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Effects of different cooking methods on health-promoting compounds of broccoli*

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Abstract: The effects of five domestic cooking methods, including steaming, microwaving, boiling, stir-frying, and stir-frying followed by boiling (stir-frying/boiling), on the nutrients and health-promoting compounds of broccoli were investigated. The results show that all cooking treatments, except steaming, caused significant losses of chlorophyll and vitamin C and significant decreases of total soluble proteins and soluble sugars. Total aliphatic and indole glucosinolates were significantly modified by all cooking treatments but not by steaming. In general, the steaming led to the lowest loss of total glucosinolates, while stir-frying and stir-frying/boiling presented the highest loss. Stir-frying and stir-frying/boiling, the two most popular methods for most homemade dishes in China, cause great losses of chlorophyll, soluble protein, soluble sugar, vitamin C, and glucosinolates, but the steaming method appears the best in retention of the nutrients in cooking broccoli.

Key words: Broccoli, Cooking, Glucosinolates, Vitamin C, Chlorophyll, Soluble sugar
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INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica*) contains high levels of vitamins, antioxidants, and anticarcinogenic compounds and has been described as a vegetable with high nutritional value. Glucosinolates, a diverse class of sulfur- and nitrogen-containing secondary metabolites, are found in *Brassica* vegetables including broccoli. These compounds have gained renewed interest in recent years due to the chemoprotective properties of their major hydrolysis products, isothiocyanates. Glucosinolates are chemically stable until they come in contact with the degradation enzyme myrosinase (β-thioglucoside glucohydrolase, EC 3.2.1.147), which is stored in different compartments of the plant cells to separate from glucosinolates. When plant tissues are damaged, myrosinase rapidly hydrolyzes the glucosinolates to glucose and other unstable intermediates, which spontaneously rearrange to a variety of biologically active products, including isothiocyanates, thiocyanates, epithionitriles, or nitriles depending on chemical conditions (Jia *et al*., 2009). The hydrolysis products vary depending largely upon the level and activity of myrosinase, presence of specifier protein, e.g., epithiospecifier protein, and hydrolysis conditions, e.g., pH, metal ions and temperature, and these can be influenced by species, cultivar, and cooking time and conditions (Verkerk *et al*., 2008). Epidemiological studies and experimental researches with cell and animal models have shown that isothiocyanates have the health-promoting effects, e.g., cancer protection (Traka and Mithen, 2009).

Most vegetables are commonly cooked before being consumed. In general, vegetables are prepared at home on the basis of convenience and taste

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preference rather than retention of nutrient and health-promoting compounds (Masrizal *et al*., 1997). It is known that cooking induces significant changes in chemical composition, affecting the bioavailability and content of chemopreventive compounds in vegetables. Cooking methods were shown to affect the contents of nutrient and health-promoting compounds such as vitamin C, carotenoids, polyphenols, and glucosinolates in broccoli (Cieslik *et al*., 2007; Lin and Chang, 2005; Sikora *et al*., 2008; Vallejo *et al*., 2002). The cooking procedures such as boiling and microwaving used in these studies were based on the dietary habit in western society. In contrast, stir-frying and stir-frying followed by boiling (stir-frying/boiling) are used to prepare most home-made dishes in China (Liu and Li, 2000). Data on the effects of stir-frying and stir-frying/boiling on nutritional properties of broccoli are still limited. A more integrated analysis of nutritional change of broccoli is needed to obtain insight into the effects of Chinese traditional cooking methods, stir-frying and stir-frying/boiling, as well as boiling, microwaving, and steaming. The purpose of this study is to investigate the effects of five different cooking procedures on the nutrients (vitamin C, soluble protein and sugar) and phytochemical compounds (carotenoids and glucosinolates) in broccoli.

MATERIALS AND METHODS

Plant materials

Broccoli heads (*Brassica oleracea* var. *italica* cv. Youxiu) of prime quality were harvested in the early morning, immediately top-iced, and transported to the laboratory within 10 min. Broccoli heads were cleaned by removing the inedible parts and then chopped into homogeneous pieces.

Processing treatments

In boiling method, 200 g of homogeneous pieces of broccoli were immersed in 400 ml of boiling water, which instantly made boiling. The broccoli was drained off after being boiled for 5 min. Steaming was conducted by suspending 200 g of cut broccoli above 200 ml of boiling water for 5 min in a steamer with a lid. A microwave oven (LG Electronics, Tianjin Appliances Co., Ltd., Tianjin, China) at full power (1000 W) for 5 min was used for microwaving. 200 g of broccoli were placed in a plate and 10 ml water was added to prevent broccoli from being burned during cooking. The broccoli in the plate was placed in the microwave oven for 5-min cooking, and then drained off. For stir-frying, the soybean oil (10 ml) was preheated to 140 °C in a wok and broccoli (200 g) was placed in and stir-fried for 5 min. At the end of each trial, samples were drained off and dabbed with blotting paper to allow for the absorption of exceeding oil. For stir-frying/boiling, the soybean oil (10 ml) was preheated to 140 °C in a wok and broccoli (200 g) was placed in and stir-fried for 2 min. Then tap water (50 ml) was added, and they were further cooked in the closed wok for 3 min and then drained in the same way as for the stir-fried broccoli.

Each process was conducted three times in a randomized way for all the five cooking methods. Fresh and cooked broccoli was taken immediately for vitamin C analysis. The rest of the broccoli materials were frozen by liquid N_2 and kept in polyethylene bags at −70 °C. Parts of frozen samples were freeze-dried for glucosinolate assay.

Chlorophyll determination

Broccoli (0.5 g) was grinded and extracted in 10 ml of 80% (v/v) acetone. The extract was centrifuged at 1500×*g* for 10 min at room temperature and the residue was removed. Total chlorophyll content was determined by recording the absorbance at 652 nm with a spectrophotometer. Total chlorophyll content was estimated by mg/g fresh weight (FW).

Total soluble protein determination

Frozen samples (0.5 g) were grinded, homogenized in 5 ml of 50 mmol/L phosphate-buffered saline (PBS) buffer (pH 7.8), and then centrifuged at 12 000×*g* for 20 min at 4 °C. The soluble protein content in the supernatant was determined according to the method of Bradford (1976), using bovine serum albumin as standard. Results are expressed as mg soluble protein/g FW.

Total soluble sugar determination

Frozen samples (2.0 g) were grinded and extracted with 6 ml of boiling 80% (v/v) ethanol for 30 min, followed by centrifugation at 10 000×*g* at 4 °C for 10 min. The process was repeated for complete extraction. Total soluble sugar content was determined using anthrone reagent and glucose as standard

(Roe, 1955). Results are expressed as mg soluble sugar/g FW.

Total carotenoid determination

5 g of florets were grinded and extracted with a mixture of acetone and petroleum ether (1:1, v/v) repeatedly using the mortar and pestle until a colorless residue was obtained. The upper phase was collected and combined with crude extracts after washed for several times with water. The extracts were made up to a known volume with petroleum ether. Total carotenoid content was determined by recording the absorbance at 451 nm with a spectrophotometer. Total carotenoid was estimated by mg/100 g FW.

Vitamin C determination

Vitamin C content was determined according to the Association of Official Analytical Chemists (AOAC) Official Method 985.33 (2,6-dichloroindophenol titrimetric method) (AOAC, 1990). Vitamin C content is expressed as mg/100 g FW.

Glucosinolate assay

Glucosinolates were extracted and converted to desulphoglucosinolate, as described by our early report (Jia *et al*., 2009). High performance liquid chromatography (HPLC) analysis of desulphoglucosinolate was conducted using a Shimadzu-mode VP liquid chromatograph with a dual wavelength spectrophotometer, as previously reported (Jia *et al*., 2009). Otho-nitrophenyl-β-D-galatopyranoside (Sigma, USA) was used as an internal standard for HPLC analysis. Contents of individual glucosinolates were calculated according to published response factors (Haughn *et al*., 1991). The integrated area of the desulphoglucosinolates peak was converted to a molar amount by assuming that this compound has a molar extinction coefficient at 226 nm equal to that of sinigrin.

Statistical analysis

Statistical analysis was performed using the SPSS package program version 11.5 (SPSS Inc., Chicago, IL, USA). Data were analyzed by one-way analysis of variance (ANOVA), followed by Duncan's multiple range post-hoc test. Results are expressed as mean±*SD* of triplicate samples. Differences were considered significant at $P<0.05$.

RESULTS

Effect of cooking on chlorophyll

Chlorophyll content of broccoli untreated and broccoli cooked under different conditions is presented in Fig.1. The chlorophyll content in boiled, stir-fried/boiled, stir-fried, and microwaved broccoli was reduced by 27%, 23%, 18%, and 16%, respectively ($P<0.05$), while it was almost unchanged in steamed broccoli.

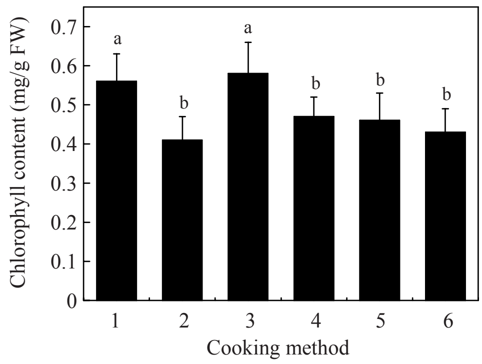

Fig.1 The chlorophyll content in broccoli cooked by different methods
Each value is mean±*SD* of three replicate samples. Values not sharing a common letter are significantly different at $P<0.05$. Cooking methods: 1. Raw; 2. Boiled; 3. Streamed; 4. Microwaved; 5. Stir-fried; 6. Stir-fried/boiled

Effect of cooking on total soluble proteins and soluble sugars

The total soluble proteins and soluble sugars were significantly affected by all cooking treatments ($P<0.05$) (Fig.2). The highest contents of total soluble proteins and soluble sugars (2.6 m/g FW and 3.5 mg/g FW, respectively) in broccoli were obtained after steaming. The lowest retention of total soluble proteins was observed in broccoli after boiling and stir-frying/boiling, while the lowest retention of total soluble sugars was found in broccoli after stir-frying/boiling and stir-frying (Fig.2).

Effect of cooking on vitamin C and total carotenoids

All cooking treatments, except steaming, caused a dramatic loss of vitamin C ($P<0.05$). The greatest loss of vitamin C was observed in broccoli after stir-frying/boiling and boiling (38% and 33%, respectively) treatments, followed by microwaving and stir-frying (16% and 24%, respectively) treatments. In contrast, steaming did not cause any significant loss of vitamin C, compared with the raw sample (Fig.3).

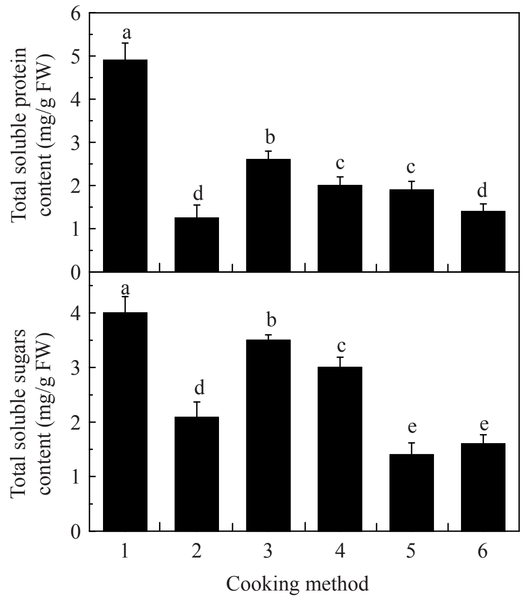

Fig.2 The contents of total soluble proteins and soluble sugars in broccoli cooked by different methods
Each value is mean±*SD* of three replicate samples. Values not sharing a common letter are significantly different at $P<0.05$. Cooking methods: 1. Raw; 2. Boiled; 3. Streamed; 4. Microwaved; 5. Stir-fried; 6. Stir-fried/boiled

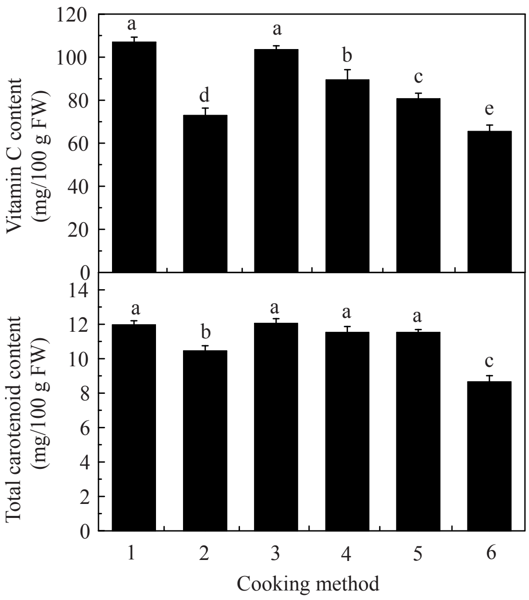

Fig.3 The contents of vitamin C and total carotenoids in broccoli cooked by different methods
Each value is mean±*SD* of three replicate samples. Values not sharing a common letter are significantly different at $P<0.05$. Cooking methods: 1. Raw; 2. Boiled; 3. Streamed; 4. Microwaved; 5. Stir-fried; 6. Stir-fried/boiled

The cooking methods of microwaving, steaming, and stir-frying mostly kept the content of total carotenoids after cooking (Fig.3), while boiling and stir-frying/boiling caused the loss of total carotenoids by 13% and 28%, respectively ($P<0.05$) (Fig.3).

Effect of cooking on total and individual glucosinolates

The contents of total and individual glucosinolates were quantitatively determined in broccoli cooked by different methods. The main aliphatic glucosinolates in broccoli were glucoraphanin, followed by glucoiberin, while the main indole glucosinolates were glucobrassicin and neoglucobrassicin (Table 1). The glucosinolate profile of broccoli in our study was consistent with the previous reports (Jia *et al*., 2009; Schreiner *et al*., 2006).

The contents of total aliphatic and indole glucosinolates in broccoli after different cooking treatments are presented in Fig.4. Total aliphatic glucosinolates were significantly decreased by 55%, 54%, 60%, and 41%, respectively in stir-fried, stir-fried/boiled, microwaved, and boiled broccoli ($P<0.05$). However, the contents of total aliphatic glucosinolates remained almost unchanged in steamed broccoli (Fig.4).

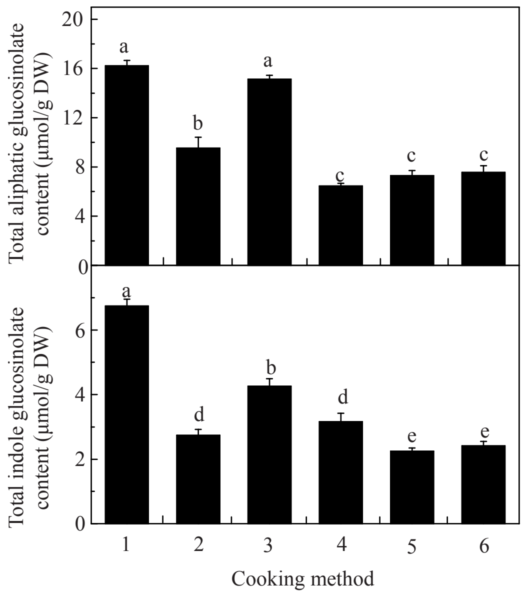

Fig.4 The contents of total aliphatic and indole glucosinolates in broccoli cooked by different methods
Each value is mean±*SD* of three replicate samples. Values not sharing a common letter are significantly different at $P<0.05$. DW: dry weight. Cooking methods: 1. Raw; 2. Boiled; 3. Streamed; 4. Microwaved; 5. Stir-fried; 6. Stir-fried/boiled

Table 1 Glucosinolates identified in broccoli (*Brassica oleracea* L. var. *italica* cv. Youxiu)

Type	Trivial name	Glucosinolate side chain
AG	Glucoraphanin	4-Methylsulphinylbutyl
	Glucoiberin	3-Methylsulfinylpropyl
	Progoitrin	2(R)-2-hydroxy-3-buteny
IG	Glucobrassicin	3-Indolylmethyl
	Neoglucobrassicin	1-Methoxy-3-indolylmethyl
	4-Methoxyglucobrassicin	4-Methoxy-3-indolylmethyl

AG: aliphatic glucosinolates; IG: indole glucosinolates

The content of total indole glucosinolates in broccoli was significantly decreased by all cooking treatments (P<0.05); moreover, the loss rate of total indole glucosinolates in broccoli was significantly higher than that of total aliphatic glucosinolates by all cooking treatments, except microwaving (P<0.05). The steaming led to the lowest loss of total indole glucosinolates (36.8%), while stir-frying and stir-frying/boiling presented the highest (67% and 64%, respectively).

Individual glucosinolates showed analogous responses to the cooking treatments with total aliphatic and indole glucosinolates. However, the loss of glucobrassicin was notably higher compared with other glucosinolates, with a loss rate ranging from 42% to 71% (P<0.05). For glucoraphanin, the highest loss was found in microwaving (62%), while it was not significantly affected by steaming (Table 2).

Table 2 Individual glucosinolate content in broccoli cooked by different methods

Treatments	Aliphatic glucosinolates (μmol/g DW)			Indole glucosinolates (μmol/g DW)		
	PROG	IB	RAPH	GB	4-mtGB	NEO
Raw	0.43 ± 0.03^{a}	2.20 ± 0.10^{a}	13.60 ± 0.30^{a}	4.10 ± 0.16^{a}	0.41 ± 0.02^{a}	2.23 ± 0.18^{a}
Boiled	0.23 ± 0.01^{b}	1.01 ± 0.09^{b}	8.30 ± 0.88^{b}	1.52 ± 0.23^{c}	0.19 ± 0.02^{cd}	1.03 ± 0.19^{cd}
Steamed	0.36 ± 0.02^{a}	1.98 ± 0.03^{a}	12.80 ± 0.29^{a}	2.40 ± 0.11^{b}	0.37 ± 0.02^{b}	1.49 ± 0.17^{b}
Microwaved	0.20 ± 0.01^{b}	1.15 ± 0.07^{b}	5.10 ± 0.19^{d}	1.80 ± 0.13^{c}	0.20 ± 0.01^{c}	1.16 ± 0.15^{c}
Stir-fried	0.19 ± 0.02^{bc}	1.01 ± 0.04^{b}	6.10 ± 0.42^{c}	1.18 ± 0.29^{d}	$0.16\pm0\ .02^{d}$	0.91 ± 0.09^{cd}
Stir-fried/boiled	0.17 ± 0.02^{c}	0.88 ± 0.03^{b}	6.50 ± 0.29^{c}	1.40 ± 0.30^{cd}	0.17 ± 0.03^{cd}	0.84 ± 0.13^{c}

All values are mean±SD (n=3). Values in the same column sharing a common superscript letter are significantly different at P<0.05. DW: dry weight; PROG: progoitrin; IB: glucoiberin; RAPH: glucoraphanin; GB: glucobrassicin; 4-mtGB: 4-methoxyglucobrassicin; NEO: neoglucobrassicin

DISCUSSION

The effects of five different cooking methods (steaming, microwaving, boiling, stir-frying, and stir-frying/boiling) on the contents of chlorophyll, vitamin C, total carotenoids, total soluble sugars, total soluble proteins and glucosinolates were investigated in the present study. The degree of greenness, due to chlorophyll content, is important in determining the final quality of green vegetables (Nisha *et al*., 2004). It was also reported that chlorophyll and its derivatives exerted beneficial effects such as anticarcinogenic and antimutagenic activities (Turkmen *et al*., 2006). Green vegetables exhibit poor color quality and decreased chlorophyll content as compared with the raw material after thermally processed (Adebooye *et al*., 2008; Turkmen *et al*., 2006). In the present study, boiling, stir-frying/boiling, stir-frying, and microwaving led a great loss of chlorophyll in broccoli. In contrast, steaming did not cause any significant loss of chlorophyll content.

Soluble proteins and soluble sugars are important chemical compounds with nutritional value for human. However, few data are available on the influence of cooking methods on total soluble proteins and soluble sugars. Our study shows that all cooking methods caused great losses of total soluble proteins and soluble sugars, particularly the boiling and stir-frying/boiling that use a great amount of water. It is possible that soluble proteins and soluble sugars in broccoli were lost by leaching to surrounding water.

Vitamin C is one of the most important nutrients in broccoli as well as in many other horticultural crops and has many biological functions in the human body (Lee and Kader, 2000). The concentration of ascorbic acid (the predominant form of vitamin C) in broccoli generally was decreased after cooking (Serrano *et al*., 2006). Previous studies have shown that boiling and microwaving caused a great loss of vitamin C (López-Berenguer *et al*., 2007; Sikora *et al*., 2008; Vallejo *et al*., 2002). Our study also shows that boiling and stir-frying/boiling caused a dramatic loss of vitamin C. Hudson *et al*.(1985) and Vallejo *et al*.(2002) reported that steaming caused less loss of vitamin C than boiling and microwaving, which is consistent with our study. Stir-frying caused a considerable loss of vitamin C (16%), however, much less than stir-frying/boiling and boiling (38% and 33%, respectively). Vitamin C is water soluble, stir-frying/boiling and boiling might cause great losses of vitamin C by leaching into surrounding water other than thermal degradation.

Carotenoids have been extensively studied for their potential protection against numerous cancers. Several reports on the retention of total carotenoids in cooked broccoli are available in recent years. In our study, we found that, in general, total carotenoids were retained better compared with vitamin C, which is similar to earlier reports (Zhang and Hamauzu, 2004). Gliszczyńska-Świgło *et al*.(2006) and Miglio *et al*.(2008) reported that boiling and steaming of broccoli resulted in an increase in carotenoids as compared with fresh broccoli, while frying caused a 67% loss of the initial carotenoid concentration. In the present study, it was found that boiling and stir-frying/boiling led to the losses of total carotenoids by 13% and 28%, respectively, while microwaving, steaming, and stir-frying did not cause any significant loss of total carotenoids when compared with raw sample. Similar effect of boiling on total carotenoids in broccoli was reported by Zhang and Hamauzu (2004). In our study, stir-frying followed by boiling caused much greater loss of total carotenoids than boiling and stir-frying alone, probably because of leaching into oil and then washing into the water.

Glucosinolates are one of the most important bioactive compounds in broccoli. The glucosinolates-derived isothiocyanates are known to exert the anti-carcinogenic activity in broccoli. Several isothiocyanates derived from methylsulfinyl aliphatic glucosinolates, such as sulforaphane and indole-3-carbinol (derived from glucoraphanin and glucobrassicin, respectively) in broccoli, are regarded to reduce the risk of cancers (Traka and Mithen, 2009). All the cooking treatments caused the losses of glucoraphanin and other glucosinolates, the precursors of anticancer isothiocyanates in the present study (Fig.4), which might affect the nutrition value of broccoli although the glucosinolate contents do not necessarily reflect the contents of the corresponding isothiocyanates formed (Matusheski *et al*., 2006). Broccoli suffers a series of stresses during post-harvest handlings, which might trigger complex metabolism of glucosinolates. For example, cutting before cooking brings the degradation enzyme myrosinase to contact with glucosinolates, which might cause glucosinolate hydrolysis at high degree (Jia *et al*., 2009). On the other hand, it might also induce the biosynthesis of glucosinolates during cooking treatments. The glucosinolate level in broccoli is a reflection of two opposing physiological processes, hydrolysis of glucosinolate by myrosinase and induction of glucosinolate biosynthesis in an unknown way (Jia *et al*., 2009). Cooking affects glucosinolate composition and content of *Brassica* vegetables, depending on the processing manner, cooking time, vegetable type, and damage degree of vegetable cell tissues. Steaming was reported to well preserve the total glucosinolates in broccoli (Song and Thornalley, 2007; Vallejo *et al*., 2002), brussels sprouts, cauliflower, and cabbage (Rungapamestry *et al*., 2006; Song and Thornalley, 2007), and even increase the total glucosinolates in broccoli (Gliszczyńska-Świgło *et al*., 2006; Miglio *et al*., 2008). The well-preserving or increase in glucosinolate could be partially explained by the inactivation of myrosinase and by a breakdown of plant tissue upon heat (Vallejo *et al*., 2002). Part of these molecules are bound to the cell walls and released only after a breakdown of cell structures (Gliszczyńska-Świgło *et al*., 2006). This agrees with our findings in some respects. In our study, steaming did not affect the content of total aliphatic glucosinolates; however, it significantly reduced total indole glucosinolates by 37%, although the loss rate is much less than those of other cooking methods tested in the present study. This discrepancy might be due to the difference in cut size, physical structure of broccoli, and the steaming time used.

It was reported that boiling caused great loss of glucosinolates of vegetables (Ciska and Kozlowska, 2001; Oerlemans *et al*., 2006; Volden *et al*., 2008b), and we observed in the present study that total aliphatic and indole glucosinolates were reduced by boiling and stir-frying/boiling (41% and 60%, respectively). Glucosinolates are water-soluble compounds and are usually lost during conventional cooking because of leaching into surrounding water due to cell lysis (Gliszczyńska-Świgło *et al*., 2006).

On the other hand, thermal degradation of glucosinolates occurred in high temperature (Oerlemans *et al*., 2006).

Microwaving, as well as stir-frying and stir-frying/boiling, caused a high loss of glucosinolates in the present work. The microwave cooking process presents controversial results in the literature due to the different conditions that are employed such as time, power, and the volume of added water (López-Berenguer *et al*., 2007). Vallejo *et al*.(2002) reported that cooking by microwave resulted in high losses of both aliphatic and indole/aromatic glucosinolates in broccoli. The high rate of water evaporation leaching the glucosinolates from the broccoli florets might explain those dramatic losses (López-Berenguer *et al*., 2007), which is consistent with our findings. On the contrary, Verkerk and Dekker (2004) reported an increase (about 78%) in total glucosinolate content in red cabbage after microwave cooking and it might be an result due to an increase on the chemical extractability. Under our cooking conditions, more than 5 min of cooking with microwave set at 1000 W would prevent the intact myrosinase from hydrolyzing glucosinolates, because these are denaturalizing conditions for this enzyme. Loss for glucosinolates was probably due to leaching into water (López-Berenguer *et al*., 2007); therefore, it is necessary to avoid adding excess water during cooking.

Song and Thornalley (2007) reported that the glucosinolate content of *Brassica* vegetables including broccoli cooked by the stir-frying for 3~5 min with cooking oil pre-heated to 200 °C was not significantly changed. In contrast, stir-frying and stir-frying/boiling caused great losses of glucosinolates in broccoli in our study. The myrosinase enzyme was inactivated rapidly by pre-heated cooking oil at 200 °C without any effect on glucosinolate content in broccoli. However, the cooking oil was pre-heated and maintained at 130~140 °C in our study, which could induce the broccoli thermal breakdown and/or the enzymatic degradation. In regards with these, it is better to pre-heat the oil to a high temperature (200 °C or more) that could reduce the loss of total glucosinolates. No difference in the degradation of total aliphatic and indole glucosinolates was observed between stir-frying and stir-frying/boiling in the present study, suggesting that it was the stage of stir-frying at high temperature (130~140 °C), rather than the stage of boiling, that leached the glucosinolates into water and caused the loss of glucosinolates.

The aliphatic glucosinolates were generally more stable than indole glucosinolates during post-harvest and cooking treatments of *Brassica* vegetables (Cieslik *et al*., 2007; Ciska and Kozlowska, 2001; Jia *et al*., 2009; Rungapamestry *et al*., 2007; Vallejo *et al*., 2002). Vallejo *et al*.(2002) reported that the loss of total indole glucosinolates after high pressure boiling, steam cooking, microwaving, and low pressure boiling was higher than that of total aliphatic glucosinolates. In our study, it was found that the loss rate of total indole glucosinolates was significantly higher than that of total aliphatic glucosinolates in broccoli after stir-frying, stir-frying/boiling, steaming, and boiling. However, a contrary result was observed for microwaving, after which the loss of total indole glucosinolates was significantly lower than that of total aliphatic glucosinolates, in contrast to the results reported by Vallejo *et al*.(2002).

Individual glucosinolates showed analogous responses to different cooking treatments with the total aliphatic and indole glucosinolates. However, the loss rates varied among individual glucosinolates. The loss rate of glucobrassicin was the highest among all the glucosinolates, which is somewhat agreeable with the finding that glucoiberin, sinigrin and glucobrassicin showed the highest reductions after cooking (Rosa and Heaney, 1993). However, Volden *et al*. (2008b) reported that progoitrin had an exceptionally higher decline rate in comparison with all other glucosinolates in white cabbage. They also found that reductions in progoitrin, glucoerucin and 4-hydroxyglucobrassicin in red cabbage were more dramatic for all treatments than those of other glucosinolates (Volden *et al*., 2008a). These reports are in disagreement with our results. Differences in individual diffusion and hydrophilic properties of individual glucosinolates are likely important (Volden *et al*., 2008a). For glucoraphanin and glucobrassicin, the highest retention was found in steam cooking. In this regards, it is likely that broccoli cooked by steaming will be better fit for human consumption than other cooking methods.

In conclusion, the current study clearly shows that nutrient and health-promoting compounds in broccoli are significantly affected by domestic cooking. All cooking treatments, except steaming, caused great losses of chlorophyll and vitamin C. Only boiling and stir-frying/boiling caused the loss of total carotenoids. All cooking treatments caused significant decreases of total soluble proteins and soluble sugars while steaming obtained the best retention. Total aliphatic and indole glucosinolates were significantly modified by all cooking treatments, except that total aliphatic glucosinolates were not modified by steaming. In general, the steaming led to the lowest loss of total glucosinolates, while stir-frying and stir-frying/boiling presented the highest. Among individual glucosinolates, the loss of glucobrassicin was notably higher when compared with other glucosinolates.

Steaming had minimal effects on chlorophyll, soluble proteins and sugars, and vitamin C as well as glucosinolates. On the other hand, stir-frying and stir-frying/boiling, two popular Chinese cooking methods, caused great losses of these compounds. To best retain nutritional values at maximum level, Chinese consumers may process the broccoli by steam cooking, a 'friendly' and 'better' process, instead of traditional stir-fry or stir-fry/boil cooking.

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