



Cooking methods affected the phytochemicals and antioxidant activities of potato from different varieties

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ABSTRACT

In order to investigate the effect of different cooking methods on the phytochemicals and antioxidant activities of potato from different varieties, three varieties of potatoes were cooked with seven domestic methods. The contents of total phenolic, total carotenoid, vitamin C and phenolic acids of cooked potato were analyzed as well as the antioxidant activities. Results indicated that all the cooking methods showed negative effects on the contents of vitamin C, total phenolic, phenolic acids and DPPH radical-scavenging activity, but the effects were depended on the cooking methods, as frying, air-drying and roasting showed a more intensive decrease of total phenolic, phenolic acids and antioxidant activities than that of steaming or microwaving, regardless of the potato varieties. From the perspective of remaining phytochemicals and antioxidant activities, Zhongshubahao might be an ideal potato sample and steaming or microwaving were optional methods for cooking potatoes.

Introduction

Attributing to the high yielding, environmental adaptability and diversity of cooking, potato (*Solanum tuberosum* L) has been widely planted and consumed around the world. It has been reported that potato is an important supplier of carbohydrates as well as a key supplier of nutrients (e.g. minerals, protein, vitamins and others) in our diet. In addition to those beneficial, potato is also an important supplier of phytochemicals, and contributes about 20% of total phenolics from vegetables that consumed by human body (Song et al., 2010). Phytochemicals, which are the non-nutrient compounds in plants food, have been proved to enhance the health of human body and negatively associated with chronic diseases (e.g. inflammation, cardiovascular diseases, diabetes and tumor). As one of the commonly consumed plant tubers, many kinds of phytochemicals (phenolic acids, carotenoids etc.) have been identified and numbers of studies have demonstrated that the phytochemicals extracted from potato showed a good protect against obesity, cancer inflammatory or others. Thus, ways to remain or improve the phytochemicals in potato have attracted more and more

attentions.

Different from targeted breeding to increase the phytochemicals in tubers, processing conditions were also considered as important factors to affect the phytochemicals content (e.g. different cooking methods). According to the recipes and culinary traditions of different countries, cooking conditions are quite different. For instance, stir-frying and stewing are used to prepare most homemade dishes in China and other Eastern Asia countries, whereas frying and roasting are commonly used to cook potato in Western Society (Tian et al., 2016a). There is no wonder that cooking will induce a series of changes in potato, such as the changes of phytochemicals contents and antioxidant activities. Up to now, many researchers have focused on those changes during cooking, but the conclusions were inconsistent. For instance, early researchers studied the effect of cooking methods on total phenolic changes and reported that cooking would negative associated with the total phenolic content (Lemos, Aliyu, & Hungerford, 2015), while in another study, researchers also reported that the phenolic content in potato increased significantly after boiling, steaming and microwaving (Faller & Fialho, 2009). Those different conclusions might attribute to different reasons,

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such as the varieties of potato, the pretreatment and cooking condition, or the different analytical methods, etc. (Tian et al., 2016b). Considering the different conclusions reported from previous studies, a systematic study on the effects of different cooking methods on phytochemicals changes in cooked potato from different varieties might be necessary.

Thus, in present study, in order to have a better understanding of how cooking methods affect the phytochemicals and antioxidant activities in potato, three different varieties of potatoes with different flesh color (Xiapodi: white flesh, Helanshiwu: yellow flesh, Zhongshuba: pink flesh) were cooked with seven domestic cooking methods (boiling, steaming, roasting, microwaving, frying, air-frying and stir-frying). Then the contents of total phenolic, phenolic acids and the antioxidant activities were analyzed. And the underlying mechanism of how phytochemicals and antioxidant changes of potato after cooking were also discussed. The present study will help other researchers to have a better understanding on the relationships among phytochemicals, antioxidant activities and domestic cooking methods of potato from different varieties.

Materials and methods

Materials and reagents

Three varieties of commonly consumed potato in China (Xiapodi, Helanshiwu and Zhongshubahao) were used in this study. Xiapodi and Helanshiwu were harvested in Qingzhou, Shandong Province, in September of 2019, and Zhongshuba was harvested in Baotou, Inner Mongolia, in October of 2019. All the potatoes were stored in a dark and ventilated condition at room temperature prior to using. Soybean oil (Yihai Kerry Group, Shanghai) and white vinegar (Hengshun Ltd, Jiangsu) were purchased from a local supermarket (Hangzhou, China). Phenolic acids (Chlorogenic acid, ferulic acid, coumarin, caffeic acid) of HPLC grade and 1,1-diphenyl-2-trinitrophenylhydrazine (DPPH) were purchased from Sigma (Shanghai, China), Vitamin C of HPLC grade and methanol, oxalic acid and other reagents with analytical grade were purchased from Sinopharm Reagent Company (Beijing, China) and Aladdin Reagent Company (Shanghai, China).

Cooking methods

Seven domestic cooking methods were applied in present study (boiling, steaming, roasting, microwaving, frying, air-frying and stir-frying). The cooking conditions were carried out according to our previous study (Tian et al., 2016a) (detail cooking information were attached in supplementary materials). Briefly, for boiling, steaming, roasting and microwaving, potatoes were washed, half cut and cooked, the potatoes were regarded as fully cooked when a stainless-steel probe (2 mm × 100 mm) could inserted through the tubers easily (Tian et al., 2016c). For normal frying and air-frying, potatoes (peeled) were washed and cut into strips (8 × 7 × 60 mm) manually, whereas for stir-frying, the size of the strips was cut into 2 × 3 × 60 mm size. All of the strips were soaked in running water for 1 min, and stains were removed using tissue paper. For normal frying, the strips were immersed in hot oil (185 °C) in a fryer (EF-81, VESTA, China) for about 6.5 min. For air-frying, the strips were mixed with oil (oil/potato 1/30 g/mL) and fried in an air-fryer (HAFJ2401A, Haier, China) at 180 °C for about 20 min, for stir-frying, strips were mixed with oil (potato/oil/vinegar 300:25:10) and stir-fried with an auto-cooker (YSF458, Royalstar, China) according to its introduction. After cooking, all the raw and cooked potatoes were freeze-dried in a Vacuum lyophilizer (FreeZone 6, Labconco, USA), ground and stored at -80 °C for future analysis.

Determination of ash, crude fat, crude protein and crude fiber

The content of ash, crude fat, protein and crude fiber in raw and cooked potatoes were determined according to our early researches

(Tian et al., 2016b). Briefly, the ash (%) content was determined by the ratio of potato weight before and after heating in a furnace (SX2-16-12A, Zhanlinhuanshi Ltd., China) at 550 °C for 4 h. The protein was measured by an automatic Kjeldahl Apparatus (K9860, Haineng Ltd., China) according to its introduction. The fat content was obtained by the ratio of potato weight before and after the fat extracting with *n*-hexane in a Soxhlet apparatus. The crude fiber was determined by the difference between the cooked potato and digested one (boiled in 0.255 M sulfuric acid for 30 min then boiled in 0.313 M sodium hydroxide for 30 min and drying at 130 °C for 2 h).

Determination of vitamin C

Vitamin C in raw and cooked potatoes was determined with HPLC (Waters, Corp., Milford, MA, USA). Briefly, 1.000 g power samples were mixed with 4.5 mL ethanedioic acid solution (1 g/L) for 10 min and centrifuged at 8,000 g for 5 min, then the residues were re-suspended, and the supernatants were filtered off, collected and adjusted to a final volume of 10 mL with ethanedioic acid solution (1g/mL). The residues were cleaned with 0.45 μm filters and analyzed with a Waters model 2995 separation system (C₁₈ reversed-phase column: Symmetry Waters; 5 mm, 4.6 mm, 250 mm). Ethanedioic acid (1g/L) was used as the mobile phase at a flow rate of 1 mL/min and a UV-visible photodiode array detector (Waters model 2696) at a wavelength of 254 nm was applied. Finally, the vitamin C contents were calculated according to its peak areas.

Determination of total phenolic

Total phenolics in raw and cooked potato were analyzed with Folin-Ciocalteu methods (Burgos et al., 2013). Briefly, 1.000 g sample was mixed with 7 mL 80% methanol and ultrasonic extracted for 10 min, centrifuged at 8,000g at 4 °C for 10 min, the extraction was repeated under the same condition for three times and the supernatants were collected, filtered through a 0.42 μm organic filter and adjusted to a final volume of 25 mL with 80% methanol. Then, five hundred microliters extraction were mixed with 500 μL of distilled water and 1 mL of Folin-Ciocalteu reagent, after maintaining for 5 min, 5 mL sodium carbonate (5%) was added and the volume of the reaction solution was adjusted to 10 mL with distilled water and incubated for 60 min at room temperature. The absorbance was measured at 765 nm with a spectrophotometer (UV-2550, Shimadzu, Japan) using gallic acid as a standard.

Analysis of phenolic acids

To extract the phenolic acids, 0.100 g samples were accurately weighted, mixed with 3.5 mL extraction (consisted of methanol, water and acetic acid in a ratio of 0:19.5:0.5) and ultrasonic extracted for 20 min. Then, the solutions were centrifuged at 8,000 g for 10 min and the residues were extracted again under the same conditions, and the samples were heated to 80 °C for 5 min in the third extraction. The supernatants were collected, evaporated, adjusted to 5 mL with distilled water and filtered through a 0.45 μm organic filter. In order to analyze the contents of phenolic acids, a Waters model 2995 separation system (Waters, Corp., Milford, USA) with a C₁₈ reversed-phase column (symmetry Waters; 5 mm, 4.6 mm, 250 mm) were applied (Burgos, 2009). Elution A was 1% acetic acid in water and elution B was acetonitrile containing 0.1% acetic acid. The gradient started with 3% elution B for 7 min, and increased to 5–40% between 7 and 45 min and reached to 100% of elution B at 46 min, then maintained for 5 min and decreased to 3% B in 6 min. The flow rate was set to 0.8 mL/min with a re-equilibration time of 15 min. Phenolics were detected with a UV-visible photodiode array detector (Waters model 2696) at wavelengths of 260 nm and 320 nm. The concentrations of phenolic acids were calculated according to the standard curve of phenolic acids.

Measurements of total carotenoid

Total carotenoid content was determined using a colorimetric method according to Burgos (2009). Briefly, 0.500 g samples were mixed with 5 mL extraction solution (acetone: petroleum ether was 1:1, containing 0.1% butylated hydroxytoluene), and the mixture was shaken in dark for about 30 min and centrifuged at 8,000g, 4 °C for 5 min. The residues were re-extracted for three times, and the supernatants were collected, filtered and blown dry with nitrogen. Finally, 5 mL of dichloromethane (0.1% BHT) was added to dissolve the carotenoids. Finally, the absorbance was determined at 450 nm, and total carotenoid content was calculated using the following Equation (1). A represented the absorbance, V represented a constant volume, and ϵ_2 represented the molar absorptivity (2500).

$$C(\mu\text{g/g}) = (A \times V \times 106) / (\epsilon_2 \times m \times 100) \quad (1)$$

DPPH radical scavenging assay

A DPPH radical scavenging assay was carried out according to Romanet et al. (2021). Briefly, 0.1 mL total phenolic extraction solution were mixed with 4.9 mL DPPH (0.1 mmol/L dissolved in methanol) thoroughly and reacted in dark for 30 min. Then, the absorbance was measured at 517 nm and results were expressed as milligrams of TEAC (Trolox equivalent antioxidant capacity) per gram DW.

Statistical analysis

Statistical analysis was performed using the SPSS software program (Version: 20.0, USA). The data were subjected to one-way analysis of variance (ANOVA) for mean comparison; significant differences were detected by Duncan's test at the level of 0.05.

Results and discussion

Protein and crude fiber contents in cooked potato from different varieties

The protein content in potato from different varieties were shown in Table 1. Xiapodi showed the highest protein content (11.10 g/100 g DW; Dry weight), followed by Helanshiwu (9.30 g/100 g DW), and Zhongshubahao (7.61 g/100 g DW). Compared with the raw potato, the protein content in cooked Xiapodi and Zhongshubahao showed little difference. However, in Helanshiwu, the protein content showed a decrease trend after boiling, steaming, roasting, microwaving and frying, particularly a significantly lower protein content was observed after steaming ($p < 0.05$).

The content of crude fiber in cooked potatoes were also analyzed and results were described in Table 1, after frying and air-frying, the crude fiber in Xiapodi increased from 6.17 g/100 g DW to 19.36 and 24.73 g/100 g DW, respectively. While in Helanshiwu, the crude fiber in raw potato was 7.50 g/100 g DW, after frying and stir-frying, it increased to 22.15 and 24.73 g/100 g DW, respectively. In Zhongshubahao, the crude fiber increased from 10.65 g/100 g DW to 23.36, 18.53 g/100 g DW after frying and air frying. Generally, frying and air-frying could induce a higher content of crude fiber in potato and this might attribute to the processing conditions in those frying methods. During soaking, amounts of starch granules were washed off and the ratio of crude fiber was increased. Additionally, the potato strips were dehydrated and the texture of fried potato became denser during frying and air-drying, and this also contributed to the increase of crude fiber in fried potato (Sun et al., 2014). Our results were consistent with previous studies by Thomas et al. (2021) that significantly higher crude fiber content in fried and boiled potatoes than that of the raw one was reported.

Oil and ash contents in cooked potato

The oil contents in raw potatoes were quite low, which were only about 1%. However, after frying, stir-frying and air-frying, the oil contents increased significantly ($p < 0.05$) and difference among those

Table 1
Effect of different domestic cooking methods on proximate composition of potato from different varieties (g/100 g DW).

		Raw	Boiled	Steamed	Baked	Microwaved	Fried	Air-fried	Stir-fried
Xiapodi	Protein	11.10 ± 0.82a	10.24 ± 1.67a	9.50 ± 0.72a	9.30 ± 0.98a	10.06 ± 0.86a	10.31 ± 1.25a	8.59 ± 0.97a	10.78 ± 1.15a
	Crude fiber	6.17 ± 0.32e	5.53 ± 0.64e	5.80 ± 0.70e	7.55 ± 0.83cd	9.06 ± 0.77c	19.36 ± 0.98b	24.73 ± 0.42a	6.94 ± 0.39d
	Crude oil	0.75 ± 0.20d	0.68 ± 0.30d	0.96 ± 0.07d	1.22 ± 0.36d	0.78 ± 0.33d	25.47 ± 0.85a	9.55 ± 0.54b	4.29 ± 0.38c
	Ash	5.67 ± 0.34a	5.07 ± 0.29a	5.29 ± 0.32a	4.29 ± 0.87b	4.84 ± 0.30b	5.10 ± 0.60ab	4.99 ± 0.54ab	4.42 ± 0.30b
	Vitamin C*	156.40 ± 2.59a	82.62 ± 0.98c	60.47 ± 1.70e	38.98 ± 2.59h	101.04 ± 2.13b	68.19 ± 0.99d	60.47 ± 1.23f	48.24 ± 2.59g
Helanshiwu	Protein	9.30 ± 0.73a	8.26 ± 0.67ab	5.48 ± 1.02c	7.27 ± 0.48b	8.56 ± 0.59a	8.34 ± 0.95ab	7.48 ± 0.90ab	9.28 ± 0.59a
	Crude fiber	7.50 ± 0.61b	6.49 ± 1.05b	7.21 ± 1.79b	7.23 ± 0.83b	8.11 ± 1.52b	22.15 ± 2.08a	23.53 ± 1.42a	7.68 ± 0.63b
	Crude oil	0.90 ± 0.23d	0.72 ± 0.30d	1.06 ± 0.17d	1.34 ± 0.42d	0.89 ± 0.33d	24.07 ± 0.15a	7.62 ± 0.37b	3.87 ± 0.42c
	Ash	7.04 ± 0.54a	6.92 ± 0.79ab	6.55 ± 0.42a	6.30 ± 0.87ab	5.81 ± 0.96ab	6.18 ± 0.60as	5.92 ± 0.54ab	5.43 ± 0.70b
	Vitamin C	186.58 ± 2.59a	95.62 ± 0.98d	109.47 ± 1.70c	59.98 ± 2.59f	120.04 ± 2.13b	52.19 ± 0.99g	36.47 ± 1.23h	86.24 ± 2.59e
Zhongshubahao	Protein	7.61 ± 0.51a	6.90 ± 0.77ab	6.34 ± 1.57ab	6.29 ± 0.80ab	7.56 ± 1.00ab	5.99 ± 0.87b	6.46 ± 1.08ab	7.18 ± 0.49ab
	Crude fiber	10.65 ± 0.40c	9.53 ± 0.25d	8.79 ± 1.57d	11.50 ± 0.63c	10.00 ± 0.58c	23.36 ± 1.83a	18.53 ± 1.42b	11.14 ± 0.50c
	Crude oil	0.71 ± 0.15d	0.59 ± 0.20d	0.93 ± 0.17d	1.09 ± 0.32d	0.58 ± 0.42d	20.30 ± 1.05a	10.59 ± 0.77b	3.00 ± 0.59c
	Ash	6.26 ± 0.53a	5.89 ± 0.69aa	6.06 ± 0.50a	5.85 ± 0.47a	6.25 ± 0.50a	5.66 ± 0.27a	6.33 ± 0.14a	5.54 ± 0.30a
	Vitamin C	253.24 ± 2.59a	105.62 ± 0.98d	159.47 ± 1.70b	75.98 ± 2.59g	135.04 ± 2.13c	82.19 ± 0.99e	77.47 ± 1.23f	50.91 ± 1.29h

(Note: a-e in each row indicates significantly different at $p < 0.05$; *: mg/100 g DW).

cooking methods were also observed. The highest oil content in Zhongshubahao was observed after frying (20.30 g/100 g DW), followed by air-frying (10.59 g/100 g DW) and stir-frying (3.00 g/100 g DW), similar results were also found in Helanshiwu and Xiapodi. As a new frying method, air fried potato strips have attracted more and more attentions for its similar taste and lower oil content than that of the traditional frying (Tian, 2017). During traditional frying, the potato strips were immersed in hot oil and the oil would migrated into the potato easily, while during air-frying, only slightly oil was covered on the surface of potato strips and the oil was not so easy to penetrated inside of the strips, this might partly explain why hot air-fried potato strips showed a lower oil content than that of the traditional fried one. Similar lower oil contents in air fried potato were also reported by previous studies (Liu et al., 2021). During air frying, the hot air could promote the formation of harder and denser crust of fried strips. And those structure changes inhibit the oil penetration into fried food interior, thus a significantly lower oil content than that of the normal frying were observed (Yang et al., 2019).

The ash contents in cooked potato from different varieties were also showed in Table 1, boiling, steaming, roasting and microwaving showed little effect on the ash contents regardless of potato varieties. However, frying, air-frying and stir-frying reduced the ash contents significantly. For instance, when Xiapodi potatoes were fried, air-fried and stir-fried, the ash contents decreased to 5.10, 4.99 and 4.42 g/100 g DW, respectively. This might attribute to the leaching of minerals during soaking before frying, air-frying and stir-frying. As the main compounds in ash, the minerals were easily dissolved in water, and then resulted in a lower ash contents after those cooking.

Vitamin C contents in cooked potato

The vitamin C content in potato from different varieties were described in Table 1, Zhongshubahao had the highest vitamin C content (253.24 mg/100 g DW), followed by Helanshiwu (186.58 mg/100 g DW) and Xiapodi (156.40 mg/100 g DW). Generally, all the cooking methods showed a negative effect on the content of vitamin C and the remaining of vitamin C was depended on the cooking methods as well as potato varieties. The minor loss of vitamin C in Xiapodi was observed after microwaving (101.04 mg/100 g DW), while the maximum was observed after roasting (38.98 mg/100 g DW). The microwaving also induced minor decrease of vitamin C in Helanshiwu (120.04 mg/100 g DW), while after roasting, frying and air-frying, the content decreased significantly, which accounted for only about 59.98, 52.19 and 36.47 mg/100 g DW, respectively. Minor loss of vitamin C in Zhongshubahao was observed after steaming (159.47 mg/100 g DW), but after roasting, frying, stir-frying and air-frying, the content of vitamin C decreased to 75.98, 82.19, 77.47 and 50.91 mg/100 g DW, respectively. As a water-soluble and thermal-unstable vitamin, vitamin C could be easily decreased during cooking. And a higher loss would be observed with longer cooking time and higher temperature. In a previous study, Thomas et al. (2021) also reported that the vitamin C content in potatoes

from different varieties decreased significantly after frying and boiling, with concentrations representing 12.8–51.1% after frying and 56.9–90.8% after boiling, of the initial contents (in raw tubers, before cooking).

Total phenolic contents in cooked potato

The total phenolic content in different potato varieties were showed in Fig. 1, the highest total phenolic content was observed in Zhongshubahao (992.73 mg/100 g DW), followed by Helanshiwu (759.30 mg/100 g DW) and Xiapodi (482.45 g/100 g DW). Similar to the changes of vitamin C, all the cooked potato showed a decrease in total phenolic regardless of their varieties. In Xiapodi, the minor loss of total phenolic was observed after microwaving (327.30 g/100 g DW), while the highest loss was observed after roasting (58.50 g/100 g DW). For Helanshiwu, the minor loss was observed after steaming (327.30 g/100 g DW) while the highest loss was observed after frying and air-frying, which were accounted for about 278.60 g/100 g DW and 261.75 g/100 g DW, respectively. For Zhongshubahao, the minor loss was observed after microwaving (839.60 g/100 g DW), while the highest loss was observed in roasting (204.50 g/100 g DW). Our results were consistent with early studies (Rytel et al., 2014; Lemos et al., 2015), they reported that cooking had a detrimental effect on total phenolic, after roasting, boiling, microwaving and steaming, the total phenolic content decreased from 209 ± 35.7 mg GAE/100 g (fresh weight) to 38.1 ± 7.5 , 137.6 ± 0 , 74.0 ± 1.3 , 130.4 ± 3.7 mg GAE/100 g (fresh weight), respectively. In another study, Sun et al. (2021) also showed that boiling and steaming reduced the total polyphenolic content in potato. The decrease of total phenolic in cooked potato might attribute to the thermal-degradation or the leaching during cooking. Additionally, some researchers also reported that phenolic compounds could be substrates in lard reaction, and this also decreased the total phenolic level in cooked potato (Kita, Bąkowska-Barczak, Hamouz, Kulakowska, & Lisińska, 2013).

Total carotenoids contents in cooked potato

The total carotenoids content in potato from different varieties were described in Fig. 2. Zhongshubahao had the highest total carotenoids content (1233.45 μ g/100 g DW), followed by Helanshiwu (830.60 μ g/100 g DW), and Xiapodi (482.45 μ g/100 g DW). Similar to the total phenolic content, Zhongshubahao showed the highest total carotenoids after different cooking. But different variety and cooking methods might have different effects. The minor loss of total carotenoids in Helanshiwu was observed after steaming (684.20 μ g/100 g DW), while frying and air-frying induced the highest loss (210.40 μ g/100 g DW and 182.45 μ g/100 g DW, respectively). Similar decreases were also observed in Xiapodi and Zhongshubahao. Generally, frying and air-frying affected the content of total carotenoids significantly ($p < 0.05$). This might attribute to the physicochemical properties of carotenoids, which were easily dissolved in lipid and degraded at high temperature (Olagunju et al.,

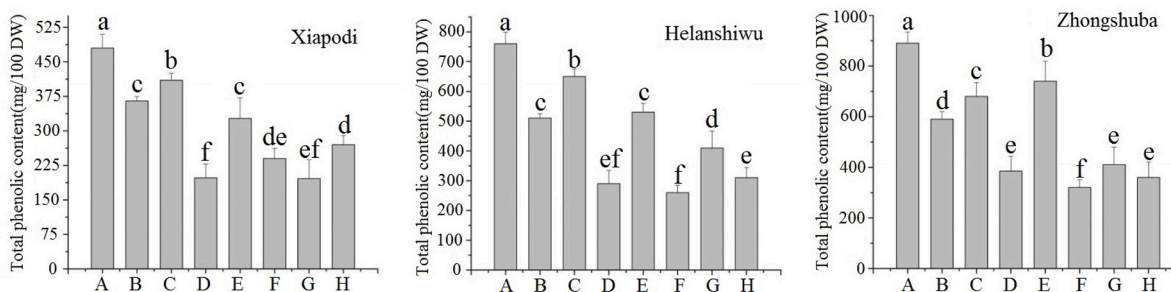


Fig. 1. Effect of cooking methods on total phenolic content in potatoes from different variety (A, B, C, D, E, F, G, H indicate the cooking methods of raw, boiled, steamed, baked, microwaved, fried, air-fried and stir-fried).

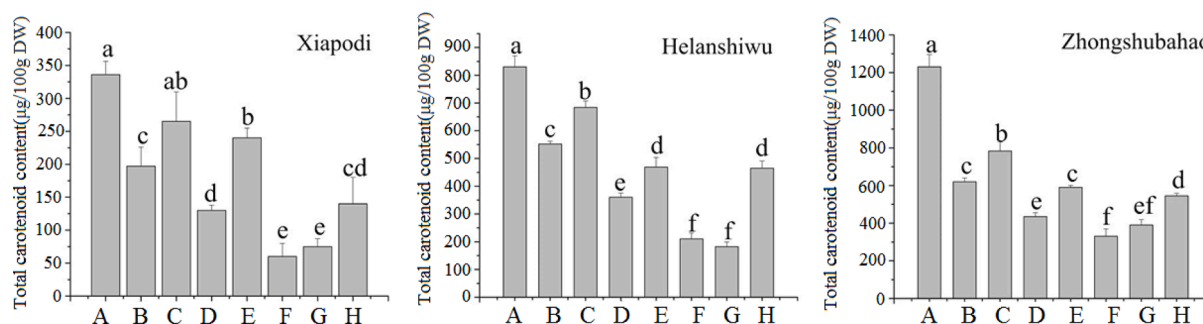


Fig. 2. Effect of cooking methods on total carotenoid content in potatoes from different variety (A, B, C, D, E, F, G, H indicate the cooking methods of raw, boiled, steamed, baked, microwaved, fried, air-fried and stir-fried).

2021).

Phenolic acids contents in cooked potato

The changes of phenolic acids in potato from different varieties were showed in Table 2; Chlorogenic acid was the main phenolic acids in potato regardless of the varieties, and accounted about 90% of the phenolic acids. This result was consistent with the early studies (Hamouz et al., 2013). The highest content of Chlorogenic acid was observed in Zhongshubahao (691.30 mg/100 g DW), followed by Helanshiwu (570.90 mg/100 g DW) and Xiapodi (348.50 mg/100 g DW). In Xiapodi, steaming showed the least effect on the content of Chlorogenic acid, no significant difference was observed when compared with the raw potato. However, other cooking methods induced significant decreases of Chlorogenic acid and the highest loss were observed after roasting, frying and stir-frying, which accounted only about 109.30, 104.20 and 89.5 mg/100 g DW, respectively. In Helanshiwu variety, all the cooking methods decreased the Chlorogenic acid significantly. Similar to Xiapodi, the highest loss of Chlorogenic acid in Helanshiwu were also observed after roasting (225.00 mg/100 g DW), frying (206.25 mg/100 g DW) and stir-frying (195.80 mg/100 g DW). The minor loss of Chlorogenic acid in Zhongshubahao were

observed after steaming (502.90 mg/100 g DW) and microwaving (556.70 mg/100 g DW), while the highest loss was observed after roasting (180.70 mg/100 g DW), frying (295.20 mg/100 g DW), air-frying (259.16 mg/100 g DW) and stir-frying (224.50 mg/100 g DW). Early studies also reported that processing would negative affect the content of Chlorogenic acid in potato, and roasting could destroy most of the Chlorogenic acid while microwaving decreasing about 60% (Dao, 1992). As the main phenolic acid in potato, Chlorogenic acid was easily dissolved in water or degraded by heating during cooking (Sukrasno, Sari, & Kusmardiyani, 2014). Additionally, some studies also reported that the Chlorogenic acid could take part in lard reaction and induced a future loss in cooked potato (de Queiroz et al., 2014).

DPPH radical-scavenging activity changes after cooking

Effects of cooking methods on DPPH radical-scavenging activity of potato from different variety were showed in Fig. 3. All the cooking methods induced a decrease in DPPH radical-scavenging activity regardless of the varieties. But the Zhongshubahao still showed higher antioxidant activity than Xiapodi and Helanshiwu, which might attribute to the higher content of total phenolic and total carotenoids content. The roasted potato showed the highest decreases, which were

Table 2

Effect of domestic cooking on the content of phenolic acids in potato (mg/100 g DW).

		Raw	Boiled	Steamed	Baked	Microwaved	Fried	Air-fried	Stir-fried
Xiapodi	Chlorogenic acid	348.52 ± 47.25a	276.25 ± 15.80b	301.52 ± 30.46ab	109.3 ± 17.31d	177.95 ± 6.40c	104.20 ± 30.20d	156.6 ± 29.75c	89.5 ± 16.58d
	Caffeic acid	17.58 ± 2.15b	10.92 ± 0.53c	12.19 ± 3.92c	22.19 ± 0.50a	20.77 ± 3.50ab	13.38 ± 2.51c	7.86 ± 0.75d	9.41 ± 1.39cd
	p-Coumaric acid	9.03 ± 0.87c	7.45 ± 1.58de	5.95 ± 1.52e	15.87 ± 1.45a	9.85 ± 0.26c	11.05 ± 0.94b	8.09 ± 1.05d	5.75 ± 0.68e
	Ferulic acid	8.50 ± 1.04b	6.38 ± 1.02cd	10.46 ± 0.88a	13.35 ± 2.31a	11.19 ± 0.99a	12.25 ± 1.53a	10.88 ± 0.92a	4.63 ± 1.27d
Helanshiwu	Chlorogenic acid	570.90 ± 9.90a	382.53 ± 20.42c	487.30 ± 28.10b	225.00 ± 19.95e	397.5 ± 41.48c	206.25 ± 32.40e	307.50 ± 16.88d	195.80 ± 15.70e
	Caffeic acid	29.41 ± 5.60a	26.78 ± 0.90b	35.33 ± 5.83a	17.26 ± 1.50c	16.68 ± 2.50c	10.27 ± 3.49d	15.73 ± 2.75c	15.30 ± 2.39c
	p-Coumaric acid	16.00 ± 1.90a	11.37 ± 4.58b	6.72 ± 4.00cd	5.84 ± 0.49d	6.69 ± 2.19cd	7.17 ± 1.88cd	6.38 ± 2.16cd	8.69 ± 1.65bc
	Ferulic acid	11.57 ± 2.74abc	9.57 ± 3.02bc	15.29 ± 3.88ab	12.20 ± 1.56ab	16.30 ± 1.80a	14.03 ± 2.47a	7.93 ± 2.92bc	6.60 ± 3.27c
Zhongshubahao	Chlorogenic acid	691.30 ± 24.15a	421.72 ± 15.60c	502.90 ± 23.56b	180.70 ± 35.40e	556.70 ± 9.98a	295.20 ± 22.17d	259.16 ± 42.10de	224.50 ± 30.45e
	Caffeic acid	33.70 ± 4.30ab	22.93 ± 2.00c	40.25 ± 5.92a	13.08 ± 1.58d	32.45 ± 3.50b	10.55 ± 1.50e	7.86 ± 1.75e	9.34 ± 0.99e
	p-Coumaric acid	15.09 ± 2.66b	17.29 ± 4.58ab	23.70 ± 4.57a	9.80 ± 0.75c	16.59 ± 2.26b	14.89 ± 1.94b	8.10 ± 2.35c	19.80 ± 2.50ab
	Ferulic acid	10.62 ± 3.58bc	12.49 ± 3.02b	8.40 ± 0.99c	3.37 ± 0.60d	18.40 ± 2.85a	20.13 ± 3.53a	10.79 ± 1.92b	12.59 ± 3.27b

(Note: a-e in each row indicate significantly different at $p < 0.05$).

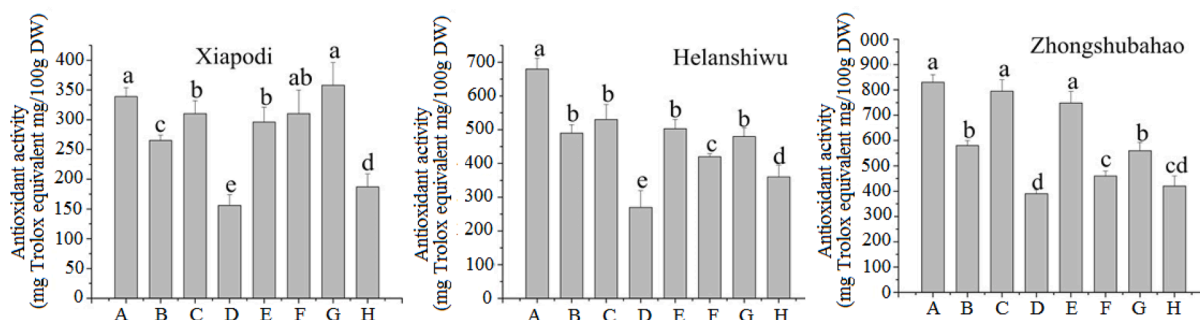


Fig. 3. DPPH radical-scavenging activity of potatoes after cooking (A, B, C, D, E, F, G, H indicate the cooking methods of raw, boiled, steamed, baked, microwaved, fried, air-fried and stir-fried).

decreased to 56 ± 18 , 270 ± 49 and 390 ± 15 mg Trolox equivalent/100 g DW in Xiapodi, Helanshiwu and Zhongshubahao, respectively. In another study, researchers compared the antioxidant activities of purple majesty potato after different cooking and reported that boiling could preserve the antioxidant activity mostly while roasting had the most detrimental effect (Lemos et al., 2015). In present study, we found that the contents of vitamin C and phytochemicals in potato decreased during different cooking methods and resulting in different antioxidant properties. The antioxidant activities in plant food were closely associated with the content of vitamin C, phytochemicals (total phenolic, Chlorogenic acids, carotenoids, etc.) or others (Eberhardt, Lee, & Liu., 2004) and during cooking, heating would promote some chemical reactions, such as degradation of polyphenols, lard reaction, hydrolysis of esters and glycosides, etc., and those reactions would destroy the natural antioxidants or generate some new antioxidants (Kita et al., 2013). Thus, different antioxidant activities in cooked potatoes were observed.

Conclusion

Seven domestic cooking methods (boiling, steaming, roasting, microwaving, frying, air-frying and stir-frying) were applied to cook the potato from three varieties, and results indicated that the highest total phenolic content and total carotenoids was observed in Zhongshubahao, followed by Helanshiwu and Xiapodi, respectively. And this might explain why Zhongshubahao showed a higher phytochemicals content or antioxidant activity than Helanshiwu and Xiapodi, regardless of the cooking methods. It was also found that all the cooked potatoes (Xiapodi, Helanshiwu and Zhongshubahao) showed a lower content of vitamin C, total phenolic, phenolic acids, and antioxidant activities than that of the raw samples. However, the contents of phytochemicals and antioxidant activities were depended on the cooking methods, as frying, air-drying and roasting showed a more intensive decrease of phytochemicals and antioxidant activities than that of the steaming or microwaving. In conclusion, steaming and microwaving could be optional cooking methods and Zhongshubahao be the optional variety from the perspective of remaining more phytochemicals and antioxidants.

Conflict of interest

The authors declare that they have no conflicts of interest.

CRedit authorship contribution statement

Haitian Fang: Methodology. **Xiuxiu Yin:** Formal analysis. **Jiequn He:** Investigation. **Shihua Xin:** Data curation. **Huiling Zhang:** Investigation. **Xingqian Ye:** Supervision. **Yunyun Yang:** Writing – review & editing. **Jinhu Tian:** Funding acquisition, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.fochx.2022.100339>.

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