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Domestic cooking methods affect the phytochemical composition and antioxidant activity of purple-fleshed potatoes

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ABSTRACT

The effects of domestic cooking methods (boiling, baking, steaming, microwaving, frying, and stir-frying) and a new cooking method (air-frying) on the composition of phytochemicals (phenolics, anthocyanins, and carotenoids) and the antioxidant activity in purple-fleshed potatoes were investigated. Compared with raw potatoes, reductions of 23.59–90.42%, 7.09–72.44%, 7.45–83.15%, and 20.15–76.16% in the vitamin C, total phenolic, anthocyanin and carotenoid contents, respectively, was observed after cooking. Decreases of 7.88%, 21.55%, 22.48, 6.31%, and 61.38% in DPPH radical-scavenging activity was also observed after boiling, steaming, baking, microwaving and stir-frying, respectively, whereas an increase of 30.52% was noted after air-frying. A correlation analysis revealed that the antioxidant activity was in accordance with the total phenolic content and that this activity showed the lowest correlation with the vitamin C content. Among all of the cooking methods investigated in this study, stir-frying retained only slight levels of the phytochemicals and antioxidant activity observed in raw potatoes, whereas steaming and microwaving were able to retain most of the health-promoting compounds found in raw potatoes and may thus be suitable methods for cooking potatoes.

1. Introduction

Phytochemicals are bioactive non-nutrient plant compounds found in fruits, vegetables, grains and other plant foods and are broadly classified as carotenoids, phenolics, alkaloids, nitrogen-containing compounds, or organosulfur compounds (Nebeling, 2003). Numerous studies have demonstrated a negative correlation between the intake of phytochemicals and various diseases (e.g., chronic inflammation, cardiovascular diseases, cancer and diabetes) (Williams et al., 2013). As the dominant tuber crops worldwide (King & Slavin, 2013), potatoes contain numerous phytochemicals that are considered important due to their beneficial effects on health and therefore highly desirable in the human diet (Wolfe et al., 2008). Phytochemical extracts from potatoes have been reported to protect against acute liver injury and oxidative damage to erythrocytes (Singh & Rajini, 2008), reduce breast cancer in rats (Thompson et al., 2009), exhibit anti-inflammatory effects and even benefit heart and eye health (Ezekiel, Singh, Sharma, & Kaur, 2013).

Potatoes are usually cooked in different ways prior to consumption according to the recipes and culinary traditions of the various countries. For example, steaming, boiling and frying conform to the dietary habits of Western society, whereas stir-frying is used to prepare most homemade dishes in China (Ruiz-Rodriguez, Marín, Ocaña, & Soler-Rivas, 2008). Those cooking conditions are distinct (e.g. high temperature and excess oil involved in frying, limited oil, long cooking time and high temperature in air-frying, short cooking time and small size of strips in stir-frying) and induce a series of changes in the physical characteristics, chemical composition and enzyme modifications of foods (Rothwell et al., 2015). Most recent studies focused on the phytochemical and antioxidant activity undergone by potatoes during domestic cooking, but the conclusions were inconsistent and sometimes contradictory. For example, Blessington and coworkers (2010) reported that boiling, baking, frying and microwaving, significantly increased the total phenolic content, chlorogenic acid content and antioxidant activity in potatoes, whereas Xu, Li, Lu, Beta, and Hydamaka (2009) concluded that all cooking methods (boiling, baking and microwaving) induced decreases in phytochemical concentrations and antioxidant activity. Faller and Fialho (2009) showed that despite a significant increase in the total phenolic content, the antioxidant activity of potatoes decreased significantly, whereas Burgos et al. (2013)

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reported that boiling increased the total phenolic content and antioxidant activity and significantly decreased the total anthocyanin content. This difference may be attributed to the different species of potato examined in the studies, the pretreatment and cooking conditions applied, and the different analytical methods used. Thus, a systematic study of the effects of different cooking methods on phytochemical changes is needed.

Potatoes are food crops grown worldwide that are considered a good source of phytochemicals with interesting and health-promoting properties. With the increasing demand for novel functionality and health awareness, one variety of potato with purple-colored flesh containing high levels of anthocyanins has attracted much attention from researchers and the public (Ezekiel et al., 2013). However, the available information of the effects of cooking methods on selected phytochemicals and the antioxidant activity of purple-fleshed potatoes is insufficient. Purple potatoes contain an abundance of phytochemicals and should thus be a suitable model for evaluating the effects of domestic cooking methods on the phytochemical composition in potato.

Thus, in the present study, we conducted a systemic evaluation of the effects of different domestic cooking methods, including boiling, steaming, baking, microwaving, frying, on the phytochemical composition (i.e., total phenolics, phenolic acids, anthocyanins, carotenoids) and antioxidant activity, and the correlations between changes in these phytochemicals and antioxidant activity were also established. In particular, the effects of two other cooking methods (stir-frying, which is used to prepare most homemade dishes in China, and air-frying, a new technique for producing healthy fried potato strips) were evaluated for the first time in the present study.

2. Materials and methods

2.1. Plant materials and cooking methods

Purple-fleshed potatoes (*Heimeiren*) (length 6–8 cm, diameter 3–4 cm, weight 100–120 g) and soybean oil were obtained from a local supermarket (Hangzhou, China). For boiling, steaming, baking and microwaving, whole tubers (unpeeled) were cooked, and a stainless-steel probe was inserted in the tubers to evaluate the cooking time (Table 1). For normal frying and air-frying, potatoes (unpeeled) were washed and cut into strips (8 × 7 × 60 mm) manually, whereas for stir-frying, the strips measured 2 × 3 × 60 mm. All of the strips were soaked in running water for 1 min to eliminate occluded starch, and stains were removed using tissue paper; the detailed frying conditions were also listed in Table 1. After cooking, the raw and cooked samples were freeze-dried (−50 °C, pressure lower than 0.1 mBar) (FreeZone 6, Labconco, USA), ground using a commercial grinder, sealed with aluminum foil and stored at −80 °C for further analysis.

Table 1
Cooking methods used in present study.

Cooking methods	Pretreatment	Cooking condition	Cooking equipment
Boiling	Whole, unpeeled,	100 °C, 20 min, penetrated easily	Supor
Steaming	Whole, unpeeled	15 min, penetrated easily	FOTILE SCD20-01
Baking	Whole, unpeeled	210 °C, 30 min, penetrated easily	FOTILE KQD50F-01
Microwaving	Whole, unpeeled	1000 W, 6 min, penetrated easily	FOTILE W25800-01AG
Frying	8 * 7 * 50 mm, soaked in water (1 min)	191 °C, 2 min; 300 g/3000 mL	VESTA EF-81
Air-frying	8 * 7 * 50 mm, soaked in water (1 min)	180 °C, 18 min; 300 g/10 mL	Haier HAF-J2401A
Stir-frying	2 * 3 * 60 mm, soaked in water (1 min)	160 °C, 3 min; 300 g/25 mL	Royalstar YSF458

2.2. Proximate composition and vitamin C

The proximate composition (ash, crude fat, crude protein and crude fiber) of the samples was determined according to the National Standard of the People's Republic of China. Briefly, the ash (%) content was determined by weighing potato samples before and after heat treatment in a furnace (550 °C for 4 h) (GB5009.4-2010). The crude protein content was determined by the Kjeldahl method using a nitrogen-to-protein conversion factor of 6.25 (GB5009.5-2010). The crude fat content was determined by weighing potato samples and extracting the crude fat with n-hexane with a Soxhlet apparatus (GB/T 14772-2008). To determine the crude fiber content, a sample of potato powder was boiled in 0.255 M sulfuric acid for 30 min, filtered, washed, boiled in 0.313 M sodium hydroxide, filtered, washed again, and dried at 130 ± 2 °C for 2 h (GB/T 5009.10-2003).

To determine the vitamin C content, the freeze-dried material (1.000 g) was mixed with 4.5 mL of an ethanedioic acid solution (1 g/L) for 10 min and centrifuged at 8000 rpm for 5 min. The residues were resuspended, and the supernatants were then filtered off, collected and dispersed in an ethanedioic acid solution to a final volume of 10 mL. The residues were cleaned with 0.45 μm filters before being analyzed. The standard solution (vitamin C, Sigma–Aldrich, USA) concentration ranged from 10 μg/mL to 50 μg/mL. The analysis was performed in a Waters model 2995 separation system (Waters, Corp., Milford, MA, USA) using a C18 reversed-phase column (Symmetry Waters; 5 mm, 4.6 mm, 250 mm). The mobile phase was 1 g/L ethanedioic acid solution with at flow rate of 1 mL/min. Vitamin C was detected using a UV–visible photodiode array detector (Waters model 2696) at a wavelength of 254 nm.

2.3. Total phenolic content and antioxidant activity

The total phenolics were extracted using the method reported by Burgos et al. (2013). Briefly, 1.000 g of a frozen tuber sample was extracted with 10 mL of 80% methanol for 10 min using sonication (KQ-250B, KunShan, Ltd.). The extraction was repeated under the same conditions. The mixture was centrifuged at 8000*g* at 4 °C for 10 min and the supernatants were filtered and collected to a final volume of 25 mL. The total phenolic content was measured by the Folin–Ciocalteu method (Lemos, Aliyu, & Hungerford, 2015; Rytel et al., 2014). Briefly, an aliquot (500 μL) of the sample solution was mixed with 500 μL of distilled water and 1 mL of Folin–Ciocalteu reagent, and the mixture was maintained for 5 min. After 5 mL of sodium carbonate (5%) was added, the volume was adjusted to 10 mL with distilled water. The reaction mixture was incubated for 1 h at room temperature. The absorbance was measured at 765 nm with a spectrophotometer (UV-2550, Shimadzu, Japan), the total phenolic concentration was calculated using a gallic acid standard curve ($y = 0.1167x + 0.0113$, $R^2 = 0.998$, x: gallic equivalents, y: absorbance) ranging from 100 μg/mL to 1500 μg/mL.

A DPPH radical scavenging assay was performed according to the method adopted by Perla, Holm, and Jayanty (2012) with some modifications. A 20 μL aliquot of the extract was added to 20 μL of distilled water in a 96-well flat-bottomed microplate on ice. After 200 μL of 118.3 mg/L DPPH radical solution was added, the mixture was mixed thoroughly. Methanol was used to produce the DPPH radical solution. After the plates were stored in the dark for 30 min on ice, the absorbance was measured using a plate reader (1510, Thermo Fisher, USA) at 515 nm. A control containing