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Effect of Dry Heat Treatment of Six Spices on Antioxidant Activity of their Water Extracts

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ABSTRACT

This study investigated the effect of dry heat on the antioxidant capacity of water extracts of six spices, namely black pepper (*Piper nigrum* Linn.), cumin (*Cuminum cyminum* Linn.), clove (*Syzygium aromaticum* Linn.), cinnamon (*Cinnamomum verum*, syn. *C. zeylanicum* Blume), sumac (*Rhus coriaria* L.) and golpar (*H. persicum* Desf. Ex.), which were either roasted or heated in a microwave oven, powdered and extracted with water. Untreated spices served as controls. The antioxidant capacities of water extracts of spices were measured by reducing power, DPPH assay and total antioxidant capacity. Varying results were obtained depending upon the assay used and the spice. Clove had the highest radical scavenging activity (85.5% at 0.2 mg level) among all six spices and it was higher than the control in heat-treated samples. Heat-treated samples of cinnamon showed significantly lower activity with reducing power (0.609-1.910) but not with other assays whereas black pepper and cumin exhibited higher activities with reducing power (ranging from 0.276-1.026). Roasted golpar sample also had a higher antioxidant potential in all assays, but sumac was significantly different only in the DPPH assay. Microwave treatment did not affect the antioxidant activity of sumac. Results indicate that heat treatment of spices influenced the antioxidant activity of their water extracts.

Keywords: clove, cinnamon, cumin, pepper, golpar, sumac, microwave, roasting

Abbreviations: DPPH, 1,1-diphenyl-2-picryl hydrazyl; **RP**, reducing power; **RSA**, radical scavenging activity, **TAC**, total antioxidant activity

INTRODUCTION

Among the many dimensions of quality of foods, the health promoting quality is associated with the disease preventive role attributed to the presence of bioactive or antioxidant components of foods. Deterioration of food quality occurring during different processing treatments and storage is related to oxidative processes, which are often catalyzed by ferrous or copper ions (Halliwell 1997). Usually synthetic antioxidants such as butylated hydroxy anisole, or butylated hydroxy toluene are used to decelerate these processes, however, they are volatile and easily decompose at high temperatures. Additionally, it is still unclear whether chronic consumption can lead to health risks (Martínez-Tomé *et al*. 2001). In recent years, interest in plant-derived food additives has grown due to their naturalness. Many herbs and spices used for flavoring dishes are often an excellent source of phenolic compounds with good antioxidant activity; hence they may serve as natural food preservatives. They also contain essential oils, which carry flavor and show antioxidant activity (Benkeblia 2007).

The use of spices for culinary purposes is a universal practice. While some spices are common and associated with different ethnic cultures all over the world, others are specific to certain geographical locations. Black pepper, clove, cumin and cinnamon are used widely in Asian and European countries, whereas the use of sumac and golpar is limited to certain regions in the Persian gulf. Black pepper (*Piper nigrum Linn.*), known as king of spices is famous for its pungency and aroma. It is an important ingredient of indigenous medicine. The various medicinal uses of black pepper are for improving digestion, for cold, cough, sore throat and toothache and for treating worms and piles. Cloves (*Syzygium aromaticum Linn.*) are the dried flower buds of a tree of myrtle family (*Myrtaceae*). Cloves are aromatic, stimulant and carminative and are used for gastric irritation and dyspepsia. Cloves are also known to promote enzymatic flow and boost digestive functioning (Selvan 2003). Sesquiterpenes, found in clove, are said to be potential anticarcinogenic agents (Zheng *et al.* 1992). Cumin (*Cuminum cyminum* Linn.) is small slender annual herb of the coriander family *Umbelliferae* and used for many digestive disorders. It is also indicated in relieving sleeplessness and for amnesia or dullness of memory. Cinnamon (*Cinnamomum zeylanicum* Blume) from the family of *Lauraceae* is taken from the inner bark of cinnamon trees. It prevents nervous tension, improves complexion and memory. It is also a stimulant, relieves flatulence and is a diuretic. It is said to be an effective remedy for common cold (Selvan 2003).

Sumac (*Rhus coriaria* L.) a member of the *Anacardiaceae* family, grows in the region extending from the Canary Islands over the Mediterranean coast line to Iran and Afghanistan. Sumac has strong antioxidant and antibacterial activity owing to the presence of tannins (hydrolysable gallatannins), flavonoids (fustin, fisetin, sulfuretin, butein, quercetin and mycetin) and essential oil (Lauk *et al*. 1998; Nimri *et al*. 1999; Digrak *et al*. 2001; Sağdic and Özcan 2003; Zalacain *et al*. 2003; Nasar-Abbas *et al.* 2004; Son *et al*. 2005). Medicinal uses of the spice have been indicated for digestion and bowel problems and it is said to have diuretic and antipyretic properties. Golpar (*H. persicum* Desf. Ex Fischer) is an annual herb, indigenous to the Alborz region, the northern part of Iran, where it grows at an altitude ranging from 2000 to 3000 m (Mandenova 1987). Its fruits are used commonly in Iran as spices. Souri *et al*. (2004) analyzed bioactive components in fruits of *Heracleum persicum Desf. ex* Fisher and isolated four furanocoumarins that exhibit antioxidant activity.

Foods are subjected to heat processing to convert them

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to an edible form and to extend the shelf life of food products. However, there is a possibility that some of the natural components could be significantly lost during the thermal processing, as most of the bioactive compounds are relatively unstable to heat. Therefore, heat-processed foods are considered to have a lower health promoting capacity than the corresponding fresh one. Recently even mild thermal processing techniques such as blanching have raised concern regarding their impact on functional components, though they are important pre-treatment procedures for preserving foods and for maintaining functional attributes including texture, flavor, and color (Roy *et al.* 2007). However, recent studies have shown that thermally processed foods, especially fruits and vegetables, have higher biological activities due to various chemical changes taking place during heat treatment (Kim *et al.* 2000; Dewanto *et al.* 2002). Many antioxidant phenolic compounds in plants are present in a covalently bound form with insoluble polymers (Niwa and Miyachi 1986; Peleg *et al*. 1991). Heat treatment is one of the effective methods to liberate antioxidants and to obtain natural antioxidants from plants (Nicoli 1997; Niwa *et al.* 1988; Duh *et al*. 2001; Lee *et al.* 2003).

Most spices undergo a roasting step before they are added to a dish. Roasting or dry heat treatment enhances the flavour quality of spices. Roasting is carried out at a high temperature for a short time, which can alter the efficacy of bioactive components. The objective of this investigation was to study the effect of dry heat treatments, namely roasting and microwaving, on the antioxidant activity of certain selected spices which are used in Iran for culinary purposes namely, black pepper, cumin, clove, cinnamon, sumac and golpar.

MATERIALS AND METHODS

Materials

Whole spices namely black pepper (*Piper nigrum* Linn.), cumin (*Cuminum cyminum* Linn.), clove (*Syzygium aromaticum* Linn.) and cinnamon (*Cinnamomum verum*, syn *C. zeylanicum Blume*) were purchased from a supermarket in Mysore, India in a clean and packed form. Sumac (*Rhus coriaria* L.) and golpar (*H. persicum* Desf. Ex.) were procured from a market in Rasht city of Iran. All the chemicals purchased were of AR grade from Sd Fine chemicals, and Qualigens Ltd., Mumbai, India. DPPH (1,1,-dephenyl-2-picrylhydrazyl) was procured from Sigma Chemical Co., U.S.A. Glass double distilled water was used for all analyses.

Methods

Whole spices were divided into three sets. One set (50 g) was roasted on medium flame for 5 min with continuous stirring in a metal pan. Another set was microwaved for a total of 2 min at high power with intermittent stirring. The time of dry heat treatment was standardized after initial trials with each sample. Emission of a strong aroma of roasted spice was taken as the end point. The roasted spices were cooled and powdered immediately in a grinder to pass through a 40-mesh sieve and stored in airtight PET (polyethylene terephthalate) bottles under refrigeration at 4°C until further use. The third set of unheated spices served as controls. These were also powdered and stored in PET containers under similar conditions.

Preparation of water extract

One g of powdered spice sample was suspended in 100 ml distilled water and shaken at a constant rotating speed of 150 rpm/min in a water bath shaker for 30 min. It was centrifuged for 10 min at 4000 × *g* and filtered through Whatman No. 1 filter paper to get a clear extract. Fresh extract was used for each experiment. Antioxidant activity of all extracts were measured by standard techniques such as reducing power, DPPH, and phosphomolybdenum complex assay as given below. All extracts were made in duplicate and all analyses were conducted in triplicate. Hence, the results represent average and standard deviations of six determinations for all samples. Since ascorbic acid is water soluble antioxidant, it was used as a standard for comparison.

Determination of antioxidant activity by reducing power

The reducing power (RP) was determined by the method of Oyaizu (1986). One ml of extract was mixed with 2.5 ml of phosphate buffer (2 mol/1, pH 6.6) and 2.5 ml of potassium ferricyanide ($K_3Fe(CN)_6$; 1%), and incubated at 50°C for 20 min. Thereafter, 2.5 ml of 10% trichloro acetic acid was added to the mixture, which was then centrifuged at 4000 × *g* for 10 min. Finally, 2.5 ml of the supernatant solution was mixed with 2.5 ml distilled water and 0.5 ml $FeCl_3$ (0.1%) and absorbance was measured at 700 nm. Increased absorbance of the reaction mixture indicated increasing reducing power. Water extract without reagents was used as negative control.

Determination of antioxidant activity by DPPH

Free radical scavenging activity (RSA) was measured using the method of Shimada *et al.* (1992). A solution of 0.1 m mol of DPPH in methanol was prepared, 1 ml of this solution was mixed with 3 ml of extract, and after 30 min of incubation the absorbance was measured at 517 nm. Water extract without reagent was used as negative control. The DPPH concentration in the reaction medium was calculated from the following formula; percent free radical scavenging activity = (control OD- sample OD/control OD) X 100.

Determination of antioxidants by total antioxidant capacity

This assay is based on the reduction of Mo(VI) to Mo(V) by the sample and the subsequent formation of a green phosphate/Mo(V) complex at acidic pH (Prieto *et al.* 1999). An aliquot of 0.1 ml of sample solution was combined in an Eppendorf tube with 1 ml of reagent solution (0.6 M sulphuric acid, 28 mM sodium phoshphate, and 4 mM ammonium molybdate). The tubes were capped and incubated in a thermal block at 95°C for 90 min. After the samples had cooled to room temperature; the absorbance was measured at 695 nm against a blank. A typical blank solution contained 1 ml of reagent solution and the sample, and it was incubated under the same conditions as the rest of the samples. The antioxidant activity of extracts was expressed as equivalents of ascorbic acid.

Statistical analysis

The results of the analysis were subjected to statistical analysis to determine the significant difference between the control and thermally treated samples using a student's *t*-test. The level of probability was fixed at $P<0.05$.

RESULTS

Antioxidant activity of spices determined using reducing power assay

The antioxidant activity of spices determined using RP assay is presented in **Table 1**. In all the spices the antioxidant activity was dose-dependent and exhibited an increase with increasing concentration. Among all spices clove exhibited the highest antioxidant capacity, wherein the RP could be measured at a very low concentration of spice, i.e., 0.2-0.8 mg. Untreated spice (0.8 mg) exhibited an absorbance of 0.845 at 700 nm. On application of heat treatments – microwave and roasting – a significant increase in antioxidant capacity was observed compared to the control sample.

The RP of cinnamon, however, exhibited a different trend. At 2.0 mg concentration, the control sample had an absorbance of 0.66, which increased to 2.016 when the concentration was increased to 8.0 mg. The microwaved sample comparatively had a lower absorbance of 0.657 and 1.91, respectively. On roasting, there was a further decrease in absorbance indicating that heat treatment lowered the anti-

Table 1 Effect of thermal treatment on reducing power of spices (absorbance at 700 nm).

Ascorbic acid				
Concentration (mg)	**0.025**	**0.05**	**0.075**	**0.1**
Standard	0.207 ± 0.029	0.449 ± 0.031	0.510 ± 0.009	0.988 ± 0.011
Clove				
Concentration (mg)	**0.2**	**0.4**	**0.6**	**0.8**
Control	0.328 ± 0.010	0.502 ± 0.031	0.699 ± 0.007	0.849 ± 0.027
Microwave	0.412 ± 0.011	0.620 ± 0.018	0.8235 ± 0.020	1.027 ± 0.022**
Roasted	0.470 ± 0.036	0.655 ± 0.042	0.892 ± 0.016	1.084 ± 0.027**
Cinnamon				
Concentration (mg)	**2.0**	**4.0**	**6.0**	**8.0**
Control	0.660 ± 0.004	1.090 ± 0.126	1.553 ± 0.050	2.016 ± 0.004
Microwave	0.657 ± 0.037	1.041 ± 0.017	1.460 ± 0.036	1.910 ± 0.012*
Roasted	0.609 ± 0.007	0.993 ± 0.031	1.349 ± 0.059	1.707 ± 0.010*
Black pepper				
Concentration (mg)	**5.0**	**10.0**	**15.0**	**20.0**
Control	0.283 ± 0.007	0.477 ± 0.005	0.664 ± 0.006	0.814 ± 0.003
Microwave	0.311 ± 0.006	0.523 ± 0.008	0.713 ± 0.011	0.897 ± 0.024*
Roasted	0.337 ± 0.013	0.574 ± 0.010	0.789 ± 0.018	1.026 ± 0.024*
Cumin				
Concentration (mg)	**5.0**	**10.0**	**15.0**	**20.0**
Control	0.276 ± 0.004	0.466 ± 0.056	0.643 ± 0.004	0.814 ± 0.005
Microwave	0.287 ± 0.007	0.485 ± 0.009	0.679 ± 0.016	0.874 ± 0.034*
Roasted	0.322 ± 0.005	0.527 ± 0.010	0.722 ± 0.016	0.896 ± 0.008**
Golpar				
Concentration (mg)	**5.0**	**10.0**	**15.0**	**20.0**
Control	0.192 ± 0.004	0.292 ± 0.005	0.382 ± 0.004	0.474 ± 0.004
Microwave	0.240 ± 0.016	0.313 ± 0.013	0.391 ± 0.014	0.467 ± 0.003ns
Roasted	0.281 ± 0.006	0.386 ± 0.022	0.476 ± 0.007	0.551 ± 0.012***
Sumac				
Concentration (mg)	**1.0**	**2.0**	**3.0**	**4.0**
Control	0.811 ± 0.012	1.239 ± 0.004	1.572 ± 0.008	1.894 ± 0.008
Microwave	0.824 ± 0.044	1.364 ± 0.009	1.922 ± 0.093	2.537 ± 0.065ns
Roasted	0.799 ± 0.039	1.303 ± 0.082	1.789 ± 0.011	2.311 ± 0.046ns

Values represent average ± standard deviation of six determinations.

oxidant capacity of cinnamon.

The antioxidant capacity of water extracts of black pepper, cumin and golpar could be measured with 5-20 mg concentration. The water extract of unheated pepper at 5.0 mg concentration exhibited an absorbance of 0.283. On microwaving and roasting the sample, there was a slight increase in absorbance (0.311 and 0.337, respectively). The trend was evident in all other ranges of concentration. The increase in antioxidant activity of heated spice extract was marginally significant in comparison with the control. The water extract of unheated cumin had almost similar values as pepper at 5.0 mg concentration. However, heat treated samples exhibited lesser absorbance, though they were significantly higher than control.

Among all the spices examined Golpar had lowest absorbance. At 5.0 mg concentration, it had an absorbance of 0.192, which increased to 0.474 at 20 mg level. On microwave heat treatment, these values showed a slight insignificant increase ranging from 0.240 to 0.467. On roasting there was a significant increase of 0.281 and 0.551 in absorbance indicating that roasting altered the antioxidant activity in Golpar ($P \leq 0.001$). The antioxidant activity of sumac on the other hand was very high as seen in absorbance ranging from 0.811 to 1.894 for 1 and 4 mg of sample, respectively. Though microwave and roasted sample exhibited an increase in absorbance, statistically the difference was non- significant on application of student's *t*-test.

Antioxidant activity of spices determined using DPPH assay

The antioxidant activity of spice as measured by DPPH assay is presented in **Table 2**. The antioxidant activity of clove could be measured at low concentration of 0.05–0.2 mg indicating that clove is a powerful antioxidant. The RSA of water extract of control sample was 42.1% at 0.05 mg concentration and increased to 85.5% for 0.2 mg of sample. On microwaving, the sample exhibited a significant increase in antioxidant activity, which was 5-16% higher at different concentrations of spice tested. Roasted sample also showed an increase in antioxidant activity, though it was to a lesser extent than microwave sample. The RSA of cinnamon was 11% at 0.05 mg and increased to 39.0% at 0.2 mg concentration. On microwaving an increase was observed in RSA, which varied from 13.1–55.2% for different concentrations of sample. This was significantly different from control at $P<0.05$. The roasted sample also exhibited significantly higher activity than control. The antioxidant activity of essential oils of clove and cinnamon as reported by Tomaino *et al.* (2005) at room temperature was 34.8 and 55.3%, respectively.

The antioxidant activity of black pepper and cumin were lower in comparison to clove and cinnamon, hence a higher concentration was used to measure RSA. Black pepper exhibited 6.8–24.3% RSA for different samples. There were no differences between control and roasted samples, but the RSA of microwave-heated sample was significantly lower than control.

Cumin however, exhibited a very different profile wherein a progressive decrease in antioxidant activity of samples heated in microwave and roasted samples was observed. The extent of decrease was more prominent at higher concentration level tested. Golpar also showed a similar trend, wherein the microwave and roasted samples had lower antioxidant activity than the control. The RSA of control sample ranged from 20.3–51.4% whereas that of microwave and roasted samples ranged from 14–40 and 12.1–35.6%, respectively. The differences were significant in comparison with control ($P<0.05$). The RSA of sumac, which showed antioxidant activity at much lower concentration of 0.1–0.4 mg ranged between 40.7–84.9% for control sample. There was no difference in antioxidant activity of microwaved sample, wherein values were similar, but on roasting a significant increase was noted.

Table 2 Effect of thermal treatment on free radical scavenging activity of spices (%).

Ascorbic acid				
Concentration (mg)	**0.01**	**0.02**	**0.03**	**0.04**
Standard	27.7 ± 0.043	61.0 ± 0.008	82.6 ± 0.003	97.2 ± 0.001
Clove				
Concentration (mg)	**0.05**	**0.1**	**0.15**	**0.2**
Control	42.1 ± 0.720	57.1 ± 2.311	71.8 ± 0.591	85.5 ± 0.581
Microwave	57.7 ± 1.621	73.7 ± 0.966	84.5 ± 0.689	90.7 ± 0.388**
Roasted	56.2 ± 0.880	71.3 ± 0.864	82.3 ± 0.488	89.8 ± 0.271**
Cinnamon				
Concentration (mg)	**0.05**	**0.1**	**0.15**	**0.2**
Control	11.0 ± 0.462	20.7 ± 0.909	30.0 ± 0.806	39.0 ± 0.691
Microwave	13.1 ± 1.418	27.7 ± 1.028	41.8 ± 0.327	55.2 ± 0.937*
Roasted	11.7 ± 0.524	22.5 ± 0.519	31.0 ± 01.181	40.0 ± 0.750**
Black pepper				
Concentration (mg)	**0.5**	**1.0**	**1.5**	**2.0**
Control	6.8 ± 0.459	13.8 ± 1.613	19.5 ± 1.386	24.3 ± 0.926
Microwave	6.6 ± 1.275	12.0 ± 0.771	17.0 ± 0.897	22.0 ± 1.630*
Roasted	7.0 ± 0.892	14.0 ± 0.683	19.0 ± 1.593	24.0 ± 1.034ns
Cumin				
Concentration (mg)	**0.5**	**1.0**	**1.5**	**2.0**
Control	18.2 ± 1.711	30.8 ± 1.971	42.8 ± 0.509	54.8 ± 1.166
Microwave	13.0 ± 1.115	23.0 ± 0.697	33.0 ± 1.902	43.0 ± 2.130**
Roasted	9.0 ± 0.672	18.0 ± 0.836	25.0 ± 1.496	33.0 ± 1.174**
Golpar				
Concentration (mg)	**2.0**	**4.0**	**6.0**	**8.0**
Control	20.3 ± 1.290	32.8 ± 1.109	43.5 ± 0.431	51.4 ± 0.628
Microwave	14.0 ± 2.111	23.0 ± 1.185	31.3 ± 0.852	40.0 ± 3.439**
Roasted	12.1 ± 0.95	20.2 ± 2.297	27.8 ± 2.793	35.6 ± 0.728**
Sumac				
Concentration (mg)	**0.1**	**0.2**	**0.3**	**0.4**
Control	40.7 ± 0.689	58.9 ± 0.455	73.2 ± 0.407	84.9 ± 0.568ns
Microwave	42.9 ± 2.197	60.6 ± 2.067	73.9 ± 0.451	84.8 ± 0.793***
Roasted	45.3 ± 1.064	64.7 ± 0.714	79.6 ± 0.629	90.5 ± 0.214

Values represent average ± standard deviation of six determinations.

Table 3 Total antioxidant capacity of dry heat-treated spices (µmoles of ascorbic acid/g).

Spices	Control	Microwave treated	Roasted
Clove	150294 ± 5377	181829 ± 10059	179346 ± 4397
Cinnamon	120654 ± 4656	171738 ± 6712	166307 ± 4092
Black Pepper	35967 ± 1580	29820 ± 901	36209 ± 2021
Cumin	76584 ± 2565	59950 ± 2541	74591 ± 1404
Golpar	56127 ± 600	56715 ± 2563	73169 ± 1211
Sumac	73856 ± 3082	76209 ± 2941	93529 ± 8531

Values represent average ± standard deviation of six determinations.
Comparative value for ascorbic acid: 134216/0.01 mg.

Total antioxidant capacity of heat treated spices

The total antioxidant capacity of heat treated spices presented in **Table 3** showed that both clove and cinnamon showed a very high antioxidant capacity which increased on microwave treatment and roasting. The values for black pepper and cumin were lesser than clove and cinnamon. However, on microwaving there was a decrease in total antioxidant while there was no change on roasting. Golpar and sumac exhibited an opposite trend, wherein, the microwave sample had similar values as control but on roasting a significant increase was observed.

DISCUSSION

Since in the present study three different methods were used to determine the antioxidant capacity of heated spices, it was worthwhile to compare whether the differences were significant in comparison with control or unheated sample and whether methodwise variations were observed in antioxidant properties. The overall results of the study in terms of increased or decreased values and T value as determined by student's *t*-test in comparison to control are presented in **Table 4**.

As can be seen, the thermal treatments of clove increased antioxidant capacity as observed both in microwave and roasted samples analysed by three different methods. This indicates that clove has a very high antioxidant capacity which increases significantly on application of heat ($P<0.01$ and $P<0.001$). Clove is strongly aromatic with intensive fragrance, and a fiery and burning taste. The antioxidant activity in clove is reported to be due to the presence of components such as β-caryophyllene, eugenol and acetyleugenol (Lee and Shibamoto 2001)

For cinnamon, the results were different with different methods. In RP, the values were lower than control, though the differences were marginal ($P<0.05$). When determined as RSA, it was higher than control in microwave and roasted sample ($P<0.05$) on application of student's *t*-test. In total antioxidant capacity, microwave and roasted samples exhibited higher values than control, which were highly signficant ($P<0.001$). The high antioxidant activity of cinnamon is said to be due to components such as cinnamaldehyde, eugenol, and β-caryophyllene (Murica *et al.* 2004)

Tomaino *et al.* (2005) investigated the influence of heating on antioxidant activity of selected spice essential oils. All the spice essential oils exhibited good RSA as determined by DPPH assay. When heated to 180°C, nutmeg oil exhibited a significantly higher RSA. However, this was not seen in other oils investigated, such as basil, cinnamon, clove, oregano and thyme indicating that antioxidant properties of all spices may not respond similarly to heating and variations may be observed. An increase in the RSA and RP of grape seed ethanolic extracts from roasted whole and powdered seeds have been reported by Kim *et al.* (2006).

The sources of antioxidant activity in pepper are reported to be flavonoids, capsaicinoid, phenolic acid, piperin, chavicine, and monoterpenes (Jiménez *et al.* 2003). In black pepper, RP showed marginally higher values in

Table 4 Statistical differences in antioxidant activities as a measure of different assays, processing techniques and type of spice.

Method	Clove	Cinnamon	Black Pepper	Cumin	Golpar	Sumac
Reducing power						
Microwave treated						
Difference from control	+	-	+	+	+	+
'T' value	0.0037**	0.0374*	0.0104*	0.0278*	0.1195 ns	0.0675 ns
Roasted						
Difference from control	+	-	+	+	+	+
'T' value	0.0016**	0.0340*	0.0173*	0.0018**	0.000***	0.0839 ns
DPPH						
Microwave treated						
Difference from control	+	+	-	-	-	=
'T' value	0.0084**	0.0279*	0.0235*	0.0044**	0.0023**	0.0581 ns
Roasted						
Difference from control	+	+	-	-	-	+
'T' value	0.0093**	0.0087**	0.3067 ns	0.0057**	0.0026**	0.0003***
Total Antioxidant Capacity						
Microwave treated						
Difference from control	+	+	-	-	=	+
'T' value	0.0014**	0.000***	0.0004***	0.0001***	0.3202 ns	0.1239 ns
Roasted						
Difference from control	+	+	=	-	+	+
'T' value	0.000***	0.000***	0.377 ns	0.0757 ns	0.000***	0.0012**

Level of significance: ns: not significant, *: $P \leq 0.05$, **: $P \leq 0.01$, ***: $P \leq 0.001$.

both heat treated samples. Radical scavenging activity demonstrated a decrease which was significant only for microwave sample (P<0.05). Total antioxidant capacity was also non-significant for roasted sample but was highly significant for microwave treated sample.

Cumin is one of the commonly used spices in food preparations. It is also used in traditional ayurvedic medicine as a stimulant, carminative and astringent. Cumin seeds are a very good source of iron and a good source of manganese (Thippeswami and Naidu 2005). Cuminaldehyde, cymene and terpenoids are the major constituents of volatile oils of cumin (Behera *et al.* 2004). Different results were also obtained for cumin wherein with reducing power the sample had significantly higher capacity but with DPPH it was significantly lower. With total antioxidant capacity, microwave sample was significantly lower but there was no difference in roasted sample.

With golpar microwave sample did not show any significant difference with reducing power and total antioxidant capacity but was significantly lesser in DPPH assay where the roasted sample was significantly higher in reducing power and total antioxidant capacity.

In sumac, most of the samples did not show any difference except roasted sample with DPPH assay and total antioxidant capacity, which were higher than control and significant at P<0.001 and P<0.05 respectively. Use of Sumac as a natural antioxidant has been recommended by Koşar *et al*. (2007) who investigated the antioxidant activity of fractionated methanolic extract of sumac. They found that the fractions of extract rich in anthocyanins and hydrolysable tannins had high antioxidant activities.

While there are very few studies on antioxidant activities of water extract of heated spices as such, Lee *et al.* (2006) reported the effect of far-infrared radiation and heat treatment on the antioxidant activity of water extract of peanut hulls. They reported an increase in antioxidant activity of water extracts in all samples as determined by RP and DPPH assay. The activities were also reported to increase with increasing time and temperature exhibiting a positive dose dependent response of antioxidant activity to heat treatments.

The results of Roy *et al*. (2007) were in contrast to what was observed by Lee *et al*. (2006). They studied the antioxidant potential of water soluble fractions of thermally treated vegetables and reported that while mild heat treatment (up to 50°C for 10-30 min) did not affect the antioxidant properties significantly, temperatures higher than these had an adverse effect. Similar results were also reported for vegetables on conventional and microwave cooking by Zhang and Hamauzu (2004).

It can be concluded from the overall result of the study that clove exhibited a higher antioxidant potential on microwave and roasting with all the three assays. Cinnamon showed higher activity on heat treatment in two methods of assay (RSA and TAC). Black pepper and cumin had higher activity with RP in both microwave and roasted sample. With TAC, microwave sample showed significantly lower values. Varying results were obtained for golpar, whereas in sumac, only microwave sample showed significantly higher values. Hence, it can be said that the antioxidant potential of water soluble components of spices treated with microwave heat and roasting differed according to the spice.

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