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RESEARCH ARTICLE

EFFECT OF COOKING METHODS ON ANTIOXIDANT PROPERTIES OF VEGETABLES

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ABSTRACT

Fruits and vegetables are valued for not only the nutrients but also for the nutraceuticals like antioxidants in them. They are the most important dietary sources of nutraceuticals that are valued for preventing lifestyle diseases like cancer, diabetes and cardiovascular disease. Such foods should be cooked/processed in a way to retain the goodness of nutraceuticals. Retention of antioxidants during cooking such as boiling, pressure cooking, microwave cooking, stir-frying and frying of vegetables was investigated. Fresh and cooked vegetables were analysed for ascorbic acid content (AA), total polyphenols (TP), total flavonoids (TF), tannin and total antioxidant activity by 1,1-diphenyl-2-picrylhydrazyl (DPPH) and ferric reducing antioxidant power (FRAP) assays. Results showed that the AA, TP, TF, tannin and antioxidant activities were affected by cooking methods, the retention varying among individual compounds. Boiling, pressure cooking and microwave cooking brought about appreciable reduction in AA, TP, TF, tannin and antioxidant activity in vegetables, while frying and stir-frying showed less losses. The highest antioxidant retention was observed in frying followed by stir-frying, microwave cooking, pressure cooking and boiling. The study indicated that short time heat treatments such as frying and stir-frying help to retain the antioxidant properties of vegetables.

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INTRODUCTION

Diets naturally rich in bioactive compounds are very popular among the consumers with an increase in awareness for healthy food and living. Fresh fruits and vegetables contain wide range of phytochemicals having antioxidant and other health promoting properties. Although fruits are mostly consumed in raw form, vegetables need to be cooked to enhance their palatability and digestibility. However, cooking brings about a number of physical and chemical changes in the vegetables (Rehman *et al.,* 2003). These changes could be both beneficial and detrimental depending on the extent and type of cooking/processing conditions. Antioxidant activities of vegetables in different cooking procedures such as pressure-cooking, microwaving, and frying were changed depending on some parameters like the type of vegetable, kind of cooking, the bioavailability of phenolics, temperature, duration, peeling, chopping, and stability of the structure to heat (Ali and Nooshin, 2014). In general, vegetables are prepared at home on the basis of convenience and taste preference rather than retention of nutrient and health-promoting compounds (Masrizal *et al.,* 1997).

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Cooking would bring about a number of changes in physical characteristics as well as chemical composition of the vegetables. Bearing on this point, the study was planned with an objective to evaluate the effect of domestic cooking on the antioxidant properties of beetroot, carrot, small onion, bitter gourd, brinjal and tomato that are widely consumed in India.

MATERIALS AND METHODS

Fresh samples of beetroot (*Beta vulgaris*), carrot *(Daucus carota subsp. Sativus),* small onion *(Allium cepa L.))* bitter gourd *(Momordica dioica*), brinjal (*Solanum melongena) a*nd tomato (*Solanum lycopersicum)* were purchased in local market. All the vegetables were sorted, washed properly before use and cut into uniform pieces. Each vegetable batch was divided into five equal portions. One portion was retained as raw and the remaining four were subjected to cooking treatments of boiling, pressure cooking, microwave cooking and Stir frying respectively.

Cooking methods

Boiling

Each vegetable (100g) was added to the150 ml of distilled water in stainless steel vessel covered with a lid and cooked on a moderate flame at 100 °C for 10 min. It was drained off and cooled to room temperature.

Pressure cooking

Each vegetable (100g) was placed in stainless steel vessel containing 80 ml of distilled water and kept inside pressure cooker and cooked for 7 min. It was drained off and cooled to room temperature.

Microwave cooking

Each vegetable (100g) was placed in a plastic microwavable bowl with 60 ml of distilled water, covered with a lid and cooked in a microwave oven using high power for 5 min. It was cooled to room temperature.

Stir frying

Each vegetable (100g) was stir fried in a frying pan with 5 ml of hot refined sunflower oil for 2 min and 70 ml of distilled water was added and covered with a lid to prevent water loss and cooked on a low flame for 8 min. It was cooled to room temperature.

Chemicals and reagents

All chemicals used were of analytical grade and purchased from Sisco Research Laboratories Pvt. Ltd., Mumbai, India.

Analysis of antioxidant components and activity

Ascorbic acid content was estimated by titration method and total polyphenols and tannins were determined by the spectrophotometric method, as described by Sadasivam and Manickam (2008). Total flavonoids were measured using aluminium chloride colorimetric assay, as described by Marinova *et al*. (2005). Total carotenoid content was determined as per the method described by Ranganna (1986). The analysis of antioxidant activity was carried out using DPPH assay, as per the method given by Goupy *et al.* (1999) and Ferric reducing antioxidant power (FRAP) assay by the modified method of Benzie and Strain (1996).

Statistical analysis

Data from all experiments were performed in triplicate for each sample. The results of the three replicates were pooled and expressed as mean ± standard deviation. Factorial completely randomized design (FCRD) as per method described by Gomez and Gomez (1984) was employed for analysis of data at 0.05 level of significance.

RESULTS AND DISCUSSION

Effect of cooking on antioxidant properties of beet root

Table 1 shows that fresh beet root brought about appreciable increase in all the three antioxidant components namely total poly phenols, total flavonoids and tannin except ascorbic acid. They increased many folds upon boiling, pressure cooking, microwaving and stir frying. Stir frying and boiling were found to be most suitable for retention of ascorbic acid. DPPH radical scavenging activity was highest for stir frying while ferric reducing antioxidant power was highest in boiled beetroot. The results are in agreement with the findings of Poornakala *et al.* (2012) who reported that cooking methods significantly increased the antioxidant component and activity.

Table 1. Effect of cooking on antioxidant properties of beet root

Beet root	Ascorbic acid (mg/ 100g)	Total Polyphenols (mg GAE/ 100g)	Total Flavonoids (mg CE/ 100g)	Tannin (mg TAE/ 100g)	DPPH radical scavenging activity AAEAA (mg/ 100g)	Ferric Reducing Antioxidant Power AAEAA (mg/ 100g)
Fresh	12.15±0.26	96.83±3.68	40.07±0.40	32.66 ±0.79	125.38±5.50	45.75 ±1.60
Boiling	ND	349.66±3.46	213.48±4.04	126.26±4.55	239.75 ±0.64	81.44 ±3.08
Pressure cooking	ND	251.80±9.53	154.14±6.39	84.51 ±0.07	193.0 ±8.52	58.79 ±0.21
Microwave cooking	ND	195.40±6.51	115.70±4.69	70.32 ±2.78	160.33 ±2.02	79.04±0.04
Stir frying	ND	329.20±8.30	194.27±6.12	116.69±3.68	275.0± 5.70	50.0 ±0.36
SE.D	-	5.5132	3.9481	2.3846	4.3196	1.2788
CD (0.05)	-	12.2843**	8.7970**	5.3133**	9.6247**	2.8493**

Table 2. Effect of cooking on antioxidant properties of carrot

Carrot	Ascorbic acid (mg/ 100g)	Total Polyphenols (mg GAE/ 100g)	Total Flavonoids (mg CE/ 100g)	Tannin (mg TAE/ 100g)	Total Carotenoids (mg/ 100g)	DPPH radical scavenging activity AAEAA (mg/ 100g)	Ferric Reducing Antioxidant Power AAEAA (mg/ 100g)
Fresh	7.05±0.15	13.48±0.35	1.05±0.35	4.82 ±0.12	4.84 ±0.21	5.63 ±0.18	2.31 ±0.10
Boiling	ND	20.62±0.31	1.74±0.04	8.97 ±0.34	4.02 ±0.08	10.93 ±0.14	4.28 ±0.08
Pressure cooking	ND	19.07±0.44	1.40±0.03	7.50 ±0.08	4.14 ±0.08	10.30 ±0.12	4.08 ±0.07
Microwave cooking	ND	16.15±0.62	1.34±0.01	7.32 ±0.01	3.98 ±.16	9.32 ±0.35	3.42 ±0.10
Stir frying	ND	22.57±0.18	2.19±0.01	11.18±0.14	3.97 ±0.03	12.40± 0.06	4.72 ±0.03
SE.D	-	0.3353	0.0256	0.1483	0.1054	0.1626	0.0668
CD (0.05)	-	0.7470**	0.0570**	0.3304**	0.2349**	0.3623**	0.1488**

Boiling of beet root exhibited the highest value among the cooking methods. Saikia and Mahanta, (2013) also stated that among the three cooking methods employed, steaming emerged as the most suitable method followed by microwave cooking in terms of retention of phytochemicals and antioxidant activities of beetroot.

Table 3. Effect of cooking on antioxidant properties of small onion

Small onoin	Ascorbic acid (mg/ 100g)	Total Polyphenols (mg GAE/ 100g)	Total Flavonoids (mg CE/ 100g)	Tannin (mg TAE/ 100g)	DPPH radical scavenging activity AAEAA (mg/ 100g)	Ferric Reducing Antioxidant Power AAEAA (mg/ 100g)
Fresh	87.12±1.72	23.88±0.30	18.50±0.28	1.75±0.02	16.48±0.53	15.29±0.37
Boiling	82.28±±3.26	18.33±0.47	20.50±0.90	3.79±0.10	13.86±1.12	11.29±0.38
Pressure cooking	77.44±0.48	16.11±0.49	31.02±1.37	3.87±0.01	15.51±0.32	18.52±0.43
Microwave cooking	75.02±1.75	16.66±0.34	37.43±1.31	3.50±0.06	13.06±0.30	10.15±0.23
Stir frying	72.60±2.22	30.55±0.38	51.63±1.76	5.50±0.01	11.82±0.28	10.80±0.13
Frying	67.76±2.93	35.00±1.51	48.79±0.21	8.87±0.31	16.00±0.31	19.55±0.37
SE.D	1.8417	0.5893	0.9227	0.1142	0.4634	0.2760
CD (0.05)	4.0128**	1.2839**	2.0104**	0.2489**	1.0098**	0.6013**

Table 4. Effect of cooking on antioxidant properties of bitter gourd

Bitter gourd	Ascorbic acid (mg/ 100g)	Total Polyphenols (mg GAE/ 100g)	Total Flavonoids (mg CE/ 100g)	Tannin (mg TAE/ 100g)	Total Carotenoids (mg/ 100g)	DPPH radical scavenging activity AAEAA (mg/ 100g)	Ferric Reducing Antioxidant Power AAEAA (mg/ 100g)
Fresh	76.33±0.34	36.28±1.34	6.21±0.16	26.24± 0.40	0.98 ±0.03	27.43 ±0.81	17.62 ±0.20
Boiling	7.66±0.33	52.76±1.04	8.37±0.12	44.11± 0.95	0.85 ±0.03	53.25 ±0.95	30.33 ±0.79
Pressure cooking	11.12±0.05	44.69±1.57	7.06±0.17	38.44± 0.65	0.87 ±0.01	41.16 ±1.52	27.21 ±0.34
Microwave cooking	28.80±1.24	42.10±1.82	7.15±0.23	33.18± 0.86	0.86 ±0.03	38.84±0.42	24.13±0.02
Stir frying	18.70±0.08	58.86±2.28	9.14±0.001	47.04±1.65	0.90 ±0.01	55.0 ±2.18	33.15 ±0.05
Frying	ND	40.55±1.13	31.79±1.06	48.45±0.52	ND	33.00±0.95	16.76±0.10
SE.D	0.4891	2.3936	0.4054	0.7645	0.0220	0.9668	0.3870
CD (0.05)	1.0899**	5.1342**	0.8696**	1.6658**	0.0490**	2.0738**	0.8302**

Table 5. Effect of cooking on antioxidant properties of Brinjal

Brinjal	Ascorbic acid (mg/ 100g)	Total Polyphenols (mg GAE/ 100g)	Total Flavonoids (mg CE/ 100g)	Tannin (mg TAE/ 100g)	DPPH radical scavenging activity AAEAA (mg/ 100g)	Ferric Reducing Antioxidant Power AAEAA (mg/ 100g)
Fresh	34.48±1.21	78.88±2.55	3.22±0.06	18.50±0.31	28.75±0.98	15.44±0.09
Boiling	15.00±0.64	148.05±1.46	6.76±0.21	20.50±0.60	12.66±0.26	10.73±0.25
Pressure cooking	7.44±3.00	107.22±3.96	9.37±0.16	31.02±0.67	20.74±0.04	16.91±0.30
Microwave cooking	4.35±0.16	165.83±7.02	9.06±0.20	37.43±0.16	37.77±1.19	16.17±0.42
Stir frying	14.56±4.44	265.55±7.42	10.15±0.07	51.63±1.34	26.66±1.12	21.61±0.39
SE.D	2.1473	3.9675	0.1349	0.7763	0.6832	0.3876
CD (0.05)	4.6786**	8.6445**	0.2939**	1.6914**	1.4886**	0.8446**

Table 6. Effect of cooking on antioxidant properties of tomato

Tomato	Ascorbic acid (mg/ 100g)	Total Polyphenols (mg GAE/ 100g)	Total Flavonoids (mg CE/ 100g)	Tannin (mg TAE/ 100g)	Total Carotenoids (mg/ 100g)	DPPH radical scavenging activity AAEAA (mg/ 100g)	Ferric Reducing Antioxidant Power AAEAA (mg/ 100g)
Fresh	24.75±0.89	30.06±1.08	4.60±0.16	20.82 ±0.11	4.84 ±0.21	38.95 ±1.26	22.27 ±0.20
Boiling	ND	35.92±0.77	12.50±0.54	26.67 ±0.62	4.02 ±0.08	56.47 ±0.76	32.14 ±0.75
Pressure cooking	ND	41.00±1.18	14.10±0.17	31.93 ±0.34	4.14 ±0.08	73.80 ±1.79	44.35±0.39
Microwave cooking	2.18±0.07	39.87±1.43	9.41±0.39	27.63 ±0.54	3.98 ±.16	64.70 ±1.86	35.71 ±0.12
Stir frying	1.14±0.03	51.75±2.05	14.70±0.59	35.13±0.88	3.97 ±0.03	90.30 ±2.68	48.68±2.01
SE.D	0.4221	1.1228	0.3385	0.4629	0.0180	1.4640	0.8054
CD (0.05)	1.0328**	2.5018**	0.7541**	1.0314**	0.0401**	3.2620**	1.7944**

Effect of cooking on antioxidant properties of carrot

Carrots were found to contain good amounts of carotenoids than other components. Cooking did not bring about much improvement in antioxidant activity which is also observed in the content of antioxidant components in the cooked samples (Table 2). Gayathri *et al*. (2004) found that pressure cooking reduced the beta carotene content of carrot (27 per cent) than boiling in water (16 per cent) for a similar period. Miglio *et al.* (2008) reported that the FRAP activity increased by 114 per cent, 81 per cent and 379 per cent in boiled, steamed and fried carrots respectively on DWB.

Yamaguchi *et al.* (2001) reported that carrot had a very poor radical-scavenging activity in spite of its high content of β carotene. Since β carotene is an efficient singlet oxygen quencher but is not a hydrogen donor in the present DPPH-HPLC reaction system.

Effect of cooking on antioxidant properties of small onion

Table 3 indicates that small onion contained more of ascorbic acid and poly phenols. Ascorbic acid was lost in all types of cooking. Poly phenols, flavonoids and tannins increased to a very small extent upon stir frying. Antioxidant activity remained close to that of fresh one. Ioku *et al*. (2001) found that boiling of onion leads to about 30% loss of quercetin glycosides, which leaches in to the boiling water. Microwave cooking without water better retains flavonoids and ascorbic acid. It is reported that the cause for change of bioactive substances, antioxidant property in onions following various cooking procedures can be explained by their different physical characters such as matrix softening, texture, color and increased extractability.

Effect of cooking on antioxidant properties of bitter gourd

Bitter gourd (Table 4) contained appreciable amount of ascorbic acid which was lost on cooking particularly boiling. Poly phenols, flavonoids and tannins showed significant increase upon all the cooking methods, the highest being in stir frying. Carotenoids showed small losses upon cooking, the least being in stir frying. DPPH and FRAP assay showed that stir frying is the best way to retain antioxidant activity. Aminah and Permatasari, (2013) stated that deep frying of bitter gourd had the highest total phenolic content followed by microwave cooking. However, microwave cooked samples have significantly higher percentage of DPPH radical scavenging activity (88.54%) and FRAP (65.85 µmol/g FE) compared to oven-dried, boiling or deep frying. Xie *et al*. (2015) reported that as for bitter gourd, all three cooking methods caused significant elevation of water soluble phenolic content: microwaving (70%), boiling (65%) and pressure-cooking (17%). According to Zhi-xiang *et al.* (2011) the FRAP activity increased by 272 per cent in bitter gourd after boiling, 231 per cent in microwave cooking and 27 per cent in pressure cooking.

Effect of cooking on antioxidant properties of brinjal

Table 5 shows that brinjal has appreciable amounts of ascorbic acid in the fresh state but is lost upon cooking by all the four methods. Poly phenols and tannins showed 2 to 3 fold increase on cooking, with stir frying showing best retention. Flavonoids showed marginal increase upon cooking. There was a small increase in antioxidant activity particularly in microwave cooking and stir frying. The result is in agreement with Chumyam *et al*. (2013) who reported that microwave cooking caused the highest antioxidant capacity, followed by steaming, and boiling. The possible reason is that phenolic and antioxidant compounds activated by microwaving were retained in eggplant fruits, whereas cooking by boiling and steaming processes released them to water, as fruits heated with these two methods have direct and indirect contact with hot water, respectively. Kalkan and Yucecan (2013) in their study reported minimum loss of antioxidant activity was acquired with steaming whereas maximum loss occurred with frying in oil and boiling in large volume of water in eggplant.

Effect of cooking on antioxidant properties of tomato

Tomatoes were found to lose much vitamin C and carotenoids on cooking (table 6). Poly phenols and tannins increased in all the four methods of cooking. Stir fried samples contain more of these antioxidants. Flavonoid content increased nearly three folds upon cooking. Stir fried tomatoes exhibited highest antioxidant activity in both assays. The results are in agreement with the findings of Saikia and Mahanta (2013) who reported that cooking methods significantly increased the antioxidant component and activity. Among the three cooking methods employed, boiling showed highest antioxidant activity and steaming retained more poly phenols and flavonoids. The possible reason for the above results could be that there are many hundreds of different phytochemicals present in food and each has different characteristics of reacting to the changes in their cellular matrix caused by heat treatments or cooking.

This could lead to an increase or decrease in the antioxidant activities of the vegetables. In some cases, increase in antioxidant activity was observed due to transformation of phytochemicals into more active compounds like deglycosylation of some flavonoids. Other factors like polymerization of polyphenols during cooking may result in higher antioxidant activities (Nicoli *et al.,* 1999). Apart from these, inactivation of oxidative enzymes which are responsible for increase in oxidation of phenolic compounds could lead to an increased activity. Moreover, enhanced antioxidant activity could also be witnessed due to the production of novel compounds due to Maillard reaction (Morales and Babel, 2002). Application of heat during cooking involves changes in the structural integrity and cellular matrix of the vegetables and this causes both positive and negative effects on the phytochemical properties. It was observed that cooking caused a significant change in the phenolic and flavonoid content in the selected vegetables. Usually, thermal treatments have destructive effect on the flavonoid and phenolic compounds as they are highly unstable compounds (Ismail *et al.,* 2004).

Conclusions

Antioxidant constituents such as ascorbic acid and carotenoids were found to be lost by the different cooking methods. On the other hand total poly phenols, total flavonoids, tannin and the antioxidant activities increased by the heat treatments. The present study indicates that processing of vegetables, particularly cooking can enhance antioxidant potential by inhibition of enzyme activity and transformation of antioxidants into more active compounds on contrary to the common belief that the antioxidant concentrations and activities in processed vegetables are lower than those of the corresponding raw samples. However, the extent of increase depended on the cooking methods employed. Stir frying of vegetables is a very common method of preparing vegetables in South India. It involves minimum cooking time and use of minimum water to cook thus helping to retain the potency of antioxidant compounds at the same time softening of the tissue which perhaps makes them more available. It is important to adopt milder methods of cooking or processing so as to retain and derived the goodness of nutrients and bioactive compounds that we required badly to keep away major diseases.

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