooking. Some literature has suggested that a shorter cooking time and lower temperature increased or did not change the total phenolic content and the antioxidant capacity (Perla, Holm, & Jayanty, 2012). Furthermore, microwave treatments have also become popular in food processing due to high heating rates and lower cooking times (Chandrasekaran, S. R., & Basak, 2013). However, microwave heating often causes serious water loss during cooking. In addition, nonuniform heating is the greatest issue in microwave processing, which can affect the palatability of cooked food. Considering the aforementioned bioactive compounds and physical changes caused by current cooking techniques, individual steaming and microwaving methods cannot meet consumers' needs, such as sensory quality, nutrition and saving time. The simultaneous combination of steaming and microwaving as a new cooking method can incorporate the advantages of steaming and microwaving but decrease the disadvantages.

Although the sensory quality and bioactive compounds in cooked PSPs using different individual cooking methods have been published, the effects of simultaneous combination of microwave and steam cooking on phytochemicals change of PSPs is still unclear. Therefore, in the present study, we conducted a systemic evaluation of the effects of simultaneous combination of microwave and steam cooking on the phytochemical composition (total anthocyanins, phenolics and flavonoids, phenolic acids, anthocyanins), carbohydrate and antioxidant activity in PSPs. In addition, we also compared simultaneous combination of microwave and steam cooking with individual steaming and microwaving in changes of these phytochemicals, carbohydrate and antioxidant activity in PSPs.

2. Materials and method

2.1. Materials and standard sample

Purple sweet potatoes (Dphi potato 1, Wuxi, Jiangsu) with individual weights at approximately 80 g and similar shapes (length: 7–8 cm, diameter: 3–4 cm) were purchased from a local market (Wuxi Jiangsu Province) and stored in a cool and dark environment.

Vanillic acid and cyanidin-3-o-gluctose were provided by J&K Scientific Ltd. (China). Tans-p-coumaric acid, caffeic acid and p-hydroxy-benzoic acid were purchased from Tokyo Chemical Industry. Chlorogenic acid, fructose, fructose, maltose, and sucrose were provided by Sigma-Aldrich. Thermostable α-amylase and amyloglucosidase were purchased from Sigma-Aldrich.

2.2. Cooking techniques

PSPs were cleaned by tap water and divided into seven groups. Cooking was performed with simultaneous combination–steam-microwave box (Fotile ZW-C2S, Ningbo, Zhejiang) and using different procedures as follows: (1) steaming (1700 W) for 30 min (S_{1700}-30); (2) simultaneous combination of microwaving (1000 W) and steaming(1700 W) for 7 min (M_{1000}-S_{1700}-7); (3) simultaneous combination of microwaving (800 W) and steaming(1700 W) for 10 min (M_{800}-S_{1700}-10); (4) simultaneous combination of microwaving (500 W) and steaming(1700 W) for 12 min (M_{500}-S_{1700}-12); (5) simultaneous combination of microwaving (300 W) and steaming(1700 W) for 15 min (M_{300}-S_{1700}-15); (6) microwaving (1300 W) for 5 min (M_{1300}-5); (7) raw PSPs. Each cooking procedure was run in triplicate.

Duration of each cooking procedure was previously determined using its tenderness assessed by stabbing with a chopstick. After cooking, each group of cooked PSPs was freeze dried, ground into powder and stored at −18 °C for further analysis.

2.3. Extraction and quantification of total phenolics and flavonoids

One gram of dried powder was extracted with 25 mL of a solution (85% methanol and 15% 1 M hydrochloric acid, v/v) on basis of the method (Hosseinian, Li, & Beta, 2008) with slight modifications. Then the tube was shaken on vortex shaker for 90 s and then sonicated for 30 min, and then centrifuged (5000 *g*, 15 min). The remaining pellet was reextracted as aforesaid. The obtained extract was stored at 4 °C until further analysis of total phenolics, anthocyanins and flavonoids within 24 h.

Total phenolics content of PSPs was determined by the Folin–Ciocalteau colorimetric method (Grace et al., 2014). The concentration of the total phenolic compounds was expressed as gram gallic acid equivalents per 100 g of dried PSPs.

The content of flavonoids was determined according to Barakat and Rohn (2014). The absorbance was measured at 510 nm by visible-UV Spectrophotometer (UV1000, Techcomp Shanghai China). The total flavonoid content was expressed as milligram rutin equivalents per 100 g dried PSPs.

2.4. Extraction and determination of soluble sugar and resistant starch

For extraction of soluble sugar, PSPs powder (0.1 *g*) was extracted with 25 mL of distilled water for 45 min at 60 °C, and then centrifuged(15 min, 5000 *g*)according to Gangola, Jaiswal, Khedikar, and Chibbar (2014). Extraction was repeated twice. The content of soluble sugar was detected using the anthrone/H_2SO_4 method (Wu, Li, et al., 2015). Resistant starch (RS) was measured based on the method of Hung, Vien, and Lan Phi (2016). The content of resistant starch was calculated as follows:

$$RS(\%) = (G_{120} - G_{20}) \times 0.9 \times 100$$

2.5. Composition of soluble sugar

The extraction of soluble sugar was similar to preceding method. The obtained supernatant was filtered through 0.22 μm organic membrane filters and used for chromatography analysis according to the method of Kami, Muro, and Sugiyama (2011). Quantification of glucose, fructose, sucrose and maltose concentrations was carried out by HPLC equipped with Waters Sugar-Pak1 column (300 mm × 7.8 mm) and differential refractive index detector.

2.6. Extraction and determination of phenolic acids

The extraction of phenolic acids was according to procedure of León-González et al. (2013). The residue was reconstituted with 10 mL methanol and then centrifuged (10 min, 10,000 *g*). The supernatant was used for analysis with HPLC.

The phenolic acids were identified and quantified by an Agilent series 1100 HPLC instrument with a reverse-phase C_{18} column (Waters, 4.6 mm × 250 mm) and UV detector. The phenolic acids including trans-p-coumaric acid, chlorogenic acid, vanillic acid, caffeic acid and p-hydroxy-benzoic acid were detected at 280 nm, and quantified by comparing retention time and area of the peaks in the extracts with related standard phenolic acids.

2.7. Determination and identification of anthocyanins by HPLC-MS

Extraction of PSPs anthocyanin was same with the procedure that was described above. The combined supernatants were evaporated to dryness at 40 °C and redissolved by methanol. The extracts were centrifuged (10,000 *g*, 10 min) and stored in 4 °C until LC-MS analysis of anthocyanin. The analysis of anthocyanins was performed on acquity UPLC (Waters, USA) equipped with a PAD (photo diode array detector) and a QT/MS (quadrupole time of flight mass spectrometer, Waters Maldi Synapt, USA). The column used was a 2.1 mm × 100 mm, C18 (BEH, Waters, USA). Solvent A was formic acid/water (0.1: 99.9), and solvent B was acetonitrile. The solvent gradient was according to