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Effect of three cooking methods on nutrient components and antioxidant capacities of bamboo shoot (*Phyllostachys praecox* C.D. Chu et C.S. Chao)*

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Abstract: Three cooking methods, namely boiling, steaming, and stir-frying for 5 to 10 min, were used to evaluate the effect on nutrient components, free amino acids, L-ascorbic acid, total phenolic contents, and antioxidant capacities of bamboo shoots (*Phyllostachys praecox*). Results showed that boiling and stir-frying had a great effect on the nutrient components and they decreased the contents of protein, soluble sugar, and ash, and caused a great loss in the total free amino acids (decreased by 38.35% and 34.86%, respectively). Significant differences ($P<0.05$) in free amino acids were observed in the samples cooked by different methods. Stir-fried bamboo shoots had a high fat content which increased by 528.57% because of the addition of edible oil. After boiling, the L-ascorbic acid and total phenolic contents were significantly reduced, while steaming increased total phenolic content by 3.98% and stir-frying well-preserved L-ascorbic acid (78.87% of its previous content). Results of the antioxidative property study showed that stir-frying could increase antioxidant capacities of bamboo shoots. It is concluded that stir-frying is more suitable for bamboo shoots because it could obtain the maximum retention of antioxidant capacities.

Key words: Cooking methods, Bamboo shoot, Nutrition, Antioxidant capacities
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1 Introduction

Bamboo shoots are the young tender stalks emerging from nodes of the (pseudo-)rhizome of bamboo plants. The edible part consists of meristematic cell tissue with regions of rapid cell division and differentiation, which is enveloped in protective, non-edible leaf sheaths (Kleinhenz *et al*., 2000). Bamboo shoots are rich in both amino acids and antioxidants and taste fresh, crisp with aromatic quality, and are delicious. Therefore, they are usually called "the top grade vegetable" (Xu *et al*., 2003; Zhang *et al*., 2008). The shoot of *Phyllostachys praecox* is a higher quality bamboo shoot among dozens of edible ones (Xu *et al*., 2003) in China, and is widely distributed in various parts of the world.

It is known to all that China has an extensive and profound food culture with many cooking methods, such as boiling, steaming, stir-frying, roasting, decocting, and deep-frying. These cooking treatments can not only increase the palatability but can also make the food more conducive to digestion and absorption (Kong *et al*., 2007; Cho *et al*., 2008). Many research reports and cooking practices have shown that different cooking methods have varying degrees of influence on food nutritional contents and functional ingredients (Dzudie *et al*., 2000; Moynihan *et al*., 2000). The bamboo shoots are available for consumption only after cooking. Because of heat

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treatments on the changes of protein, carbohydrates, free amino acids, L-ascorbic acid, flavonoids, phenolic acids, and other nutritional and functional components (Dzudie *et al*., 2000; Kong *et al*., 2007), the real nutritional value of cooked bamboo shoots is not equal to that of the fresh ones. However, the studies on the nutritive composition of bamboo shoots were mainly limited in their fresh or dried raw materials (Luo *et al*., 2008a; 2008b; Li *et al*., 2010). Until now, no studies exist on the cooked bamboo shoots.

The bamboo shoot (*Phyllostachys praecox*) was used as the material in this paper to elucidate the nutrients and antioxidant functional composition changes and the antioxidant capacity changes after three cooking methods, namely boiling, steaming, and stir-frying. This research could provide theoretical guidance for a modern healthy diet.

2 Materials and methods

2.1 Bamboo shoot materials

The bamboo shoots (*Phyllostachys praecox* C.D. Chu et C.S. Chao, cv. Ventricousinternode) were purchased from the market in the year of 2010 in Hangzhou, Zhejiang Province, China and stored at 4 °C.

2.2 Sample treatments

The fresh bamboo shoots were cooked in the same way as when prepared for consumption. In brief, fresh bamboo shoots were firstly peeled and washed clean and then cut vertically into slices with about 2–3 mm thickness. The bamboo shoot slices were collected and weighed (~300 g). The first portion was used raw while the other three portions were subjected to steaming, boiling, or stir-frying as below. Each sample was cooked by the same chef to ensure its stable quality.

2.2.1 Boiling treatment

Bamboo shoot slices were placed into a pot filled with 1000 ml boiling water and then boiled for 10 min with a pot cover to prevent water loss. They were scooped up and cooled to room temperature.

2.2.2 Steaming treatment

Bamboo shoot slices were placed in the centre of the top steamer with 1000 ml boiling water at the bottom. After steaming for 10 min, they were scooped up and cooled to room temperature.

2.2.3 Stir-frying treatment

A small amount (20 g) of peanut oil was placed in a pan, and then bamboo shoot slices were put into it and stir-fried for 5 min. They were scooped up and cooled to room temperature.

Each 300 g of cooked bamboo shoot samples were divided into three groups: the first 100 g samples were used for the nutrient component detection; the second 100 g were used for free amino acid detection; the remaining samples were frozen quickly in liquid nitrogen, then freeze-dried in vacuum freeze-drying equipment (Taitec VD-400F, Japan), and crushed immediately after drying. The powder was stored at −80 °C for antioxidative property test.

2.3 Nutrient component analysis

The moisture contents were measured by the difference of the sample weight after drying at 105 °C for 20 h. Ash, fat, soluble sugar, starch, and crude fibre contents were determined using the standard method of the Association of Official Analytical Chemists (AOAC, 1990). The protein content was determined by the semi-micro Kjeldahl method (ISO 5983-1-2005).

2.4 Free amino acid analysis

The free amino acids were extracted from bamboo shoot samples using the method mentioned by Antoine *et al*. (1999). The amino acids' compositions were analyzed according to Norziah and Ching (2000), using the Waters Associates AccQ·Tag method (pre-column derivatization of samples with AccQ·Fluor reagent and analysis by reverse phase high-performance liquid chromatography (HPLC)). Identification of the amino acids in the sample was carried out by comparing their retention time with that of the standards.

2.5 L-ascorbic acid analysis

L-ascorbic acid was immediately analyzed on the same day of sample preparation. A total of 10 g fresh or cooked bamboo shoot slices were homogenized with 30 ml of 1 mg/ml oxalic acid and centrifuged at 4000 r/min for 5 min. The aquatic supernatant was collected, and the residue was again extracted with

10 ml of 1 mg/ml oxalic acid. The aquatic supernatants were combined and the volume was made up to 50 ml with 1 mg/ml oxalic acid, and then filtered through a 0.45-μm Advantec filter for HPLC analysis, according to Xu *et al.* (2008). The L-ascorbic acid contents were calculated according to standard solution (80 mg/L).

2.6 Antioxidative properties of bamboo shoots

Aqueous extracts of bamboo shoot samples (3.0 g powder samples) were prepared by homogenizing bamboo shoot powder in 30 ml of distilled water and filtered. The filtrates were made to 30 ml with distilled water. These extracts were used for determining total phenolic content, total antioxidant activity, and other in vitro antioxidant activities.

2.6.1 Total phenolic content

Total phenolics were determined according to the method mentioned by Prabhasankar *et al.* (2009). In a test tube, 0.2 ml of the aqueous extract was mixed with 4.0 ml of 0.02 g/ml Na_2CO_3 and then 0.2 ml of 0.5 g/ml Folin Ciocalteau's phenol reagent was added. The reaction mixture was mixed thoroughly and allowed to stand for 30 min at room temperature in the dark. After incubation, the solution was measured at 720 nm against a blank. Results were expressed as mg gallic acid equivalents per 100 g dry weight (mg GAE/100 g DW).

2.6.2 Total antioxidant activity

The total antioxidant capacities of the bamboo shoot extracts were measured with the method mentioned by Abdel-Hameed (2009). Based on the reduction of Mo(VI) to Mo(V) by the extract and subsequent formation of a green phosphate/Mo(V) complex at acid pH, 0.2 ml of sample was mixed with 0.1 ml distilled water and 3.0 ml reagent solution (0.6 mol/L sulphuric acid, 28 mmol/L sodium phosphate, and 4.0 mmol/L ammonium molybdate). A typical blank solution contained 3 ml of reagent solution and the appropriate volume of the same solvent used for the sample. All tubes were incubated at 95 °C for 90 min under water bath. After incubation, absorbance values of all the sample mixtures were measured at 695 nm against the blank using an ultraviolet-visible (UV-Vis) spectrophotometer. Total antioxidant activity is expressed as mg ascorbic acid equivalents per gram dry weight (mg AAE/g DW).

2.6.3 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging activity

The DPPH radical-scavenging activity was measured with the method mentioned by Prabhasankar *et al*. (2009). Briefly, 0.2 ml of the aqueous extract was mixed with 1.8 ml distilled water and 2.0 ml of 0.16 mmol/L DPPH solution (in methanol). The mixture was vortexed for 1 min and kept at room temperature for 30 min in the dark. The absorbance of the solution was measured at 517 nm. The scavenging effect (%) was calculated by using the formulae mentioned by Xu *et al*. (2007).

2.6.4 Superoxide radical-scavenging activity

Antioxidant capacity of the aqueous extract of bamboo shoot samples against superoxide radicals was determined by the method of Prabhasankar *et al.* (2009). Briefly, in a test tube, 0.2 ml of the aqueous extract was mixed with 0.1 ml distilled water, 2.6 ml of 50 mmol/L phosphate buffer (pH 8.2), and 0.09 ml freshly prepared pyrogallol (3 mmol/L dissolved in 10 mmol/L HCl). The mixture was vortexed for 0.2 min. The inhibition rate of pyrogallol autooxidation was measured at 325 nm at every 1 min interval for 10 min. The scavenging activity (%) was calculated using the formula mentioned by Xu *et al.* (2007).

2.7 Statistical analysis

Data were analyzed by Duncan's multiple range tests using statistical package Statistica V 5.5 software. A significant level was defined as $P<0.05$. Determinations were carried out in triplicate.

3 Results and discussion

3.1 Effects of cooking methods on nutrient components

Table 1 clearly indicates that the basic nutrient components of bamboo shoots had been influenced in different degrees by boiling, steaming, and stir-frying. After boiling, the crude protein, crude fat, soluble sugar, and ash had all been significantly influenced ($P<0.05$) and their loss ratios were 7.38%, 23.81%, 14.39%, and 7.71%, respectively. The losses of starch, crude fiber, and water were not obvious. These

Table 1 Nutrient contents of different cooked bamboo shoots

Macronutrient	Raw	Boiling		Steaming		Stir-frying	
	Content (g/100 g FW)	Content (g/100 g FW)	Loss (%)	Content (g/100 g FW)	Loss (%)	Content (g/100 g FW)	Loss (%)
Water	91.25±0.01a	91.76±0.12a	−0.56±0.13	91.65±0.09a	−0.44±0.09	90.31±0.25b	1.03±0.25
Crude protein	3.25±0.02a	3.01±0.04b	7.38±1.12	3.21±0.02a	1.23±0.61	3.20±0.05a	1.54±0.97
Crude fat	0.21±0.01b	0.16±0.01c	23.81±4.77	0.20±0.01b	4.76±3.75	1.32±0.05a	−528.57±23.81
Soluble sugar	1.32±0.02a	1.13±0.02b	14.39±1.52	1.31±0.02a	0.76±1.26	1.09±0.03b	17.42±2.27
Starch	1.75±0.02a	1.72±0.03a	1.71±0.07	1.75±0.01a	0.00±0.07	1.74±0.02a	0.57±0.36
Crude fiber	1.37±0.01a	1.38±0.02a	−0.73±1.46	1.37±0.01a	0.00±0.09	1.37±0.01a	0.00±0.00
Ash	0.85±0.01a	0.81±0.01b	4.71±1.18	0.85±0.01a	0.00±0.00	0.84±0.01a	1.18±0.95

Data presented as arithmetic mean±SD (n=3). Mean values with different letters in the same row are significantly different (P<0.05). FW: fresh weight

changes occurred because of the diffluent and volatile substances in bamboo shoots lost to the soup. After steaming, the losses of crude protein and crude fat were 1.23% and 4.76%, respectively, with tiny changes of other nutrient components. After stir-frying, the content of soluble sugar was significantly decreased by 17.42% (P<0.05). The addition of peanut oil during the treatment caused a crude fat increase of 528.57% and the energy increase of 34.4%.

After three conventional cooking treatments, the crude protein content all had decreased, as well as the crude fat content in boiling and steaming samples. These phenomena were related to the protein denaturation and fat oxidation at high temperature (Wei *et al*., 2009). In addition, during the high temperature process of stir-frying, both protein and its decomposition products and soluble sugar participated in Maillard reaction, then resulted in their content decline.

3.2 Effects of cooking methods on free amino acids

In fresh bamboo shoots, we detected out 12 free amino acids altogether, included 6 unessential amino acids (UAA, namely, Asp, Glu, Gly, Ala, Tyr, and His) and 6 essential amino acids (EAA, namely, Val, Met, Ile, Leu, Phe, and Lys). The total free amino acid (TFAA) content was 550.92 mg/100 g fresh weight (FW) and total free essential amino acid (TFEAA) content was 163.77 mg/100 g FW, which demonstrated that bamboo shoots belonged to the vegetables with high free amino acid content.

As important flavor substances, the free amino acids in cooked samples showed a variety of different types of free amino acids in the boiled, steamed, and stir-fried samples when compared to those in fresh bamboo shoots (Table 2). Moreover, their contents also had various degrees of difference after cooking treatments. The boiled bamboo shoots' free amino acids decreased substantially (P<0.05) with TFEAA by 38.85% and TFAA by 38.35%. This is possible due to the loss of free amino acids to the fluid which the samples were boiled in. TFEAA and TFAA contents in steamed bamboo shoots had no significant changes, but the contents of Glu, Gly, Tyr, and Ile increased substantially (P<0.05) by 23.18%, 128.40%, 7.07%, and 3.92%, respectively. In stir-fried bamboo shoots, most free amino acid contents reduced dramatically (P<0.05) with TFEAA by 39.20% and TFAA by 34.86%; however, Gly content increased by 5.64%.

Under the heat treatments, some proteins and short peptides may have degraded into free amino acids (Cho *et al*., 2008), then reacted with reducing sugar at high temperature and produced not only specific food flavors but also colored substances. On the other hand, after cooking, some free amino acids were run off along with bamboo shoots' juice.

3.3 Effects of cooking methods on L-ascorbic acid

Processing methods utilizing heat can irreversibly inactivate ascorbate oxidase, thus counteracting enzymatic decomposition; however, reduction of L-ascorbic acid may also occur as a function of thermal decomposition and leach into the cooking medium (Davey *et al*., 2000). In fresh bamboo shoots, the content of L-ascorbic acid was 12 mg/100 g FW. After three conventional cooking treatments, L-ascorbic acid content in bamboo shoots all dropped apparently (Fig. 1). The retention was 47.37% in boiled bamboo shoots and 57.83% in steamed ones,

Table 2 Effects of cooking methods on the contents of free amino acids in bamboo shoots

Amino acid	Raw	Boiling		Steaming		Stir-frying	
	Content (mg/100 g FW)	Content (mg/100 g FW)	Loss (%)	Content (mg/100 g FW)	Loss (%)	Content (mg/100 g FW)	Loss (%)
Asp	32.17±2.11a	19.82±2.07c	38.39±2.51	27.61±1.27b	14.17±0.74	20.87±2.58c	35.13±4.21
Ser	ND	1.75±0.07b	−	2.31±0.21a	−	2.06±0.43a	−
Glu	15.62±0.61b	11.06±0.92c	29.19±3.11	19.24±1.04a	−23.18±1.11	12.53±0.41c	19.78±1.12
Pro	ND	ND	−	ND	−	ND	−
Gly	5.14±0.21b	3.92±0.13c	23.74±2.01	11.74±0.51a	−128.40±9.08	5.43±0.21b	−5.64±0.31
Ala	55.03±3.17a	21.94±1.05c	60.11±4.07	45.86±3.25b	16.62±1.05	22.01±1.07c	59.98±5.07
Cys	ND	ND	−	0.12±0.07a	−	0.17±0.03a	−
Tyr	163.87±11.97a	102.78±8.32bc	37.28±2.95	175.45±10.42a	−7.07±0.93	121.2±6.72b	26.04±1.92
His	115.35±10.61a	78.21±5.62c	32.19±2.76	107.58±10.65ab	6.74±0.61	75.16±5.63c	34.84±4.66
Arg	ND	ND	−	ND	−	0.11±0.02	−
Val*	39.62±2.51a	21.37±1.61bc	46.06±3.55	38.17±2.31a	3.66±0.50	25.91±1.47b	34.60±3.53
Met*	10.56±1.51a	7.29±0.57bc	30.97±2.52	9.76±0.65a	7.58±0.31	6.51±0.52c	38.35±4.51
lle*	25.28±0.91a	20.12±0.93b	20.41±1.98	26.27±2.95a	−3.92±0.33	17.73±0.91c	29.86±1.93
Leu*	32.71±2.93a	19.25±0.83b	41.14±3.91	31.81±2.95a	2.75±0.91	17.16±1.75b	47.54±3.92
Phe*	30.30±1.25a	13.19±0.51d	56.46±4.22	28.75±1.23ab	5.12±0.21	16.51±1.32c	45.51±3.27
Lys*	25.30±1.21a	16.21±0.82c	35.92±2.25	22.87±1.17b	9.60±0.61	14.61±1.28d	42.25±3.21
Thr*	ND	2.71±0.21a	−	2.25±0.21b	−	1.13±0.21c	−
TFEAA	163.77±11.27a	100.14±9.21b	38.85±3.55	159.88±12.22a	2.37±0.21	99.56±7.61b	39.20±3.28
TFAA	550.92±0.61a	339.62±27.25b	38.35±2.62	549.67±22.21a	0.23±0.01	358.82±37.21b	34.86±3.73

Data presented as arithmetic mean±SD (n=3). Mean values with different letters in the same row were significantly different (P<0.05). * Essential free amino acid. TFEAA: total free essential amino acids; TFAA: total free amino acids; ND: not detected

Fig. 1 L-ascorbic acid contents of fresh and cooked bamboo shoots

which could be attributed to the fact that L-ascorbic acid is very soluble in water and not stable at high temperature. However, the short time stir-frying retained the maximum content of L-ascorbic acid at 78.87%, much more than the other two. This result was consistent with the observation of Somsub *et al.* (2008) who also found that conventional cooking methods (blanching, boiling, or stir-frying) led to excessive loss of L-ascorbic acid in most Thai vegetables.

3.4 Effects of cooking methods on total phenolic content and total antioxidant activity

Phenolic compounds are commonly found in plants and have been reported to possess biological activity similar to antioxidants (Udayakumar *et al.*, 2010). Aqueous extracts of uncooked and cooked bamboo shoots exhibited high phenolic content (Fig. 2a).

Total phenolic contents in both boiled and stir-fried samples decreased slightly while steaming made phenolic content increase. On the one hand, heat treatment had a decomposition effect on phenolic compounds (Ranilla *et al.*, 2010), which also may have been lost to the solution, in which the bamboo shoots were boiled; on the other hand, heat treatment could make the existed polyphenol oxidases inactive so that prevented polyphenols' decomposition (Yamaguchi *et al.*, 2003), and heat treatment could promote dietary fiber-binding type polyphenols decomposition into free phenolic compounds and then made the detected value much higher (Stewart *et al.*, 2000).

In contrast with fresh bamboo shoots, the antioxidant capacity of boiled samples reduced apparently, steamed ones remained unchanged, and stir-fried ones increased slightly (Fig. 2b).

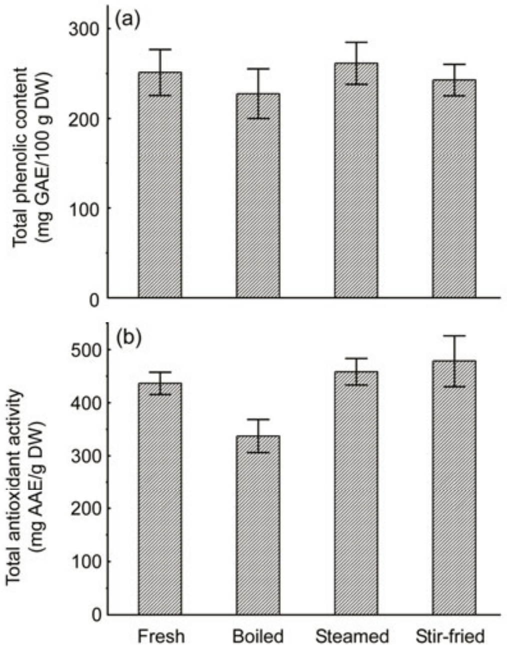

Fig.2 Total phenolic contents (a) and total antioxidant activities (b) of fresh and cooked bamboo shoots

The antioxidant capacity of bamboo shoot was closely related to L-ascorbic acid and total phenolic compounds. After boiling, a lot of the antioxidant substances were running off into the boiling medium, which then led to the decrease of their antioxidant capacities. This result was similar to the research of Chuah *et al.* (2008) who indicated that almost all of the antioxidant substances in colored peppers run off and dissolve in the water during boiling process. Kenny and O′Beirne (2009) indicated that the loss of antioxidant activity was relative to the contact area between vegetables and water as well as processing time. It was clear that the contact areas in steaming and stir-frying processes were much smaller than that in boiling, so their antioxidant substances lost relatively very little. The higher content of total phenolic compounds, the stronger antioxidant activity (Baardseth *et al.*, 2010). During steaming, the increase of total phenolic compounds made up for the loss of L-ascorbic acid, so that their antioxidant capacities corresponded to the fresh ones. However, in short time and high temperature stir-frying, both L-ascorbic acid and total phenolic contents in bamboo shoots decreased but the antioxidant capacity increased. This might be due to the Maillard reaction. Since the surface temperature of stir-fried bamboo shoots could reach 150 °C, the soluble sugar decreased by 17.42%, the TFEAA decreased by 39.2% and strong aromatic flavors were generated, it is reasonable to assume that the Maillard reaction occurred, which could promote the generation of antioxidant substances and increase their antioxidant capacities (Nicoli *et al.*, 1997).

3.5 Effects of cooking methods on in vitro antioxidative properties

DPPH has been used extensively as a free radical to evaluate reducing substances and is a useful reagent for investigating in vitro free radical-scavenging activities of compounds. As shown in Fig. 3a, all the four bamboo shoot samples exhibited appreciable scavenging properties against DPPH radicals. It was evident that the stir-fried bamboo shoots were proven to be the most powerful antioxidant, as their radical-scavenging activities were significantly different from those of any other kinds of cooked bamboo shoots. However, the boiled samples

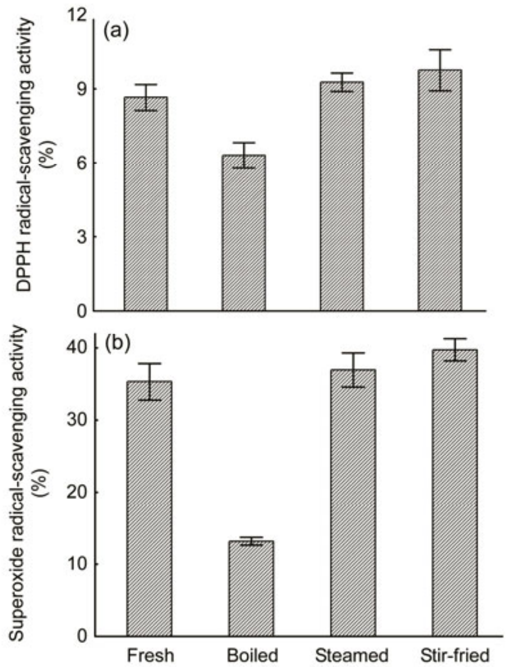

Fig. 3 In vitro antioxidant activities of fresh and cooked bamboo shoots

(a) DPPH radical-scavenging activity; (b) Superoxide radical-scavenging activity exhibited the lowest radical-scavenging activity and this could be attributed to the heat-degraded compounds from carbohydrates having leached into the cooking medium.

Sawa *et al*. (1999) suggested that studies on vegetables concerning superoxide anion-scavenging activity were of increasing interest due to the harmful effect of the superoxide. The superoxide-scavenging activity of fresh bamboo shoots was 35.31%, which decreased dramatically to 13.17% after boiling for 10 min. Steamed and stir-fried bamboo shoots exhibited higher superoxide-scavenging activity as compared to fresh ones (Fig. 3b). In general, the difference of these three cooked bamboo shoots' antioxidant activities could be attributed to reaction products with radical-scavenging activities generated by different cooking methods (Sawa *et al*., 1999).

4 Conclusions

After three conventional cooking treatments, the boiled bamboo shoots had serious losses of crude protein, soluble sugars, ash, free amino acids, and L-ascorbic acid, meanwhile their antioxidant capacities also decreased significantly ($P<0.05$); in steamed bamboo shoots, the basic nutrient components, TFAA, and antioxidant capacity changed very little, and however, each free amino acid had changed to various extents and the L-ascorbic acid content was considerably reduced with a loss percentage of 42.17%; during stir-frying, the addition of peanut oil increased the crude fat content, while both the soluble sugar and TFAA contents decreased dramatically ($P<0.05$). High temperature and short time stir-frying promoted the occurrence of the Maillard reaction and then generated specific flavor and antioxidant substances. At the same time, L-ascorbic acid was preserved at maximum extent with just 21.13% loss. In conclusion, from the perspective of nutrition and health, stir-frying is the best cooking method to use when cooking bamboo shoots.

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