Effect of Home Freezing and Italian Style of Cooking on Antioxidant Activity of Edible Vegetables

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ABSTRACT: In this study, we analyzed the modifications of antioxidant activity consequent to 3 typical home cooking practices (steaming, boiling, and microwave cooking) in fresh and home frozen vegetables. Six different vegetable species were examined: carrots (Daucus carota L.), zucchini (Cucurbita pepo L.), tomatoes (Solanum lycopersicum L.), green beans (Phaseolus vulgaris L.), peas (Pisum sativum L.), and yellow peppers (Capsicum annuum L.). All vegetables were conventional products and were analyzed in season to minimize differences due to agricultural practice and storage. Cooking and freezing were generally regarded as destructive to antioxidants, and this has fostered a belief among many consumers that raw vegetables are nutritionally superior to their frozen and/or cooked forms. In the current study, we provide evidence that this is not always the case.

Keywords: antioxidants, home cooking, home freezing, total antioxidant activity, vegetables

Introduction

Phytochemicals in fruits and vegetables have been receiving increased interest from consumers and researchers for their beneficial health effects on human diseases, mainly due to their antioxidant activity. Epidemiological studies have provided evidence of an inverse association between a vegetable-rich diet and diseases such as cardiovascular diseases (Dauchet and others 2006; He and others 2006) and cancer (Riboli and Norat 2003); however, clinical trials using "nutritional" antioxidants as vitamin C and E have given equivocal results (Emmert and Kirchner 1999; Hercberg and others 1999). A possible explanation is the presence of other components in foods having higher activity than the well-known nutrient antioxidants. Furthermore, since there are thousands of antioxidants in most foods, the total antioxidant capacity of a given food may result from the integrated and synergistic action of different compounds instead of the sum of each single compound. The concept of total antioxidant activity (TAA) reflects the integrated and, if any, synergic effects of all the antioxidants. It is recognized that foods with high TAA might be protective, and recommendations about a "healthy" diet regard consumption of high amounts of fruit and vegetables.

A number of factors, including genetics and growing conditions (that is, fertilization, moisture, pest, and disease burden, and so on), are known to affect the concentration of plant secondary metabolites having antioxidant activity, therefore modulating their TAA (Kalt 2005). Processing, particularly cooking of food, is another factor that can impact TAA (Papas 1996). It is particularly important for vegetables, since some of them are commonly eaten in cooked form. Thus cooking, especially home cooking, is an important issue that needs to be considered in estimating the daily antioxidant intake. Another important topic about antioxidant activity of vegetables is freezing. Although it is known that the nutritional quality of the vegetables depends not only on the nutrient content when harvested but also on the changes occurring during postharvest handling, storage conditions, processing, and preparation (Howard and others 1999; Nursal and Yücecan 2000), few studies have quantified the supposed decrease in TAA of vegetables after freezing and cooking at home.

It is a conventional wisdom that processed fruits and vegetables have a lower nutritional values than their respective fresh commodities, mainly due to the loss of vitamin C content in the processing (Dewanto and others 2002). Knowledge about the effective loss of TAA consequent to home processing may have a significant impact on consumers’ food selection and processing.

In this study, we measured the antioxidant activity (AA) related to water soluble antioxidants of 6 different vegetables and compared the results obtained in raw foods to those obtained in cooked (boiled, steamed, and microwave cooked), frozen, and frozen-cooked foods. Vegetables were not thawed before cooking, since thawing significantly reduces the antioxidant components (Nursal and Yücecan 2000).

Materials and Methods

Six different vegetable species were examined: carrots (Daucus carota L.), zucchini (Cucurbita pepo L.), tomatoes (Solanum lycopersicum L.), green beans (Phaseolus vulgaris L.), peas (Pisum sativum L.), and yellow peppers (Capsicum annuum L.).

All samples were bought in season from a local shop the same day of the analysis. Vegetables were weighed, washed, and dried, and possible petioles were eliminated. Each vegetable sample was divided in 2 parts; the first one was immediately used for the analysis on fresh products, the other was frozen in plastic bags, without blanching, at −18 °C in a conventional home freezer (Electrolux, Stockholm, Sweden). Storage lasted for 6 mo at −18 °C.

Fresh vegetables

Vegetables were homogenized in a food processor without addition of any solvent, and 20 g of the homogenized material were dissolved in 60 mL of 5 mM phosphate buffer saline, pH 7.4 (PBS),
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getting a dilution 1:3 (w/v). Yellow pepper (fresh and cooked) samples were diluted 1:10 (w/v), due to their high antioxidant activity. The samples were then filtered and the resulting filtrate was used to determine the antioxidant activity (AA). All phases of homogenization were done in ice and each extract immediately analyzed. Two replicates were prepared from each sample, and at least 3 different samples, bought in different days, were considered for each vegetable.

Frozen vegetables

Before analysis, frozen vegetables were weighed again to evaluate possible variation induced by freezing, and then they were directly processed as described for fresh vegetables without defrosting.

Cooked vegetables

Vegetables were cooked using 3 different home processing methods: boiling (20 min in 1.5 L of salty water); steaming (30 min); and microwave (700 W for 5 min, followed by a standing for 2 min). Vegetables were cooked as a whole, without cutting, peeling, and eventually defrosting, and then processed as described for fresh samples. For each sample, the amount of homogenate dissolved in 60 ml PBS was calculated taking into account possible weight variation due to freezing or cooking, and corresponded to 20 g of the fresh, uncooked vegetable.

Antioxidant activity (AA)

AA was measured using the method of Re and others (1999) on the basis of the ability of the antioxidant molecules in the sample to reduce the radical cation of 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), determined by the decolorization of ABTS+, and measured as the quenching of the absorbance at 734 nm. Values obtained for each sample were compared to the concentration-response curve of the standard trolox solution and expressed as micromoles of Trolox equivalent (TE).

All data are means ± SD. Statistical analyses were carried out using the Student’s t-test comparing value of fresh cooked vegetables and frozen cooked vegetables with the corresponding fresh uncooked one, and by the 1-way analysis of variance (ANOVA) followed by Bonferroni test to compare the 3 cooking methods for each fresh and frozen vegetable.

Results and Discussion

Although antioxidants in plant can be divided in lipophilic, hydrophilic, and amphiphatic compounds, and antioxidant activity may be accounted to all components, we decided to assess only the modification of antioxidant activity due to hydrophilic/amphiphatic ones (AA) for 2 reasons: (1) the contribution to total antioxidant activity of lipophilic antioxidant in the examined vegetables is very poor (Wu and others 2004); (2) evaluation of the activity of lipophilic antioxidants requires the use of different solvents, causing an extraction of lipophilic compounds that could be much more exhaustive than the digestive process, so causing nonphysiological results.

Our results in uncooked foods indicate not only that AA varies in different fresh vegetables according to their qualitative/quantitative content of antioxidants, but also that the effect of home freezing largely depends on the type of vegetables (Figure 1). Notably, freezing increased AA in green vegetables (green beans, zucchini, and peas), while decreasing or not affecting it in yellow/red ones (carrots, tomatoes, and yellow pepper). Phenolic compounds are associated not only with AA, but also with color characteristic of vegetables; it is conceivable that compounds related to green color are more resistant to freezing than those related to yellow/red.

The cooking practices differently influenced the AA with respect to raw material, depending on the vegetable considered and the storage condition (fresh or frozen). Vegetables were not peeled before cooking or freezing, since numerous phenolic compounds are located in the periderm of vegetables (Mercier and others 1994); it has been demonstrated that in onions the greatest loss of flavonoids takes place during the preprocessing step, where the onion is peeled, trimmed, and chopped (Ewald and others 1999).

Regarding orange/red vegetables, AA of fresh carrots was increased or unaffected by cooking (Figure 2A), in agreement with the data of Talcott and Howard (1999), who observed a 70% increase of carrot total soluble phenolics immediately after thermal processing. The increase in AA due to thermal process has been mainly attributed to transformation of chlorogenic acid, the predominate phenolic acid in carrots, into caffeic acid (Talcott and others 2000). Statistical analysis indicated boiling as the worst cooking practice in fresh carrots. Since phenolic antioxidants are water soluble and can be leached from vegetable tissues by processing in water, this can explain the highest AA decrease after boiling. In frozen carrots, AA was significantly decreased by cooking; it is conceivable that freezing had altered the peel barrier, allowing a loss of antioxidants during the cooking procedures.

AA in fresh tomatoes was decreased by boiling, while in frozen tomatoes it was significantly affected by all cooking procedures (Figure 2B). Tomato is widely consumed either fresh or after processing into various (cooked) products, and its consumption has been proposed to reduce the risk of several chronic diseases. These health protective effects have been widely attributed to the presence of key antioxidants such as lipid-soluble lycopene and β-carotene as well as water-soluble vitamin C, and compounds of intermediate hydrophobicity such as quercetin glycosides, naringenin chalcone, and chlorogenic acid. All of these are known to contribute significantly to the antioxidant activity of tomato (Abushita and others 2000). In the literature, there are several reports on the effects of processing on tomato compounds, or on the total antioxidant potential of the processed tomato materials, and a number of studies indicate that the content of carotenoids and vitamin C may be negatively affected by various thermal treatments such as boiling, frying, drying, and microwaving (Takeoka and others 2001). Little is known about the effects of thermal treatments on tomato (poly)phenolic antioxidants, including flavonoids. Since in this study we measured only AA related to hydrophilic compounds, our results indicate a loss of water-soluble molecules due to cooking. This loss was higher in frozen tomatoes, possibly due to the
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alteration of the peel barrier. This decrease in AA is in agreement with the recent study of Capanoglu and others (2008), who showed that processing significantly affects the levels of antioxidants and many other metabolites present in commercial tomato paste.

AA was decreased by microwave cooking in fresh yellow pepper and by all cooking practices in frozen Capsicum annuum (Figure 2C), allowing hypothesizing that both freezing and high frequency may alter the barrier effect of peel, therefore causing antioxidant loss. The higher decrease in AA in frozen yellow peppers after cooking could be related to the reported decrease in ascorbic acid content due to the exposure to low temperature (Martinez and others 2005).

Among green vegetables, AA of fresh green beans was reduced by boiling and increased by steaming (Figure 3A), in agreement with Marszal and others (1997), who observed that boiling of green beans causes the major loss of vitamin C. Steaming and microwave cooking reduced AA in frozen green beans; this decrease could be mainly attributed to the loss of ascorbic acid, since green beans do not retain their vitamin C very well. Lee and Kader (2000) categorizing different vegetables as being good, moderate, or poor in their retention of ascorbic acid, and designated green beans as poor.

Fresh zucchini appeared very sensitive to cooking, their AA decreasing independently from the practice used. Conversely, AA of frozen zucchini did not decrease after cooking, with microwave practice actually increasing it (Figure 3B). Little data are available in the literature on cooked zucchini, but the negative effect of boiling is in agreement with Andlauer and others (2003).

Finally, AA of fresh peas was modified by boiling only (Figure 3C), probably due to the least percentage loss of vitamin C in these vegetables compared to others (McErlain and others 2001). According to Hunter and Fletcher (2002), who showed, after a 20% loss during blanching, no further loss of ascorbic acid during freezing of peas, frozen peas appeared particularly resistant to AA loss due to cooking (Figure 3C). Our results partially agree with those of Ewald and others (1999), who reported small effects on flavonoid content due to cooking of green beans and peas.

The antioxidant profile has been recognized to represent an important parameter to predict the impact of food on human health, and a growing body of evidence suggests that compounds with antioxidant activity play a major role in explaining the benefits of vegetable consumption.

Cooking and freezing are generally regarded as destructive to antioxidants, so supporting the consumers’ assumption that only fresh vegetables are healthy. It is documented that vitamin C is lost during processing, but ascorbic acid represents only a minor part of the AA, polyphenols being very important antioxidant compounds even in vegetables where the vitamin is present in high concentration (Miller and others 1995). Notwithstanding, there are limited data on polyphenol content, and even less data on AA, of cooked...
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vegetables. Information on AA in terms of the food as eaten needs to be generated, taking into account that home cooking still represents the most frequent method of food processing, and it is applied in different ways not only to fresh foods but also to frozen ones. One of the main differences between home freezing and industrial deep-freezing is the blanching procedure, which is generally not used in home practice. Studies performed on deep-frozen vegetables do not allow us to understand the impact of low temperatures on antioxidant activity of vegetables, since blanching often modifies it much more than freezing (Hunter and Fletcher 2002; Puupponen-Pimiä and others 2003).

In this study, we have shown that the assumption that frozen vegetables have a lower antioxidant potential than fresh ones is not a universal truth, but depends on the vegetable considered. Cooking negatively affects green vegetables AA more than freezing, and frozen cooked vegetables often present a higher AA than the corresponding fresh ones. Conversely, frozen yellow/red vegetables are more susceptible to AA loss due to cooking than the corresponding fresh ones. This has to be carefully considered since frozen vegetables are always cooked before consumption. Regarding cooking practice, boiling often appears to be the worst practice in terms of AA preservation.

Overall, changes in AA appeared dependent on the type of vegetable considered, as already reported by Turkmen and others (2005), and on the type of cooking practice.

Conclusions

Nowadays, consumers are aware of the need to consume a variety of fresh vegetables to get the most complete antioxidant support (Prochaska and others 2000); however, many people do not have the opportunity to eat fresh vegetables every day and frequently use frozen vegetables, and many vegetables are consumed as cooked. The aim of this study was neither a classification of different plant foods on the basis of their total antioxidant activity nor the analysis of the modifications occurring in single antioxidant molecules after thermal treatment, but the evaluation of AA modification occurring in the same sample of vegetable food after freezing, cooking, and freezing/cooking. Our results indicate that, at least for hydrophilic molecules, changes in AA due to home processing are very different in different vegetables. This is probably related to their different contents of vitamins, carotenoids, and phenolic compounds, which act synergistically but are differently sensitive to processing. Overall, the decrease in AA occurring after home processing is relatively small, and it is not likely to cause a significant decrease in antioxidant intake, at least in the considered conditions. Notwithstanding, it remains that home processing is an important issue that needs to be considered in estimating the daily total antioxidant intake, and better measurements and understanding of AA on common foods may help nutritionists.

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References


