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A Comparative Study on Chemical Composition and Antioxidant Activity of Ginger (*Zingiber officinale*) and Cumin (*Cuminum cyminum*)

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Spices are the building blocks of flavor in foods. This research work was focused on two important spices, i.e., ginger and cumin. Ginger and cumin both are recognized for their antioxidant properties. So, this study was designed to evaluate the chemical composition and antioxidant activity of ginger (*Zingiber officinale*) and cumin (*Cuminum cyminum*). The highest yield for volatile oil was obtained by the cumin sample, which was 2.52 ± 0.11%, while the fresh ginger showed the lowest yield (0.31 ± 0.08%). The analysis of volatile oils of fresh and dried ginger showed camphene, *p*-cineole, α-terpineol, zingiberene and pentadecanoic acid as major components, while the major components in cumin volatile oil were cuminal, γ-terpinene and pinocarveol. In nonvolatile extracts the highest yield was obtained by the methanol extract of cumin (4.08 ± 0.17% w/w), while the *n*-hexane extract of fresh ginger showed the lowest yield (0.52 ± 0.03% w/w). Maximum total phenolic contents were observed in the methanol extract of fresh ginger (95.2 mg/g dry extract) followed by the hexane extract of fresh ginger (87.5 mg/g dry extract). The hexane extract of cumin showed the lowest total phenolic content (10.6 mg/g dry extract). The DPPH method showed the highest antioxidant activity for cumin essential oil (85.44 ± 0.50%) followed by dried ginger essential oil (83.87 ± 0.50%) and fresh ginger essential oil (83.03 ± 0.54%). The FRAP of essential oils showed almost comparative results with DPPH. Cumin essential oil was found best in reducing Fe^{3+} ions, followed by dried and fresh ginger. Our results suggest that both ginger and cumin can be used as potential sources of natural antioxidants in foods.

KEYWORDS: Ginger; cumin; essential oil; antioxidants; phenols

INTRODUCTION

Nowadays, food professionals are continually searching for "new" and unique spice flavorings because of the rising global demand for authentic ethnic and cross-cultural cuisines. Consumers are also in quest of natural foods and natural preservatives for healthier lifestyles and natural ways of preventing ailments. So, spices are being sought for their medicinal value, as antioxidants and as antimicrobials (*1*).

The spice ginger is obtained from the underground stems or rhizomes of *Zingiber officinale* (Rosc.), family Zingiberaceae. Ginger rhizome is typically consumed as a fresh paste, dried powder, slices preserved in syrup, or candy (crystallized ginger) or for flavoring tea. The underground stem or rhizome of this plant has been used as a medicine in Asian, Indian and Arabic herbal traditions since ancient times (*2*). It has been used in herbal medicine practice for the treatment of arthritis, rheumatological conditions and muscular discomfort (*3*). Ginger has also been suggested for the treatment of various other conditions, including atherosclerosis, migraine headaches, rheumatoid arthritis, high cholesterol, ulcers, depression, and impotence. In addition to these medicinal uses, ginger continues to be valued around the world as an important cooking spice and is believed to help against common cold, flu-like symptoms, and even painful menstrual periods (*4*).

Cumin is a strong aromatic dried ripe fruit (seed) of *Cuminum cyminum* L. It belongs to the Apiaceae family (parsley family). Cumin seeds are ancient spices with a strong aromatic smell and warm, bitterish taste. It is widely used as a condiment and flavoring in many eastern dishes. Cumin is a common flavor in confectionery, meat, sausage and bread manufacturing and as a preservative in food processing (*5*). Cumin not only is a spice but also has great medicinal value. Cumin is used widely in traditional medicine to treat flatulence, digestive disorders, and diarrhea and in the treatment of wounds. It is valuable in dyspepsia, diarrhea and hoarseness, and as remedy against indigestion and colic (*6*).

The essential oil from ginger is pale yellow in color and ranges from 1% to 4%, depending upon the variety. Raghavan (*1*) described that the essential oil of ginger is a mixture of monoterpenic and sesquiterpenic compounds. The most important chemical component of cumin fruits is essential oil content, ranging from 2.5% to 4.5%, which is pale to colorless depending

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on age and regional variations. The essential oil is responsible for the characteristic cumin odor. The odor and flavor are due principally to the aldehydes present. Cumin is a potent antioxidant capable of scavenging hydroxy, peroxy and DPPH free radicals and thus inhibits radical-mediated lipid peroxidation (*7*).

Natural antioxidants are of plant origin, and they include vitamins, phenolic compounds and flavonoids (*8*). The recent research activities are focused on finding natural sources of antioxidants as consumers are more conscious about their diet, and synthetic antioxidants are being restricted these days due to their carcinogenicity. Thus there is growing trend in searching for antioxidants of natural origin. Spices are an excellent source of antioxidants, and some of them even outperform the synthetic antioxidants and are safer also from the health point of view. The research project was planned for the isolation of volatile and nonvolatile compounds from ginger and cumin by using hydrodistillation and solvent extraction, respectively, and analysis of volatile compounds isolated from ginger and cumin by using GC−MS. Antioxidant activities of volatile and nonvolatile extracts of ginger and cumin by different methods such as DPPH and ferric reducing power were also determined.

MATERIALS AND METHODS

Procurement of Samples and Chemicals. Fresh rhizomes of ginger and cumin seeds were procured from the local market of Faisalabad Pakistane. The samples were kept in a freezer at −18 °C to avoid the loss of chemical compounds and maintain their quality. The chemicals and reagents used in the study were *n*-hexane, methanol, Folin−Ciocalteu reagent, gallic acid, anhydrous sodium carbonate, 1,1-diphenyl-2-picrylhdrazyl (DPPH), potassium hexacyanoferrate, trichloroacetic acid, ferric chloride and phosphate buffer. All the chemicals and reagents were of either analytical or lab grade. All the standard compounds for volatile components were bought from Sigma Chemical Company.

Drying of the Ginger Rhizomes. The ginger rhizomes were dried in shade for 2 days. The initial weight before drying and final weight of the samples after drying were noted. After drying the sample was ground in powder form and kept in a dry place for further analysis. Fresh sample of ginger was used for chemical analysis after crushing, and the cumin sample was used in ground form.

Proximate Analysis of Ginger and Cumin. All the samples (fresh ginger, dry ginger and cumin) were analyzed for the moisture, ash, fat and protein contents according to methods No. 44-15A, 08-01, 30-25, 46-30 and 32-10, respectively, as given in AACC (*9*). Carbohydrate contents of cumin and ginger were determined as nitrogen free extract (NFE) by the following formula:

$$\text{NFE}\,\% = 100 - (\text{moisture} + \text{crude fat} + \text{crude protein} + \text{crude fiber} + \text{total ash})$$

Extraction of Volatile Compounds. The volatile compounds were extracted by using hydrodistillation (*10*). A weighed amount of all the samples (100 g) was put in the Clevenger type apparatus and filled with distilled water. Then these samples were heated up continuously for 3 h. Heating was stopped after 3 h. The experiment was repeated three times, and the essential oil obtained was collected in the sample tubes and stored in the freezer at −18 °C for further analysis.

Identification of Volatiles. Volatile compounds were identified by using GC−MS (*11*). Volatile compounds in the essential oil were identified by comparison with the Kovats gas chromatographic retention index (KI) and by the mass spectral fragmentation pattern of each GC component compared to those of authentic compounds. An Agilent model 6890 gas chromatograph equipped with a 30 m × 0.25 mm i.d. (df) 0.25 μm) bonded phase DB-1 fused silica capillary column (Agilent, Folsom, CA) and a flame ionization detector (FID) was used to obtain the KI, which also was compared to published data. The oven temperature was programmed from 35 to 220 at 3 °C/min and held for 40 min. The linear helium carrier gas flow rate was 29 cm/s. The injector temperature was 200 °C, and the detector temperature was 250 °C.

Extraction of Nonvolatile Compounds. The nonvolatile compounds were extracted by the solvent extraction method (*10*). A weighed amount of all the samples (300 g for fresh and 125 g for dried samples) was taken in a flask, and the flask was filled with the solvent (*n*-hexane or methanol) until a layer was formed above the sample. These samples were continuously shaken for 48 h with the 3 h interval. Then these were filtered by filter paper, and the extract obtained was subjected to rotary evaporation for the removal of solvent from the samples. The distillation was stopped when the volume of extract remained ∼1−2 mL. The solvent was further removed under a purified N_2 stream. The experiment was repeated three times, and the samples were stored under N_2 in sealed vials at −5 °C until further analysis.

Total Phenolic Content (TPC). The total phenolic compounds were estimated by the Folin−Ciocalteu method (FCM) (*12*). From a known concentration of the sample solution 125 μL samples were taken in test tubes. Then 500 μL of distilled water was added to it. After that 125 μL of Folin−Ciocalteu reagent was added to it and was left to stand for 6 min. Then 1.25 mL of 7% sodium carbonate was added to it. The final volume was made 3 mL by addition of 1 mL of distilled water. A standing time of 90 min was given to the samples for completion of reaction. The absorbance of the samples was taken in triplicate at 760 nm by using a UV−vis spectrophotometer. Gallic acid was run as a standard along with the samples, and its absorbance was taken at 725 nm. Its solution was prepared by dissolving 25 mg in 25 mL of distilled water. Concentrations of gallic acid ranging from 0 to 450 μg/mL were used, and its standard curve was used for the calculation of the total phenolic contents in the samples. All the samples were run in triplicate.

Determination of Antioxidant Activity. The antioxidant activity of volatile and nonvolatile compounds was determined by the two methods:

a. 1,1-Diphenyl-2-picrylhdrazyl (DPPH) Scavenging Activity. The free radical scavenging activity of essential oils and solvent extracts of ginger and cumin was measured by spectrophotometer at 517 nm (*13*). A methanol solution of DPPH was prepared immediately before the assay. Various concentrations of each sample (40, 80, 120, 160, 200, and 240 μg/mL) were added to a 1 mL DPPH solution. The reaction mixtures were shaken vigorously and allowed to stand for 30 min at room temperature. The absorbance of the samples was measured by a spectrophotometer at 517 nm. In this assay, BHT (butylated hydroxyl toluene) was used as a standard antioxidant to validate the assay. The experiment was repeated three times.

b. Ferric Reducing Antioxidant Power (FRAP). Antioxidant activity was also determined by ferric reducing power using a spectrophotometer at 700 nm (*14*). 1 mL of extract solution (40−240 μg/mL) was mixed with 2.5 mL of phosphate buffer (0.2 M, pH 6.6) and 2.5 mL of 1% potassium hexacyanoferrate. The mixture was incubated at 50 °C for 20 min. 2.5 mL of 10% tricholroacetic acid was then added to the mixture and centrifuged at 3000 rpm for 20 min. A 1 mL aliquot of supernatant was mixed with 2.5 mL of distilled water and 0.5 mL of $FeCl_3$ (0.1%), and absorbance was measured at 700 nm. Increase in absorbance was interpreted as increased ferric reducing activity. Readings were taken in triplicate.

Statistical Analysis. Data obtained was analyzed using the statistical package Costat-2003. Data is presented as mean + standard deviation (*15*).

RESULTS AND DISCUSSION

In this study, fresh and dried samples of ginger rhizomes (*Zingiber officinale*) and dry seeds of cumin (*Cuminum cyminum*) were used to assess their chemical composition and antioxidant activity of their volatile oils and nonvolatile extracts.

Proximate Analysis. The fresh ginger rhizome showed (**Table 1**) the highest moisture content, which was 88.5 ± 0.396, compared to the dry sample of ginger, which was 10.0 ± 0.007. Previous study indicates that moisture content of fresh ginger rhizome is 80% (*16*), which is significantly lower than our results. This may be due to difference in climatic and storage conditions. Cumin showed the lowest moisture content (6.1 ± 0.042%) because its seeds are already in dried form and retain less moisture compared to cumin.

The second major component of the samples was their carbohydrate content, which was calculated as nitrogen free extract

Table 1. Proximate Analysis of Fresh Ginger, Dried Ginger and Cumin[a]

parameter	fresh ginger	dried ginger	cumin
moisture %	88.5 ± 0.39	10.0 ± 0.00	6.1 ± 0.04
crude fat %	0.2 ± 0.01	1.4 ± 0.04	11.5 ± 0.38
crude fiber %	1.1 ± 0.16	8.2 ± 0.36	37.2 ± 0.37
ash %	1.5 ± 0.07	6.1 ± 0.05	9.3 ± 0.24
crude protein %	1.2 ± 0.17	7.2 ± 0.09	15.7 ± 0.32
NFE[b] %	7.6 ± 0.67	67.0 ± 0.15	20.1 ± 0.02

[a] The results are presented as mean ± standard deviation (SD). [b] Nitrogen free extract.

Table 2. Essential Oil Yields of Ginger and Cumin Samples

sample no.	sample	essential oil %
1	fresh ginger	0.31 ± 0.08
2	dried ginger	1.1 ± 0.14
3	cumin	2.52 ± 0.11

The results are presented as Mean ± Standard Deviation (SD)

(NFE). Dried ginger showed highest total carbohydrates, which were 67.0 ± 0.156%, while cumin and fresh ginger had a total carbohydrate content of 20.1 ± 0.021% and 7.6 ± 0.679%, respectively. Crude fiber content was highest in cumin, which was 37.2 ± 0.375%. The literature also shows a high amount of dietary fiber in cumin, which is up to 59% depending upon the varieties (*17*). Protein content is important from the nutritional point of view. The protein content of fresh and dried samples of ginger was 1.2 ± 0.177% and 7.2 ± 0.092%, respectively, on fresh weight basis. The literature shows relatively high protein content compared to these results, which are 2.3% for fresh and 12.4% for dried (*16*, *18*). The reason is high moisture content of our samples, which significantly lowers the other constituents. Cumin sample showed crude protein content of 15.7 ± 0.325%. The crude fat content of the fresh and dry ginger samples was 0.2 ± 0.014% and 1.4 ± 0.049%, respectively, which are significantly lower than the previous study (1.0% for fresh ginger), while cumin had a higher crude fat content, i.e., 11.5 ± 0.389%, which is comparable to the literature where it is indicated 10% (*19*). In the case of ash content cumin showed the highest value, i.e., 9.3 ± 0.247%, while dry and fresh ginger samples showed ash content of 6.1 ± 0.057 and 1.5 ± 0.071%, respectively, which are comparable to the previous literature, where total ash content of dry ginger has been reported 6.64% while for fresh ginger it has been reported 1.2% (*16*).

Extraction of Volatile Compounds. The volatile compounds of ginger and cumin samples were extracted by the hydrodistillation method (*10*). **Table 2** shows yields of the different essential oils which were extracted from ginger (fresh and dried) and cumin samples. Cumin (*Cuminum cyminum*) had the highest amount of volatiles, 2.52 ± 0.11%. These results are comparable to the results present in the literature. Essential oil content of cumin ranged from 2.5 to 4.0% (*19*). The essential oil from ginger is pale yellow in color. The oil gives ginger its characteristic aroma but not its bite. Ginger (*Zingiber officinale*) used in this research had an essential oil content of 0.31 ± 0.08% for fresh samples and 1.1 ± 0.14% for dried ones. These results are in comparison with the results present in the literature, where the essential oil content of dry ginger for most of the varieties is around 1 to 4% depending upon the variety, climatic variation and locality (*1*).

Chemical Composition of Volatile Oils. Volatile compounds of the essential oils of fresh ginger, dried ginger and cumin samples were identified by using gas chromatography. The main volatile compounds identified in the essential oils of fresh and dried ginger are presented in **Table 3**. The major compounds in fresh ginger essential oil were camphene (15.9%), α-terpineol (8.8%), farnesene (8.8%), *p*-cineole (8.4), *β*-mycrene (7.7%), pentadecanoic acid (7.9%), zingiberene (7.5%), geranyl isobutyrate (5.8%), 3,7-dimethyl-1,3,7-octatriene (5.7%), 9,12-octadecadienal (4.9%), 9,12,15-octadecatrienal (4.6%), nerolidol (4.4%) and α-phellandrene (3.9%), while dried ginger had the major compounds as camphene (14.1%), α-terpineol (10.9%), *p*-cineole (9.4%), 9,12,15-octadecatrienal (9.1%), zingiberene (8.4%), pentadecanoic acid (8.0%), farnesene (7.5%), geranyl isobutyrate (7.0%), limonene (3.3%), 9,12-octadecadienal (2.9%), 3,7-dimethyl-1,3,7-octatriene (1.9%), nerolidol (2.0%) and α-phellandrene (1.0%).

Table 3. The Chemical Composition of Essential Oils of Fresh and Dried Ginger (*Zingiber officinale*) Analyzed by Gas Chromatography

		peak area %	
peak no.	compound	fresh ginger	dried ginger
1	butanol		1.1
2	3-methyl butanol	0.9	
3	hexanal		4.0
4	3,7-dimethyl-1,3,7-octatriene	5.7	1.9
5	camphene	15.9	14.1
6	2,3-bis[methylene]bicyclo[3.2.1]octane		2.1
7	*β*-mycrene	7.7	
8	α-phellandrene	3.9	1.0
9	limonene	1.9	3.3
10	*p*-cineole	8.4	9.4
11	3,7-dimethyl-1,6-octadiene-3-ol	0.9	2.6
12	hydrate camphene	1.6	1.9
13	borneol	0.4	2.8
14	α-terpineol	8.8	10.9
15	geranyl isobutyrate	5.8	7.0
16	zingiberene	7.5	8.4
17	farnesene	8.8	7.5
18	nerolidol	4.4	2.0
19	pentadecanoic acid	7.9	8.0
20	9,12-octadecadienal	4.9	2.9
21	9,12,15-octadecatrienal	4.6	9.1

These results are in agreement with the findings of Gong et al. (*20*), who analyzed the essential oil of ginger by GC−MS and reported that the major volatile components present in fresh and dried ginger samples were camphene, *p*-cineole, geranyl isobutyrate, zingiberene, α-terpineol, farnesene, *β*-mycrene and α-phellandrene. An important fact which can be noticed from **Table 3** is the difference between the chemical composition of essential oils of fresh and dried ginger. It can be seen that components like 3-methylbutanol and *β*-mycrene are present in fresh ginger while they were not identified in dried ginger essential oil. Similarly butanol, hexanal and 2,3-bis(methylene)bicyclo-(3.2.1)octane were identified in the essential oil of dried ginger while they were not present in fresh ginger essential oil. There is also a significant difference in the quantities of other components between both samples in terms of 3,7-dimethyl-1,3,7-octatriene, α-phellandrene, limonene, borneol, nerolidol and 9,12,15-octadecatrienal. So, these results conclude that drying had a significant effect on the chemical composition of essential oil of ginger.

The essential oil of cumin was also analyzed for its chemical components. **Table 4** shows the chemical composition of the volatile oil of cumin analyzed by gas chromatography. The results indicated that the major chemical components present in cumin essential oil were cuminal (27.7%), *γ*-terpinene (23.7%), pinocarveol (11.4%), 1-methyl-2-(1-methylethyl)benzene (7.7%), copaene (6.0%), (5*R*)-5-methyl-2-(1-methylethylidene)cyclohexanone (5.5%), carotol (4.4%), 2-ethylidene-6-methyl-3,5-heptadienal (2.8%) and sabinene (1.2%). These results are comparable to the findings of Li et al. (*21*), who studied the chemical composition

Table 4. The Chemical Composition of Essential Oil of Cumin (*Cuminum cyminum*) Analyzed by Gas Chromatography

peak no.	compound	peak area %
1	α-pinene	0.6
2	sabinene	1.2
3	1-methyl-2-(1-methylethyl)benzene	7.7
4	1-methyl-4-(1-methylethyl)-1,4-cyclohexadiene	1.3
5	β-terpineol	0.9
6	linalool	4.9
7	6,6-dimethyl-2-methylene-bicyclo[2.2.1]heptan-3-one	1.1
8	pinocarveol	11.4
9	(5*R*)-5-methyl-2-(1-methylethylidene)cyclohexanone	5.5
10	cuminal	27.7
11	γ-terpinene	23.7
12	2-ethylidene-6-methyl-3,5-heptadienal	2.8
13	myrtenal	0.8
14	copaene	6.0
15	carotol	4.4

Table 5. The Extraction Yield of Nonvolatile Compounds of Ginger (*Zingiber officinale*) (Fresh and Dried) and Cumin (*Cuminum cyminum*) by Using Different Organic Solvents

sample	yield % w/w[a] ± SD[b]
hexane fresh ginger	0.52 ± 0.03
hexane dried ginger	2.47 ± 0.05
hexane cumin	3.51 ± 0.21
methanol fresh ginger	0.69 ± 0.04
methanol dried ginger	2.92 ± 0.08
methanol cumin	4.08 ± 0.17

[a] w/w = on weight/weight basis. [b] SD = standard deviation.

of essential oil of cumin by gas chromatography and found as major components cuminal, γ-terpinene, 2-ethylidene-6-methyl-3,5-heptadienal, (5*R*)-5-methyl-2-(1-methylethylidene)cyclohexanone, 1-methyl-2-(1-methylethyl)benzene and sabinene. However, our results are in contrast to the study of Jalali-Heravi et al. (*22*), who characterized the essential oil components of Iranian cumin. The common components between that study and our results are carotol, sabinene, β-terpineol, linalool, pinocarveol, γ-terpinene, myrtenal, copaene and α-pinene, but there is a significant difference between their quantities. These differences might be due to the different climatic conditions and locality of the samples, which ultimately affects the chemical composition.

Extraction of Nonvolatile Compounds. The nonvolatile flavor components of spices, also referred to as oleoresins, are produced by grinding or crushing the spices, extracting with a solvent, and then removing the solvent. Oleoresins have the full flavor, aroma, and pungency of fresh or dried spices because they contain the high boiling nonvolatiles, including resins and gums that are native to spices (*1*). The nonvolatile compounds of ginger and cumin were extracted by using different organic solvents by the method of El-Ghorab et al. (*10*). Two solvents were used for the extraction, which were *n*-hexane and methanol.

The percent yield of nonvolatile extracts on a weight/weight (w/w) basis is shown in **Table 5**. It is evident that the methanol extracts have higher yield compared to the *n*-hexane extracts. The methanol extract of cumin has the highest yield (4.08 ± 0.17), while the *n*-hexane extract of fresh ginger has the lowest yield (0.52 ± 0.13). These results are in agreement with the findings of Thippeswamy and Naidu (*7*), who found high yield for the nonvolatiles of cumin (*Cuminum cyminum*) extracted with methanol. The yields of nonvolatile extracts of ginger are also in comparison with the findings of Zancan et al. (*23*), who reported the extraction yield of nonvolatiles from ginger (*Zingiber officinale* Roscoe) ranging from 1.93% to 2.65%.

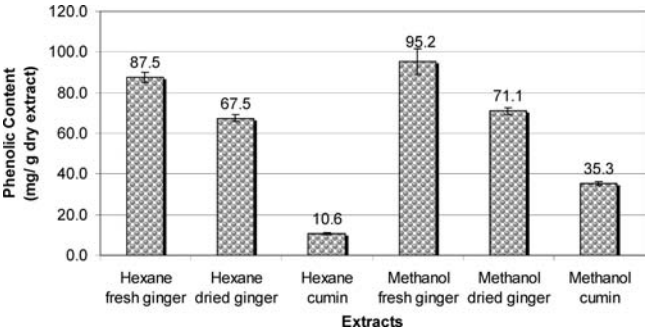

Figure 1. Total phenolic content of hexane and methanol extracts of ginger (fresh and dried) and cumin.

Total Phenolic Contents. Total phenolic content of the *n*-hexane and methanol extracts of ginger and cumin samples was measured by using Folin's reagent. The results are presented as milligrams of gallic acid equivalent (GAE) per one gram of dry extract **Figure 1** shows the total phenolic content of all the three samples for *n*-hexane and methanol extracts. It was shown that methanol extract of fresh ginger had the highest total phenolic content, which reached 95.2 ± 6.2 mg/g dry extract (equivalent to 5.70 mg/g dry weight of the sample). Similarly the *n*-hexane extract of fresh ginger also showed high total phenolics, which were 87.5 ± 2.3 mg/g dry extract (equivalent to 3.96 mg/g dry weight of the sample). These results agree with a previous study in which Shan et al. (*24*) studied the antioxidant activity of the methanol extracts of ginger and estimated its phenolic content, which was 6.3 mg GAE/g dry weight of the sample. In a recent study, Liu et al. (*25*) studied the polyphenol contents and antioxidant capacity of the ethanol extracts of ginger, which showed a total phenolic content of 21.24 mg GAE/g dry weight of sample. This difference from our samples may be due to using different solvents, which significantly affects the quantification of total phenolics. Both the extracts (hexane and methanol) of dried ginger sample showed lower total phenolics compared to the fresh samples, which indicated that drying significantly reduced the amount of total phenolics. Cumin showed the lowest total phenolics, particularly the hexane extract, which was 10.6 ± 0.5 mg/g dry extract, and the methanol extract showed a total phenolic amount of 35.3 ± 1.1 mg/g dry extract. These results are in accordance with the findings of Thippeswamy and Naidu (*7*), who reported the total phenolic content of methanol extracts of cumin to be 9 mg/g dw. In another study, Shan et al. (*24*) found a total phenolic content of 2.3 mg/g dw for 80% methanol extract of cumin. The difference between the results may be due to variation in climate and locality of the plants.

Antioxidant Activity. Antioxidant activity of the volatile and nonvolatile components of fresh and dried ginger (*n*-hexane and methanol extracts) was determined by using DPPH and ferric reducing antioxidant power (FRAP). The results were compared with the synthetic antioxidant BHT, which is an efficient synthetic antioxidant agent in food.

a. 1,1-Diphenyl-2-picrylhydrazyl (DPPH) Scavenging Activity. Different concentrations of the volatile oils and nonvolatile components (*n*-hexane and methanol extracts) of ginger (fresh and dried) and cumin samples were treated with DPPH radical, starting from 40 μg/mL to 240 μg/mL, and the effect of these concentrations on the inhibition of the DPPH radical was studied.

DPPH radical scavenging ability of the essential oils of ginger (fresh and dried) and cumin is depicted in **Figure 2**. Fresh ginger essential oil showed a significant effect in inhibiting DPPH radical, reaching up to 83.03 ± 0.54%, at a concentration 240 μg/mL.

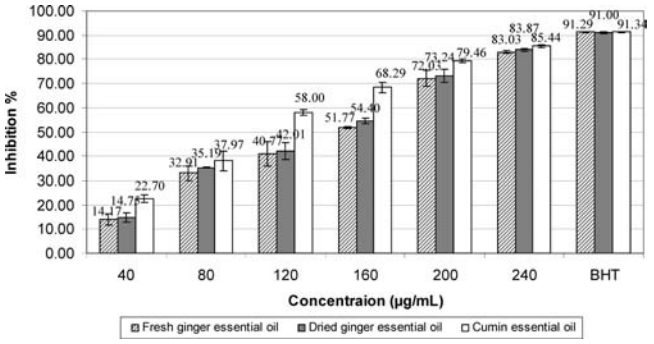

Figure 2. DPPH assay of the essential oils of ginger (fresh and dried) and cumin.

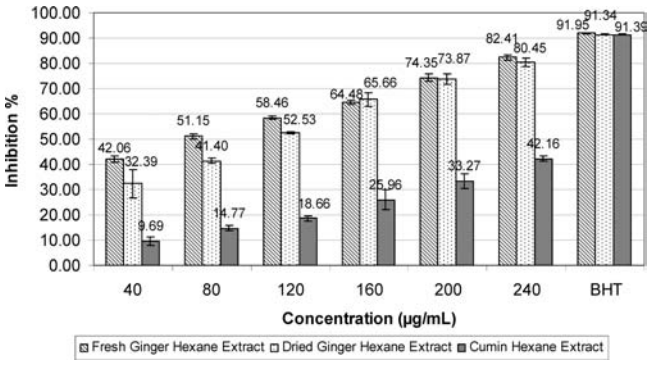

Figure 3. DPPH radical scavenging activity of the *n*-hexane extracts of ginger (fresh and dried) and cumin.

For the validation of this method BHT was run as a standard along with the samples. It showed a high inhibition percentage of 91% at a concentration 60 μg/mL, confirming the validity of the method. These results are in agreement with the findings of Wei and Shibamoto (*26*), who examined the antioxidant activity of ginger (*Zingiber officinale* R.) essential oil by DPPH radical scavenging activity, and found its inhibition above 50% at a concentration of 200 μg/mL. The results of our study showed comparatively higher inhibition (72%) at the same concentration. So the essential oil of our samples seems to have better antioxidant activity. This might be due to the presence of appreciable amounts of antioxidant compounds such as camphene, *p*-cineole, borneol, α-terpineol and zingiberene (*26*). The essential oil of dried ginger showed higher DPPH radical inhibition compared to the fresh ginger, which was 83.87 ± 0.50% at a concentration of 240 μg/mL. According to **Table 3**, antioxidant compounds identified through GC are higher in dried ginger compared to the fresh samples, which may be the reason for higher antioxidant activity of dried ginger essential oil. The essential oil of cumin showed higher inhibition than both the samples of ginger, which reached 85.44 ± 0.50% at a concentration of 240 μg/mL. The GC profile of cumin presented in **Table 4** indicates the presence of higher amounts of antioxidant compounds compared to ginger, e.g., cuminal, γ-terpinene, pinocarveol, carotol, pinocarveol, α-pinene, sabinene, β-terpineol and linalool. These compounds seem to be responsible for higher antioxidant action of the cumin essential oil (*26*).

DPPH radical scavenging activity was also performed for the nonvolatile extracts (*n*-hexane and methanol) of ginger (fresh and dried) and cumin samples. It is clear from the results that by increasing concentration of the samples the inhibition also increased. **Figure 3** also shows an increase in the inhibition of DPPH radical by increasing concentrations. The standard BHT

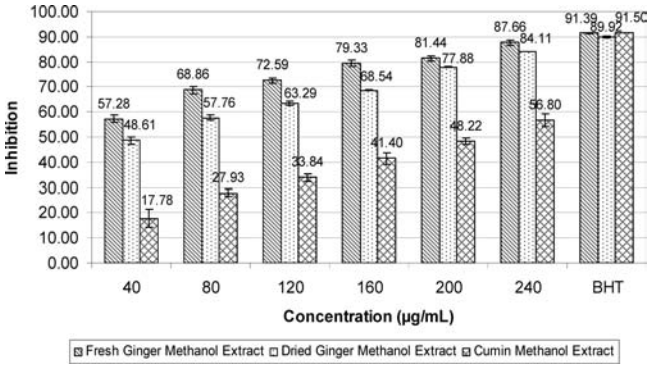

Figure 4. DPPH radical scavenging activity of the methanol extracts of ginger (fresh and dried) and cumin.

showed a high activity of 91% at a concentration of 60 μg/mL, confirming the validity of this method. The highest inhibition was attained by the fresh ginger sample, which was 82.41 ± 0.95%. The low inhibition percentage of the dried ginger sample indicated a decrease in antioxidant activity as a result of drying. This may be due to the oxidation of some antioxidant compounds of the extracts during drying. The cumin extract showed a lower antioxidant activity, which may be correlated to its lower total phenolic content (10.6 ± 2.5 mg/g dry extract) as shown in **Figure 1**.

The DPPH radical scavenging activity of the methanol extracts of ginger (fresh and dried) and cumin is represented in **Figure 4**. It can be seen that both the samples of ginger (fresh and dried) showed high antioxidant activity. However, fresh ginger showed higher antioxidant action compared to dried ginger at all concentrations. The highest value of fresh ginger extract for inhibition of DPPH radical was 87.66 ± 1.10% at a concentration of 240 μg/mL, whereas at the same concentration the antioxidant activity for dried ginger extract was 84.11 ± 0.10%. Similarly, at the lowest concentration of 40 μg/mL the antioxidant activity of fresh ginger extract was 57.28 ± 1.46% and for dried ginger it was 48.61 ± 1.57%. It was also seen that the methanol extracts showed a higher antioxidant activity compared to *n*-hexane extracts as shown in **Figure 3**. These results are in agreement with the findings of Stoilova et al. (*27*), who studied the antioxidant activity of the alcohol extract of ginger from Vietnam and found that the DPPH radical inhibition reached up to 90.1%. Hinneburg et al. (*14*) in Finland found high antioxidant action of the aqueous extracts of ginger, where the IC_{50} value for the inhibition of DPPH radical was ~9 mg/mL. Cumin methanol extract showed a lower inhibition effect on DPPH radical compared to the ginger extracts, but its effect was higher than that of the hexane extracts. The maximum value for inhibition of the cumin methanol extract reached up to 56.80 ± 2.61% at a concentration of 240 μg/mL, while for the lowest concentration 40 μg/mL, the inhibition was 17.78 ± 3.52%. All the values showed increasing antioxidant action with increase in the concentration of sample as shown in the **Figure 4**. The literature also shows low antioxidant action of the cumin extracts. Thippeswamy and Naidu (*7*) in India studied the antioxidant activity of methanol extracts of cumin and found the DPPH radical inhibition 40% at a dose level of 0.4 mg. Hinneburg et al. (*14*) reported the antioxidant activity of aqueous extracts of cumin in Finland and found its IC_{50} value for inhibition of DPPH radical ~2 mg/mL.

b. Ferric Reducing Antioxidant Power (*FRAP*). Different concentrations of essential oils and nonvolatile extracts (hexane and methanol) of ginger (fresh and dried) and cumin, ranging from 40 μg/mL to 240 μg/mL, were used to measure the ferric reducing antioxidant power of the samples that were used. Absorbance values were taken against the sample concentrations.

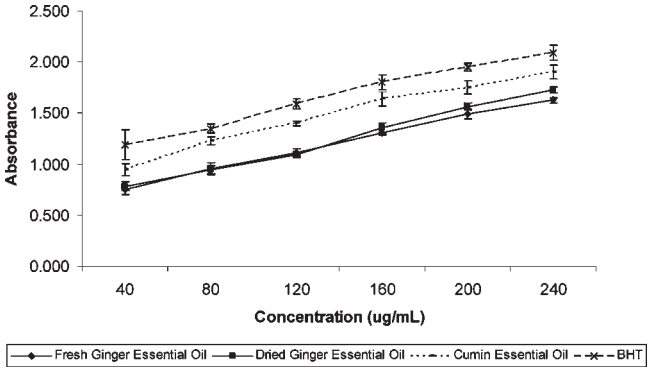

Figure 5. Ferric reducing antioxidant power (FRAP) of essential oils of ginger (fresh and dried) and cumin.

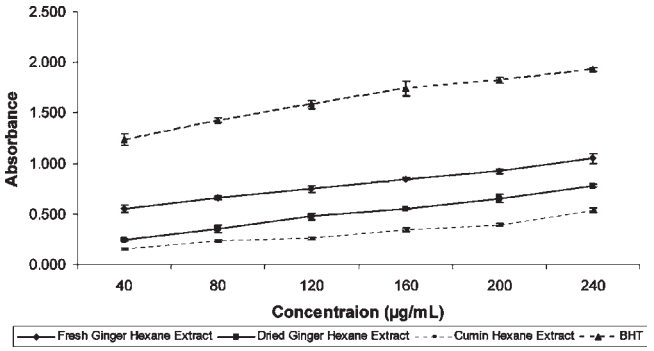

Figure 6. Ferric reducing antioxidant power (FRAP) of *n*-hexane extracts of ginger (fresh and dried) and cumin.

The ferric reducing antioxidant power of the essential oils can be seen in **Figure 5**. All the samples showed a dose dependent activity, i.e., there was an increase in the values by increasing the concentration, which indicated increase in the ferric reducing power. The highest activity was attained by cumin essential oil with an absorbance value of 1.753 ± 0.06 at a concentration of 240 μg/mL. The fresh ginger and dried ginger essential oil showed almost similar activity, but dried ginger essential oil had a slightly higher action than the fresh one. BHT was also run as a standard along with the samples to compare the antioxidant activity of the samples with it. Cumin essential oil showed almost equal antioxidant action to BHT at a concentration of 80 μg/mL. The higher ferric reducing power of essential oils may be attributed to the presence of appreciable amount of antioxidant compounds such as camphene, *p*-cineole, borneol, α-terpineol, γ-terpinene, carotol, α-pinene, sabinene and linalool (*26*).

The results for ferric reducing antioxidant power (FRAP) of *n*-hexane extracts of ginger and cumin are shown in **Figure 6**. The results showed that the extracts had a good potential to reduce the ferric ions into ferrous ions, which is a measure of antioxidant activity. All the extracts showed increasing ferric reducing ability as a result of increasing doses. The dose dependent increase in absorbance and phenolic content implies that there is a direct relationship between the reducing power and presence of phenolic compounds in the extract. Maximum absorbance value was attained by fresh ginger, i.e., 1.050 ± 0.050 at a concentration of 240 μg/mL indicating maximum ferric reducing ability, which was followed by the dried ginger hexane extract indicating an absorbance value of 0.780 ± 0.013 at the same concentration. The lowest result was obtained for cumin extract, which showed the maximum absorbance value of 0.539 ± 0.025 at a concentration of 240 μg/mL. The results were compared with synthetic antioxidant, i.e., BHT, which was run as a standard along with the samples.

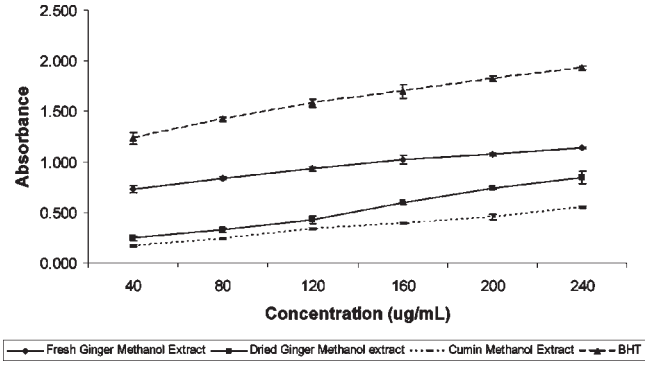

Figure 7. Ferric reducing antioxidant power (FRAP) of methanol extracts of ginger (fresh and dried) and cumin.

The results for ferric reducing antioxidant power (FRAP) of methanol extracts of ginger and cumin are depicted in **Figure 7**. All the samples showed a significant effect on reducing the ferric ion. For comparison of the antioxidant action, BHT was also run as a standard along with the samples: The methanol extracts had higher potential than hexane extracts to reduce the ferric ions to ferrous ions. The maximum absorbance value was 1.138 ± 0.009 for fresh ginger methanol extract followed by dried ginger with a value of 0.847 ± 0.063 at a concentration of 240 μg/mL, while the lowest value was observed for cumin, which was 0.553 ± 0.007 at the same concentration. These results agree with those reported by Kruawan and Kangsadalampai (*28*), who studied the antioxidant activity of the aqueous extract of ginger and found its high FRAP value, which was 1030.5 ± 11.49 μmol/g. Liu et al. (*25*) studied the antioxidant capacity of ginger ethanol extract and found its FRAP value 0.806 mmol of Fe(II)/g dry weight. The ability to reduce Fe(III) may be attributed to hydrogen donation from phenolic compounds (*29*), which is also related to the presence of reductant agent. In addition, the number and position of hydroxyl group of phenolic compounds also rule their antioxidant activity (*30*).

By comparing the antioxidant activity measured by two different methods, i.e., DPPH radical scavenging and ferric reducing power (FRAP), it is seen that all the samples showed almost similar trends in both methods. Essential oils seem to show high antioxidant activity in both cases while the methanol extracts also showed higher antioxidant action compared to hexane extracts in both methods. So it is concluded that both methods are consistent with each other in evaluating the antioxidant activity.

Conclusion. The overall evaluation of this study concludes that both spices ginger and cumin have good antioxidant potential, particularly fresh ginger. The essential oil of both spices showed appreciable amounts of antioxidant compounds having high antioxidant activity, and their nonvolatile extracts also showed good inhibition properties against free radicals. Methanol extracts of all the samples were found to have better antioxidant action than the *n*-hexane extracts. There was also a good correlation between the total phenolic content and antioxidant activities of the nonvolatile extracts. So this study concludes that ginger and cumin have good antioxidant potential and these spices can be used to produce novel natural antioxidants as well as flavoring agents that can be used in various food products.

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