

Effect of Cooking Methods on Total Phenolic and Carotenoid Amounts and DPPH Radical Scavenging Activity of Fresh and Frozen Sweet Corn (*Zea mays*) Kernels

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Abstract

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We evaluated the effect of three different cooking methods on antioxidant content and radical scavenging activity of sweet corn. Both fresh and frozen sweet corn kernels were boiled, microwaved, and stir-fried for 1, 3, and 5 min, respectively, then total phenolic (TP) and total carotenoid (TC) contents were determined by spectrophotometric methods. The free radical scavenging activity of the samples was determined using 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay. The results showed that there was a significant increase in TP (1.2–1.9 times) and TC (1.1 to 1.8 times) content of fresh sweet corn after each cooking session for 1, 3, and 5 min, the same treatment of frozen corn resulted in 47–80% losses of TP and 10 to 39% losses of TC content. The free radical scavenging activity (RSA) exhibited by cooked fresh and frozen sweet corns was found to be different, neither of them was very high, in the range of 70.2–78.6%, and the fresh cooked ones had higher values of RSA.

Keywords: *Zea mays* L.; cooking process; phenolics; β -carotene; antioxidant

Many studies have shown that diets rich in fruits or vegetables are protective against diseases and populations that consume such diets have the higher plasma antioxidant status and exhibit a lower risk of cancer and cardiovascular diseases (AZIZAH *et al.* 2009; CHIPURURA *et al.*, 2010; ADEFEGHA & OBOH 2011). Sweet corn (*Zea mays* L.) is a variety of maize with high sugar content, well received by consumers. Unlike field maize varieties, which are harvested when the kernels are dry and mature, sweet corn is picked when immature (milk stage) and prepared and eaten as a vegetable. Since the process of maturation involves converting sugar to starch, sweet corn stores poorly and must be eaten fresh, frozen, or canned, before the kernels become tough and starchy.

Vegetables are often consumed after a variable degree of freezing and cooking; it has been observed that the conditions of freezing process and preparation have significant effects on the level of phytochemicals in vegetables (WACHTEL-GALOR *et al.* 2008; MAZZEO *et al.* 2011). Most consumers likely consume a variety of fresh vegetables to get the most complete antioxidant support, however, some people cannot spend much time preparing fresh vegetable food every day, and so they frequently use frozen vegetables that can be rapidly prepared. Consequently, the consumption of frozen food has increased in recent years (DANESI & BORDONI 2008). Previous studies of sweet corn antioxidant activity were carried out on extracts of unfrozen or fresh samples, and the general opinion is that the quality

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of frozen sweet corn is sometimes inferior to that of freshly prepared products. Several researchers analysed nutrient content in fresh and frozen sweet corns, freezing produced a slight reduction of trans- β -carotene, blanching before freezing improved carotenoid retention (GEB CZYNSKI & LISIEWSKA 2006; HUNTER & FLETCHER 2012). But to date, the comparison of frozen and unfrozen samples on antioxidant capacity has not been studied properly.

Many people think that the nutritional values of fresh vegetables are better than those of the cooked ones. Despite this thinking, most vegetables are usually cooked before consumption. These cooking processes could bring about a number of changes in physical characteristics and chemical composition of vegetables (YAMAGUCHI *et al.* 2001; CHEN *et al.* 2008; SHI *et al.* 2009). PODŒEDEK (2007) suggested that both antioxidant levels and activities of processed vegetables were lower than those of the corresponding fresh samples. This is probably attributed to degradation of bioactive compounds and absorption of water during boiling, resulting in dilution of the active compounds. On the other hand, BERNHARDT and SCHLICH (2006) reported a significant increase in the release of β -carotene and tocopherol in broccoli upon cooking. Cooked sweet corn has significant antioxidant activity (DEWANTO *et al.* 2002). SCOTT and ELDRIDGE (2005) indicated that freezing could increase carotenoid content in white Shoepeg corn, which can further influence bioavailability and health benefits. However, there is still little information on the effects of cooking on total phenolics and carotenoids amounts and antioxidant activities of sweet corn. Therefore the main objective of the present study was to make a preliminary assessment of the effects of different cooking methods on the phytochemical content and antioxidant activity of fresh and frozen sweet corn, with the hope that the findings would guide future practice of suitable cooking methods in order to minimise the degradation of antioxidant activity in fresh and frozen sweet corns.

MATERIAL AND METHODS

Material. Fresh sweet corn (*Z. mays* L.) at milk stage of maturity for consumption was obtained from a local market during the summer season (July) of 2011 in Nanjing, Jiangsu. One portion of sweet corn ears were hand-sorted to thresh, then blanched and quick-frozen as frozen sweet corn

for storage at -18°C until cooked by the methods described. The other fresh sweet corn kernels threshed were directly used for cooking.

2,2-diphenyl-1-picrylhydrazyl (DPPH), gallic acid, β -carotene, and Folin-Ciocalteu reagents were obtained from Sigma-Aldrich (St. Louis, USA). Other chemicals used were all analytical grade.

Sample preparation and cooking. One portion of fresh and frozen sweet corn samples was cooked by each of three methods (boiling, microwaving, and frying). Cooking treatments were as follows: (1) Boiling. 200 ml of water in a 400 ml beaker were heated to boiling. The beaker was covered with a plate, preventing water loss. 20 g of sweet corn kernels were added to the boiling water and cooked for 1, 3, and 5 minutes. (2) Microwaving. 20 g of sweet corn kernels were added to 200 ml of boiled water (over 80°C at the beginning) in a 400-ml beaker and then cooked in a domestic microwave oven (Galanz 600W) for 1, 3, and 5 minutes. The beaker was also covered with a plate, preventing water loss. (3) Frying. 20 g of sweet corn kernels were stir-fried in hot oil (170°C) for 1, 3, and 5 minutes. In which a minimum amount of cooking oil (2–3 g) was placed in a non-stick frying pan (diameter of 20 cm) and heated at 'high' on a hot plate (Media SH2181, 2100 W, 220 V; Midea Holding Co. Ltd, Guangdong, China). After the cooking processes, the samples were all drained off, then pre-frozen, freeze-dried and ground to fine powder used for subsequent analyses. The other portion of non-cooked samples was directly freeze-dried and ground to fine powder for analysis.

Total phenolics (TP) extraction and determination. The amount of TP was determined using the Folin-Ciocalteu reagent, as described by TURKMEN *et al.* (2005) with some modification. About 1 g of cooked and uncooked samples was extracted with 85% aqueous methanol (5.0 ml) in an ultrasonic bath kept at 40°C for 30 minutes. The mixed homogenate was centrifuged at 4000 g for 10 min and the supernatant was recovered. The residue was extracted under the same conditions as described above. Supernatants were combined and filtered through Whatman No. 1 filter paper. 0.2 ml of appropriate dilutions of clear filtrate was mixed with 7.5% sodium carbonate (0.8 ml) followed by 1 ml of the Folin-Ciocalteu reagent. The mixture was then shaken vigorously. The absorbance was measured at 765 nm after 30 min at room temperature using a TU-1810 spectrophotometer (Pgeneral, Beijing, China). A mixture of water and reagents was used

as a blank. The TP was expressed as mg gallic acid equivalents (GAE)/g dry matter.

Total carotenoids (TC) extraction and determination. TC were analysed according to the methods of JATUNOV *et al.* (2010) with some modification. 1 g of fresh, frozen or cooked tissues was homogenised with 10 ml of a mixture of ether and *n*-hexane (1:1). The homogenate was filtered with four layers of cheese cloth and the residue was treated with *n*-hexane for three successive extractions until the yellow colour could no longer be visually detected in the extract and residue. The filtrate was combined and centrifuged at 3000 g for 10 minutes. The supernatant was collected and then filtered for analysis. The TC content extracted was determined by a spectrophotometer at 450 nm. A standard curve correlating the TC concentration (expressed in β -carotene) and the absorbance of the pigment solution was used. An absorptivity coefficient of 2592 ($E_{1\text{ cm}}^{1\%}$) was used for β -carotene standard quantification. The concentration of TC was expressed as μg carotenoids/g dry matter.

DPPH radical scavenging activity. The free radical scavenging activity of the samples was measured in accordance with the method of ZHANG and HAMAIZU (2004) with modifications. 1.0 ml of the TP extract solution was added to a 1.0 ml 0.2 mmol/l DPPH· methanolic solution at room temperature. The absorbance was measured at 515 nm using a TU-1810 spectrophotometer (Beijing Purkinje General Instruments Co. Ltd, Beijing, China). The results were expressed as percentage of reduction of the initial DPPH· absorption by test samples as follows:

$$\text{DPPH scavenging effect (\%)} = [(A_0 - A_t)/A_0] \times 100$$

where: A_0 – absorbance of the control at $t = 0$ min; A_t – absorbance of the antioxidant at $t = 30$ min

Data analysis. All data was reported as mean \pm standard deviation of triplicate determinations. Differences between variables were tested for significance by ANOVA. Differences between means were considered to be significantly different at $P < 0.05$ (SPSS for Windows, version 13.0; SPSS Inc, Chicago, USA).

RESULTS AND DISCUSSION

Comparison of TP, TC, and DPPH radical scavenging activity of fresh and frozen sweet corn (*Zea mays*) kernels

Frozen sweet corn kernels contained a higher total amount of phenolics (255.6 ± 5.3 mg/g) versus

the fresh ones (82.6 ± 4.8 mg/g), as well as higher amounts of total carotenoids (50.56 ± 0.51 $\mu\text{g/g}$) versus the fresh ones (25.98 ± 1.45 $\mu\text{g/g}$). The blanching and freezing process itself can dehydrate vegetables slightly resulting in water weight losses ranging from 0.3% to 5% (SCOTT & ELDRIDGE 2005). The increases in total carotenoid and total phenolic concentrations found in frozen corn may be a result of water loss from the kernels. This study also showed that the effect could be based on the release of carotenoids and phenolics from the matrix by heat disruption of protein-carotenoid complexes and protein-phenol complexes.

In relation with the antioxidant activity, this study showed that there were also significant changes in DPPH radical scavenging levels between fresh and frozen sweet corn (*Zea mays*) kernels, which were 64.35% and 93.75%, respectively. The blanching step of vegetables can increase some carotenoids and phenolics, in the way that was observed here, the increase in DPPH radical scavenging activity could be attributed to the increase in TP and TC content of frozen sweet corn. This assertion agrees with several results where correlations were established between the TP, TC content of some plant foods and their antioxidant capacity (STAHL & SIES 2003; ISMAIL *et al.* 2004; CHUAH *et al.* 2008; WACHTEL-GALOR *et al.* 2008). Yet, more studies are necessary to explain exactly which carotenoids and phenolics are influencing the antioxidant activity.

Effect of cooking methods on TP

TP content of fresh and cooked sweet corns is shown in Figure 1a. The TP content of fresh sweet corn was 82.6 ± 4.8 mg/g, as expected, thermal treatments of sweet corn for 1, 3, and 5 min, resulted in significant increases of total phenolic compounds ($P < 0.05$). A similar trend was observed in both boiled and microwaved sweet corn, especially in microwaved sweet corn, which was found to have the highest phenolic content (156.9 mg/g), but cooking by frying resulted in small effects (81.0–83.7 mg/g).

TP content of frozen and cooked sweet corns is shown in Figure 1b. The frozen sweet corn contained 255.6 ± 5.3 mg/g TP, after cooking procedures, the TP content of sweet corn was significantly ($P < 0.05$) reduced and reductions were the same in all cooking methods. Different

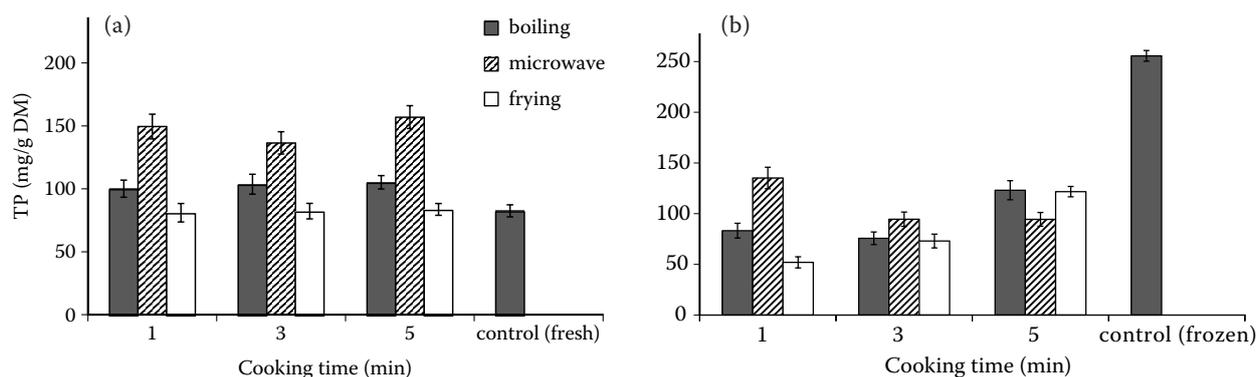


Figure 1. Effect of cooking methods on total phenolic (TP) content of (a) fresh and (b) frozen sweet corn (control sample means fresh sweet corn kernels without cooking)

types of cooking method had a different trend in TP content. The longer the microwaving time, the greater the losses of the total phenolic compounds measured, but not for boiling and frying.

Cooking is an indispensable prerequisite in order to obtain safe and high-quality food products. Cooked vegetables have much better hygienic quality and due to chemical reactions during cooking, they are much better digestible and have an increased nutritional value. However, cooking may affect the antioxidant status of sweet corn due to the release of more phenolic compounds and destruction or creation of redox-active metabolites (BISHNOI *et al.* 1994; RUIZ-RODRIGUEZ *et al.* 2008). Phenolic compounds can protect the human body from free radicals, whose formation is associated with the normal natural metabolism of aerobic cells. The antiradical activity of flavonoids and phenols is principally based on the structural relationship between different parts of their chemical structure. HUNTER and FLETCHER (2002) postulated that the effect of thermal processing on the level of phenolics depends on the type of product. Fresh sweet

corn was found to be given rise to an increase in TP, which may due to the increased levels of free flavonols as affected by the heat treatment. But the effect of cooking methods on TP of frozen sweet corn showed that the longer cooking time resulted in greater losses of TP measured. This could be due to the degradation of phenolic compounds and absorption of water during cooking.

Effect of cooking methods on TC

Figure 2a shows the effect of cooking methods on TC content of fresh sweet corn. Results from the study showed that the three cooking methods increased the TC content of sweet corn (1.1 to 1.8 times), frying for 5 min resulted in the highest (1.8 times) content of TC to 46.10 $\mu\text{g/g}$. Microwaving for 1 min, on the other hand, resulted in 1.58 times increase in TC content. Similarly, boiling for 3 min resulted in a higher TC content.

However, there is a contrary result in frozen sweet corn used for cooking. TC contents of frozen and

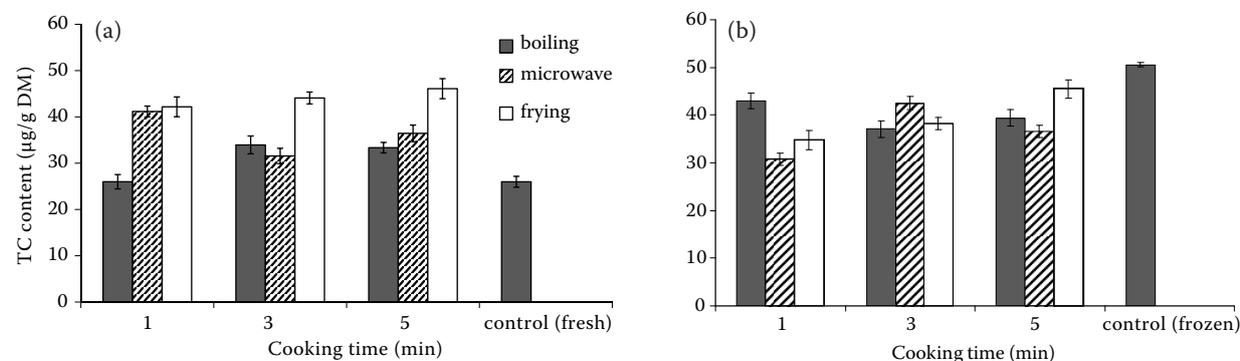


Figure 2. Effect of cooking methods on total carotenoid (TC) content of (a) fresh and (b) frozen sweet corn. Control sample means fresh sweet corn kernels without cooking

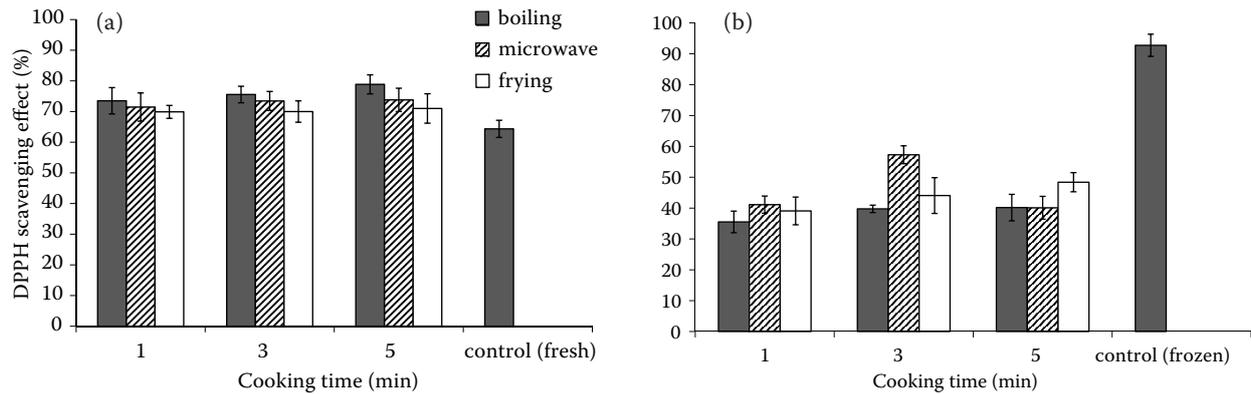


Figure 3. Effect of cooking methods on the radical scavenging activity (RSA) of (a) fresh and (b) frozen sweet corn (control sample means fresh sweet corn kernels without cooking)

cooked sweet corns are shown in Figure 2b. Compared with the frozen material, the levels of TC in samples cooked by three different methods were all reduced. In the boiling cooking, TC in sweet corn declined continuously. The frozen sweet corn cooked in a microwave for 1, 3, 5 min lost 39.3, 15.9, and 27.6%, respectively. In the microwaving cooking, TC in sweet corn overall increased with increased cooking time, which had a similar trend in the frying cooking, while treatment for 3 min resulted in the highest content in sweet corn.

Results from this study revealed that thermal treatment enhanced the availability of total carotenoids (TC). Similar results were reported by previous researchers (GAYATHRI *et al.* 2004), however, microwaving for 5 min resulted in significantly ($P < 0.05$) lower TC than that of 3 min microwaving. This may be due to the prolonged microwaving time that may result in a longer exposure of sweet corn to heat, oxygen and light.

Effect of cooking methods on radical scavenging activity (RSA)

The DPPH method was used to measure the effect of cooking methods on the radical scavenging activity of cooked sweet corn extracts. Fresh sweet corn extracts were found to possess good antioxidant activity (64.4%); total antioxidant activity of sweet corn obviously rose during the three cooking methods (Figure 3a). During the boiling cooking, the sweet corn extract retained 73.5, 75.5, and 78.5% of total antioxidant activity after being cooked for 1, 3, and 5 min, respectively. In the microwave and frying cooking, the changes in antioxidant activity showed a similar trend.

A significant reduction in antioxidant activity was observed in frozen sweet corn after cooking for 1, 3, and 5 min compared with the fresh sample. After boiling, microwaving and frying cooking for 1 min, the antioxidant activity dropped to 35.5, 41.1, and 39.1%, respectively (Figure 3b). Interestingly, results from this study showed that both boiling and frying increased RSA with the longer time ($P < 0.05$), and microwave treatment for 3 min showed the highest RSA.

From the above study, all the fresh cooked sweet corns were able to reduce the stable, purple-coloured radical, DPPH, into yellow-coloured DPPH-H reaching over 50% of the reaction. After heat treatment, small improvements in the antioxidant activity of fresh sweet corn were observed, which may due to the interaction between the increased releases of phytochemicals, such as ferulic acid from the matrix (DEWANTO *et al.* 2002), and some antioxidant substances dissolved in water.

CONCLUSIONS

Antioxidant components, such as phenolics and carotenoids, in frozen sweet corn and antioxidant activity have been shown to be heavily lost during cooking. These losses need to be taken into account when calculating the dietary intake of these compounds from cooked frozen sweet corn. Some cooking methods significantly increase the free phytochemical contents which make fresh sweet corn have a higher antioxidant activity. However, the cooking conditions used here are probably extreme, and are likely to be experienced for fresh sweet corn. In other processes, such as steaming, the extent of losses would be lower.

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