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Cumin (*Cuminum cyminum*) as a potential source of antioxidants

Muhammad Nadeem, Asad Riaz *

National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan

Corresponding Author: asadjannab@hotmail.com

Abstract

Spices are the building blocks of flavor in food. Their primary functions are to provide aroma, texture and color to food. In addition they also act as preservative, and provide nutritional, and health benefits. Cumin (*Cuminum cyminum*) locally known as 'zeera' is a flowering plant in the family Apiaceae. It is commonly used as a condiment and flavoring in many eastern dishes. Cumin is known for its antioxidant properties. 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 on age and regional variations. Studies of the chemical composition of cumin oil from different countries showed the presence of the following components: α-pinene (0.5%), Myrcene (0.3%), limonene (0.5%), 1-8-cineole (0.2%), p-menth-3-en-7-ol (0.7%), p-mentha-1, 3-dien-7-ol (5.6%), caryophyllene (0.8%), β-bisabolene (0.9%), β-pinene (13.0%), P-cymene (8.5%), β-phellandrene (0.3%), D-terpinene (29.5%), cuminic aldehyde (32.4%), cuminyl alcohol (2.8%), β-farnesene (1.1%) together with much smaller quantities of α-phellandrene, α-terpinene, cis and trans sabinene, Myrtenol, α-terpineol and phellandral. In addition to volatile oil cumin also contains nonvolatile chemical components including tannins, oleoresin, mucilage, gum, protein compounds and malates. The total phenolic content of methanolic extracts of different cumin varieties (cumin, black cumin and bitter cumin) ranged from 4.1 to 53.6 mg/g dry weight. In this comprehensive review focus will be on the antioxidant and flavoring compounds of cumin.

Keywords: Spices, cumin, Essential oils, antioxidants,

What are Spices?

Spices are non-leafy parts (e.g. bud, fruit, seed, bark, rhizome and bulb) of plants used as a flavoring or seasoning, although many can also be used as a herbal medicine. The term 'spice' originated form the Latin word 'species', meaning of specific kind. A closely related term, 'herb', is used to distinguish plant parts finding the same uses but derived from leafy or soft flowering parts. The two terms may be used for the same plants in which the fresh leaves are used as herbs, while other dried parts are used as spices, e.g. coriander, dill. Spices have many functions in food. Primarily they are used for flavoring the food products but in addition they are also used in preservation of food and provision of nutritional and health benefits (Nazeeem, 1995).

Spices have a profound influence on the course of human civilization. They permeate our lives from birth to death. In everyday life, spices succor us, cure us, relax us, and excite us. Ancient peoples such as the Egyptian, the Arab and the Roman made extensive uses of spices, not only to add flavor to foods and beverages, but as medicines, disinfectants, incenses, stimulants and even as aphrodisiac agents. In Europe, Middle East and Asia they were used to preserve meat, bread and vegetables. No wonder they were sought after in the same manner as gold and precious metals. There are many forms in which spices are available e.g. fresh, dried and frozen; whole, ground, crushed, pureed, as pastes, extracts, or infusions (Raghavan, 2007).

Spices are generally composed of fiber, carbohydrate, fat, sugar, protein, gum, ash, volatile (essential oils), and other nonvolatile components. All of these components impart each spice's particular flavor, color, nutritional, health, or preservative effects. The flavor components (volatile and nonvolatile) are protected within a matrix of carbohydrate, protein, fiber, and other cell components. When the spice is ground, cut, or crushed, this cell matrix breaks down and releases the volatile components (Raghavan, 2007).

Essential oils are the major flavoring constituents of a spice. They are soluble in alcohol or ether and are only slightly soluble in water. They provide more potent aromatic effects than the ground spices. Essential oils lose their aroma with age. Each essential oil has many chemical components, but the characterizing aroma generally constitutes anywhere from 60% to 80% of the total oil. Essential oils are very concentrated, about 75 to 100 times more concentrated than the fresh spice. They do not have the complete flavor profile of ground spices, but they are used where a strong aromatic effect is desired. Essential oils are used at a very low level of

0.01% to 0.05% in the finished product. They can be irritating to the skin, toxic to the nervous system if taken internally (by themselves), and can cause allergic reactions and even miscarriages (Raghavan, 2007).

The essential oils in spices are generally composed of hydrocarbons (terpene derivatives) or terpenes (e.g., α-terpinene, α-pinene, camphene, limonene, phellandrene, myrcene, and sabinene), oxygenated derivatives of hydrocarbons (e.g., linalool, citronellol, geraniol, carveol, menthol, borneol, fenchone, tumerone, and nerol), benzene compounds (alcohols, acids, phenols, esters, and lactones) and nitrogen- or sulfur-containing compounds (indole, hydrogen sulfide, methyl propyl disulfide, and sinapine hydrogen sulfate). Terpene compounds are the major chemical components of most of the essential oils. Depending up on the molecular size, monoterpenes, diterpenes, triterpenes, and sesquiterpenes occur. Monoterpenes are the most volatile of these terpenes and constitute the majority of the terpenes in spices. Sesquiterpenes are most concentrated in ginger family (Raghavan, 2007).

The nonvolatile and volatile 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 volatiles and non-volatiles, including resins and gums that are native to spices. The nonvolatile components create the heat and or pungency of black pepper, mustard, ginger, and chile peppers. These components can be acid-amides, such as capsaicin in red pepper or piperine in black pepper, isothiocyanates in mustard, carbonyls such as gingerol in ginger, and thioethers such as the diallyl sulfides in garlic or onion (Raghavan, 2007).

The different pungent and or heat principles give different sensations e.g. spicy, hot, sharp, biting, or sulfury. The pungent sensation of onion or garlic is sulfury, while that of Jamaican ginger is spicy. Red pepper and white pepper do not contain much aroma because they have very little essential oils, whereas ginger, black pepper, and mustard contribute aromatic sensations with their bites because of a higher content of volatile oils. White pepper has a different bite sensation than black pepper because of their differing proportions of non-volatiles, piperine, and chavicine (Raghavan, 2007).

The taste of a spice such as sweet, spicy, sour, or salty, is due to many different chemical components such as esters, phenols, acids, alcohols, chlorides, alkaloids, or sugars. Sweetness is due to esters and sugars; sourness to organic acids (citric, malic, acetic, or lactic); saltiness to cations, chlorides, and citrates; astringency to phenols and tannins; bitterness to alkaloids (caffeine and glycosides); and pungency to the acid-amides, carbonyls, thio ethers, and isothiocyanates (Raghavan, 2007).

The ratio of volatiles to non-volatiles varies among spices causing flavor similarities and differences within a genus and even within a variety. Within the genus *Allium,* for example, there are differences in flavor among garlic, onions, chives, shallots, and leeks, which differ in this ratio. They vary depending upon the species of spice, its source, environmental growing and harvesting conditions, and storage and preparation methods. Even the distillation techniques can give rise to varying components—through loss of high boiling volatiles, with some components not being extracted or with some undergoing changes. Non-volatiles in a spice also vary with variety, origins, environmental growth conditions, stage of maturity, and postharvest conditions. For example, the different chile peppers belonging to the Capsicum group, such as habaneros, cayennes, jalapenos, or poblanos, all give distinct flavor perceptions, depending on the proportion of the different nonvolatiles, the capsaicinoids (Peter, 2001).

Spices can be used in foods as antioxidants. They help fight the toxins created by our modern world. Heat, radiation, UV light, tobacco smoke, and alcohol initiate the formation and growth of the free radicals in the human body. Free radicals damage the human cells and limit their ability to fight off cancer, aging, and memory loss. Many spices have components that act as antioxidants and that protect cells from free radicals. The chemical components responsible for antioxidant activity in ginger are gingerol and shogoal (Raghavan, 2007).

Cumin (*Cuminum cyminum*)

Cumin (*Cuminum cyminum*) is a flowering plant in the family Apiaceae, native from the east Mediterranean to East India. In India cumin is known in as ‘jeera’ or ‘jira’ and in Iran it is called ‘zira’. Indonesians call it ‘jintan’ (or jinten) and in China it is called ‘ziran’ but in Pakistan it is known as ‘zeera’. Cumin is a herbaceous annual plant, with a slender branched stem 20-30 cm tall. The leaves are 5-10 cm long, pinnate or bipinnate, thread-like leaflets. The flowers are small, white or pink, and borne in umbels. The fruit is a lateral fusiform or ovoid achene 4-5 mm long, containing a single seed. Cumin seeds are similar to fennel and anise seeds in appearance, but are smaller and darker in color. The English cumin was derived from the French cumin, which was borrowed indirectly from Arabic ‘Kammon’ via Spanish ‘comino’ during the Arab rule in Spain in the 15th century. The spice is native to Arabic-speaking Syria where cumin thrives in its hot and arid lands. Cumin seeds have been found in some ancient Syrian archeological sites. The word found its way from Syria to neighboring Turkey and nearby Greece most likely before it found its way to Spain. Like many other Arabic words in the English language, cumin was acquired by Western Europe via Spain rather than the Grecian route. Some suggest that the word is derived from the Latin ‘cuminum’ and Greek ‘kuivov’. The

Greek term itself has been borrowed from Arabic. Forms of this word are attested in several ancient Semitic languages, including 'kamunu' in Akkadian. The ultimate source is believed to be the Sumerian word 'gamun' (Zohary and Hopf, 2000). The use of cumin is very common in Indian and Pakistani foods. It is used to season many dishes, as it draws out their natural sweetness. It is traditionally added to curries, enchiladas, tacos, and other Middle-Eastern, Indian, Cuban and Mexican-style foods. It can also be added to salsa to give it extra flavor. Cumin has also been used on meat in addition to other common seasonings. The spice is extensively used in the cuisines of the Indian subcontinent. Cumin was also used heavily in ancient Roman cuisine (Peter, 2001; Raghavan, 2007).

The nutritional value of cumin seeds per 100 g includes Energy 370 kcal (1570 kJ), Carbohydrates 44.24 g, Dietary Fiber 10.5 g, Fat 22.27 g, Protein 17.81 g, Water 8.06 g, Thiamin (Vit. B1) 0.628 mg, Riboflavin (Vit. B2) 0.327 mg, Niacin (Vit. B3) 4.579 mg, Vitamin B6 0.435 mg, Vitamin C 7.7 mg, Vitamin E 3.33 mg, Calcium 931 mg, Iron 66.36 mg, Magnesium 366 mg, Phosphorus 499 mg, Potassium 1788 mg, Sodium 168 mg, Zinc 4.8 mg and other trace elements (U.S.D.A., 2008).

Cumin has high total dietary fiber content and the spent residue (after oils and nonvolatiles extraction) has been also found to contain high dietary fiber. Results show that the total dietary fiber content (TDF) of cumin is 59.0%, insoluble dietary fiber (IDF) 48.5%, and soluble dietary fiber (SDF) 10.5%, while the spent residue from cumin has been found to contain 62.1% TDF, 51.7% IDF and 10.4% SDF. The spent residue also contains 7.7% starch and 5% bound fat (Sowbhagya *et al.,* 2007).

Cumin essential oil contents

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 on age and regional variations. The ripe seeds of cumin are used for essential oil production, both as whole seeds or coarsely ground seeds. If freely alcohol-soluble oil is required, the whole seed must be used. Hydro distillation is used for essential oil extraction, producing a colorless or pale-yellow oily liquid with a strong dour. The yield for oil production varies from 2.5 to 4.5%, depending on whether the entire seed or the coarsely ground seed is distilled. The volatile oil should be kept in well-sealed bottles or aluminium containers (Peter, 2001).

Different studies have been conducted on the yield of cumin essential oil. Sowbhagya *et al.* (2008) evaluated the effect of size reduction and expansion on yield and quality of cumin (*Cuminum cyminum*) seed oil. For small batch size operations (200g), oil yield was found to be the same (3.4%) for both ground and flaked samples. However, in the operations of larger batch, flakes resulted in significantly higher (3.3%) oil yield as compared to ground samples (2.8%) indicating the advantage of flaking over grinding. Aqueous portion of the distillate in both cases had equal proportion of volatile oil (0.2%). Flavor profiles of the volatile oils revealed that retention of lower boiling terpene compounds and character impact compound, cuminaldehyde were higher in oil obtained from flakes as compared to powder.

Li *et al.* (2009) explored the extraction of essential oil from *Cuminum cyminum* seeds using a combination of organic solvent with low boiling point and steam distillation. The effect of different parameters, such as particle size, temperature and extraction time, on the extraction yield was investigated. The temperature had the largest effect on the yield of the extract (oleoresin), followed by extraction time and particle size. Essential oil of *C. cyminum* seeds obtained by supercritical fluid extraction (SFE), hydrodistillation (HD), combination technology of organic solvent with low boiling point and steam distillation (OS-SD) were further analysed by GC-MS detection to compare the extraction methods. Forty-five compounds in the *C. cyminum* essential oil were identified, showing that the composition of the extraction by different methods was mostly similar.

The essential oil is responsible for the characteristic cumin odor. This odor and flavor is due principally to the aldehydes present. Studies of the chemical composition of cumin oil from different countries showed the presence of the following components: α-pinene (0.5%), Myrcene (0.3%), limonene (0.5%), 1-8-cineole (0.2%), p-menth-3-en-7-ol (0.7%), p-mentha-1, 3-dien-7-ol (5.6%), caryophyllene (0.8%), β-bisabolene (0.9%), β-pinene (13.0%), P-cymene (8.5%), β-phellandrene (0.3%), D-terpinene (29.5%), cuminic aldehyde (32.4%), cuminyl alcohol (2.8%), β-farnesene (1.1%) together with much smaller quantities of α-phellandrene, α-terpinene, cis and trans sabinene, Myrtenol, α-terpineol and phellandral (Peter, 2001).

Other studies show that cumin essential oil mainly contains monoterpene aldehydes. The major compounds include cumin aldehyde (p-isopropyl-benzaldehyde, 25 to 35%), terpinene (29.5%), α- and β-pinene (21%), ρ-cymene (8.5%), ρ-mentha-1,3-dien-7-al (5.6%), cuminyl alcohol (2.8%) and β-farnesene (1.1%). Furthermore perilla aldehyde, cumin alcohol, dipentene, and β-phellandrene are also present in cumin. In toasted cumin fruits, a large number of pyrazines have been identified as flavour compounds. Besides pyrazines and various alkyl derivatives (particularly, 2,5- and 2,6-dimethyl pyrazine), 2-alkoxy-3-alkylpyrazines seem to be the key compounds e.g. 2-ethoxy-3-isopropyl pyrazine, 2-methoxy-3-sec-butyl pyrazine, 2-methoxy-3-methyl pyrazine. A sulfur compound, 2-methylthio-3-isopropyl

pyrazine is also found. Cumin also contains 10% fixed oil (El-Hamidi and Ahmed, 1966; Raghavan, 2007).

In a study, the essential oil composition of cumin seeds after subjecting them to heating by microwaves and conventional roasting at different temperatures was studied. The conditions were standardized in both methods. The volatile oils distilled from these samples were analysed by GC and GC–MS. The results indicated that the microwave-heated samples showed better retention of characteristic flavor compounds, such as aldehydes, than did the conventionally roasted samples (Behera *et al.,* 2004).

Jalali-Heravi *et al.* (2007) used Gas chromatography–mass spectrometry to characterize the essential oil components of Iranian cumin. A total of 19 components were identified by direct similarity searches for cumin oil. This number was extended to 49 components, with the help of chemometric techniques. Major constituents in cumin are gamma-terpinene (15.82%), 2-methyl-3-phenyl-propanal (32.27%) and myrtenal (11.64%).

In addition to volatile oil cumin also contains nonvolatile chemical components including tannins, oleoresin, mucilage, gum, protein compounds and malates. The oleoresins are obtained by subjecting the ground cumin to different organic solvents such as n-hexane, ethanol, methanol etc. The extract obtained is then subjected to rotary evaporation to remove the solvent (Peter, 2001).

Kanakdande *et al.* (2007) studied the microencapsulations of cumin oleoresin by spray drying using gum arabic, maltodextrin, and modified starch and their ternary blends as wall materials for its encapsulation efficiency and stability under storage. The microcapsules were evaluated for the content and stability of volatiles, and total cuminaldehyde, γ-terpinene and p-cymene content for six weeks. Gum Arabic offered greater protection than maltodextrin and modified starch, in general, although the order of protection offered was volatiles>cuminaldehyde> p-cymene> γ-terpinene. A 4/6:1/6:1/6 blend of gum arabic/ maltodextrin/ modified starch offered a protection, better than gum arabic as seen from the $t_{1/2}$, i.e. time required for a constituent to reduce to 50% of its initial value. However protective effect of ternary blend was not similar for the all the constituents, and followed an order of volatiles>p-cymene> cuminaldehyde >γ-terpinene.

Antioxidative properties of cumin

Cumin has also been tested for its antioxidative properties. The total phenolic content of methanolic extracts of different cumin varieties (cumin, black cumin and bitter cumin) ranged from 4.1 to 53.6 mg/g dry weight. Cumin (*Cuminum cyminum*) methanol extract was found to contain a total phenolic content of 9 mg/g dry weight. It has been also shown that the methanolic extracts of cumin show higher antioxidant activity compared with that of the aqueous extract (Thippeswamy and Naidu, 2005).

In another study the antioxidant activity and the phenolic compounds of 26 spice extracts including cumin was assessed. Antioxidant activity was expressed as TEAC (mmol of trolox/ 100 g of dry weight). Cumin showed a value of 6.61 mmol of trolox/ 100 g of dry weight while the total phenolic content of cumin was 0.23g of gallic acid equivalent/ 100 g of dry weight (Shan *et al.* 2005).

The antioxidant capacity of cumin (*Cuminum cyminum*) has been tested on Fe^{2+} ascorbate induced rat liver microsomal lipid peroxidation, soybean lipoxygenase dependent lipid peroxidation and 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging methods. The total phenolic content of methanolic extract of cumin was 9 mg/ g dry weight. IC_{50} values of the methanolic extract of cumin seeds were 1.72 ± 0.02, 0.52 ± 0.01 and 0.16 ± 0.30 on the lipoxygenase dependent lipid peroxidation system, the DPPH radical scavenging system and the rat liver microsomal lipid peroxidation system, respectively. The data also showed that cumin is a potent antioxidant capable of scavenging hydroxy, peroxy and DPPH free radicals and thus inhibits radical-mediated lipid peroxidation (Thippeswamy and Naidu, 2005).

Damasius *et al.* (2007) assessed the antioxidant properties of aqueous and ethanol extracts of cumin (*Cuminum cyminum* L.). Antioxidant activity of cumin ethanol and aqueous extracts was measured in DPPH and ABTS radical scavenging reaction systems and depended on extract concentration. The aqueous extract of cumin showed higher DPPH radical scavenging activity while in ABTS reaction system the ethanol extract exhibited higher activity than the aqueous extract.

Lee (2005) studied the therapeutic properties of cumin. He evaluated the inhibitory activity of *Cuminum cyminum* seed-isolated component against lens aldose reductase and R-glucosidase isolated from Sprague-Dawley male rats and compared to that of 11 commercially available components derived from *C. cyminum* seed oil, as well as quercitrin as an aldose reductase inhibitor and acarbose as an R-glucosidase inhibitor. The biologically active constituent of *C. cyminum* seed oil was characterized as cuminaldehyde by various spectral analyses. The IC_{50} value of cuminaldehyde is 0.00085 mg/mL against aldose reductase and 0.5 mg/mL against R-glucosidase, respectively. Cuminaldehyde was about 1.8 and 1.6 times less in inhibitory activity than acarbose and quercitin, respectively. The author concluded that cuminaldehyde may be useful as a lead compound and a new agent for antidiabetic therapeutics.

Conclusion

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

Literature cited

1. Bailey-Shaw, Y. A., L. A. D. Williams, G. A. O. Junor, C. E. Green, S. L. Hibbert, C. N. A. Salmon and A. M. Smith. 2008. Changes in the contents of oleoresin and pungent bioactive principles of Jamaican ginger (*Zingiber officinale* Roscoe.) during Maturation. J. Agric. Food Chem. 56: 5564-5571.
2. Balladin, D. A., O. Headley, I. Chang-Yen and D. R. McGaw. 1997. Extraction and evaluation of the main pungent principles of solar dried West Indian ginger (*Zingiber officinale* Roscoe) rhizome. Renewable Energy 12(2): 125-130.
3. Beek, T. A. V. and G. P. Lelyveld. 2007. Isolation and identification of the five major sesquiterpene hydrocarbons of ginger. Phytochem. Anal. 2(1): 26-34.
4. Behera, S., S. Nagarajan and L. J. M. Rao. 2004. Microwave heating and conventional roasting of cumin seeds (*Cuminum cyminum* L.) and effect on chemical composition of volatiles. Food Chem. 87: 25-29.
5. Blumenthal M. 1998. The complete German Commission E monographs: therapeutic guide to herbal medicines. Austin: American Botanical Council.
6. Bode, A., 2003. Ginger is an effective inhibitor of HCT116 human colorectal carcinoma in vivo. Paper presented at the Frontiers in Cancer Prevention Research Conference, Phoenix, AZ, October 26–30, 2003.
7. Connell, D. W. 1970. Natural pungent compounds. III. The paradol and associated compounds. Aust. J. Chem. 23: 369-1970.
8. Damasius, J., M. Skemaite, G. Kirkilaite, R. Vinauskiene and P. R. Venskutonis. 2007. Antioxidant and antimicrobial properties of caraway (*Carum carvi* L.) and cumin (*Cuminum cyminum* L.) extracts. Veterinarija IR Zootechnika. T. 40 (62).
9. Denyer, C. V., P. Jackson, D. M. Loakes, M. R. Ellis and D. A. B. Young. 1994. Isolation of Antirhinoviral Sesquiterpenes from Ginger (*Zingiber Officinale*). J. Nat. Prod. 57(5): 658-662.
10. Duke, J. A. and E. S. Ayensu. 1985. Medicinal Plants of China. Medicinal Plants of the World. Vol. 1. Algonac, MI: Reference Publications, Inc.
11. El-Hamidi, A. and S. S. Ahmed. 1966. The effect of plant age on content and composition of dill essential oil *Anethum graveolens* L. Pharamazie 21: 438-439.
12. Funk, J. L., J. B. Frye, J. N. Oyarzo and B. N. Timmermann. 2009. Comparative effects of two gingerol containing *Zingiber officinale* Extracts on experimental Rheumatoid Arthritis. J. Nat. Prod. Available from: http://pubs.acs.org. Accesed: March 25, 2009.
13. Govindarajan, V. 1982. Ginger-chemistry technology and quality evaluation: Part-I CRC. Critical Reviews Food Sci. Nutr. 17: 1-96.
14. Grzanna, R., L. Lindmark and C. G. Frondoza. 2005. Ginger – an herbal medicinal product with broad anti-inflammatory actions. J. Medicinal Food 8, 125-132.
15. Hiserodt, R. D., S. G. Franzblau and R. T. Rosen .1998. Isolation of 6-, 8-, 10-gingerol from ginger rhizome by HPLC and preliminary evaluation of inhibition of *Mycobacterium avium* and *Mycobacterium tuberculosis*. J. Agric. Food Chem. 46 (7): 2504-2508.
16. Jalali-Heravi, M., B. Zekavat and H. Sereshti. 2007. Use of gas chromatography–mass spectrometry combined with resolution methods to characterize the essential oil components of Iranian cumin and caraway. J. Chromatography A. 1143: 215-226.
17. Johri, R. K. and U. Zutshi. 1992. An Ayurvedic formulation 'Trikatu' and its constituents. J. thnopharmacol 37:85-91.
18. Kanakdande, D., R. Bhosale and R. S. Singhal. 2007. Stability of cumin oleoresin microencapsulated in different combination of gum arabic, maltodextrin and modified starch. Carbohydrate Polymers 67: 536-541.
19. Kapil, U., A. K. Sood and D. R. Gaur. 1990. Maternal beliefs regarding diet during common childhood illnesses. Indian Pediatr. 27:595-599.

20. Kikuzaki, H. and Nakatani, N. 1993. Antioxidant Effects of Some Ginger Constituents. J. Food Sci. 58(6): 1407-1410.

21. Kiuchi, F., M. Shibuya and U. Sankawa. 1982. Inhibitors of prostaglandin biosynthesis from ginger. Chem. Pharm. Bulletin (Tokyo) 30: 754-757.

22. Kulka, K. 1967.Aspects of functional groups and flavour. J. Agric. Food Chem. 15: 48-57.

23. Lee, E. and Y. J. Surh. 1998. Induction of apoptosis in HL-60 cells by pungent vanilloids, 6-gingerol and 6-paradol. Cancer Letters 134: 163-168.

24. Lee, E., K. K. Park, J. M. Lee, K. S. Chun, J. Y. Kang, S. S. Lee and Y. J. Surh. 1998. Suppression of mouse skin tumor promotion and induction of apoptosis in HL-60 cells by *Alpinia oxyphylla Miquel* (Zingiberaceae). Carcinogenesis 19: 1377-1381.

25. Li, X. M., S. L. Tian, Z. C. Pang, J. Y. Shi, Z. S. Feng and Y. M. Zhang. 2009. Extraction of *Cuminum cyminum* essential oil by combination technology of organic solvent with low boiling point and steam distillation. Food Chem. 115: 1114-1119

26. Liu, H., N. Qiu, H. Ding and R. Yao. 2008. Polyphenols contents and antioxidant capacity of 68 Chinese herbals suitable for medical or food uses. Food Res. Intl. 41: 363-370.

27. Masuda, Y., H. Kikuzaki, M. Hisamoto and N. Nakatani. 2004. Antioxidant properties of gingerol related compounds from ginger. Biofactors 21: 293-296.

28. McGee, H. 2004. On Food and Cooking: The Science and Lore of the Kitchen .2nd Ed. New York: Scribner, pp. 425-426.

29. Murray, M. T. 1995. The healing power of herbs: the enlightened person's guide to the wonders of medicinal plants. Rocklin, CA: Prima Pub. xiv, 410.

30. Nazeeem, P. A. 1995. The spices of India. The Herb, Spice, and Medicinal Plant Digest 13(1): 1-5.

31. Panhwar, F. 2005. Ginger (*Zingiber officinale* Rose) cultivation in Sindh Pakistan. Digitalverlag GMBH Publishing, Germany.

32. Peter, K. V. 2001. Handbook of herbs and spices Vol. 1. Woodhead Publishing Limited Abington Hall, Abington Cambridge, England

33. Peter, K. V. and K. Kandiannan. 1999. Ginger. Tropical Horticulture Vol.1. (Eds. Bose, T.K., S. K. Mitra, A. A. Farooqi and M. K. Sadhu), Naya Prokash, Calcutta.

34. Purseglove, J. W., E. G. Brown, C. L. Green and S. R. J. Robbins. 1981. Spices Vol.2. Longman Inc. New York.

35. Qureshi, S., A. H. Shah, M. Tariq and A. M. Ageel. 1989. Studies on herbal aphrodisiacs used in Arab system of medicine. Am. J. Chin. Med. 17: 57-63.

36. Raghavan, S. 2007. Handbook of spices, seasonings, and flavorings. 2nd Ed. CRC Press, Taylor & Francis Group, Boca Raton.

37. Sanderson, L., A. Bartlett and P.J. Whitfield. 2002. In vitro and in vivo studies on the bioactivity of a ginger (*Zingiber officinale*) extract towards adult schistosomes and their egg production. J. Helminthology 76: 241-247.

38. Schulick, P. 1993. Common Spice or Wonder Drug? Ginger. Herbal Free Press, Brattleboro, Vermont, USA.

39. Sekiwa, Y., K. Kubota and A. Kobayashi. 2000. Isolation of Novel Glucosides Related to Gingerdiol from Ginger and Their Antioxidative Activities. J. Agric. Food Chem. 48: 373-377.

40. Shan, B., Y. Z. Cai, M. Sun and H. Corke. 2005. Antioxidant Capacity of 26 Spice Extracts and Characterization of Their Phenolic Constituents. J. Agric. Food Chem. 53: 7749-7759.

41. Sivarajan, V. V. and I. Balachandran. 1994. Ayurvedic Drugs and their Plant Sources. Oxford & IBH Publishing Co. Pvt. Ltd., Calcutta.

42. Sowbhagya, H. B., B. V. S. Rao and N. Krishnamurthy. 2008. Evaluation of size reduction and expansion on yield and quality of cumin (*Cuminum cyminum*) seed oil. J. Food Engg. 84: 595-600.

43. Sowbhagya, H. B., P. F. Suma, S. Mahadevamma and R. N. Tharanathan. 2007. Spent residue from cumin – a potential source of dietary fiber. Food Chem. 104: 1220-1225.

44. Srivastava, K.C. and T. Mustafa. 1992. Ginger (*Zingiber officinale*) in rheumatism and musculoskeletal disorders. Med. Hypothesis 39: 342-348.

45. Stoilova, I., A. Krastanov, A. Stoyanova, P. Denev and S. Gargova. 2007. Antioxidant activity of a ginger extract (*Zingiber officinale*). Food Chem. 102: 764-770.

46. Thippeswamy, N. B. and K. A. Naidu. 2005. Antioxidant potency of cumin varieties—cumin,

black cumin and bitter cumin—on antioxidant systems. Eur. Food Res. Technol. 220: 472-476.

47. Toure, A. and Z. Xiaoming. 2007. Gas chromatographic analysis of Guinean and Chinese ginger oils (*Zingiber officinale*) extracted by steam distillation. J. Agron. 6(2): 350-355.

48. U. S. D. A. 2008. USDA nutrient database. United States Department of Agriculture, USA. Available from: http://www.nal.usda.gov/fnic/foodcomp/search. Accessed Oct 17, 2008.

49. Unnikrishnan, M. C. and R. Kuttan. 1988. Cytotoxicity of extracts of spices to cultured cells. Nutr. Cancer 11: 251-257.

50. Wei, A. and T. Shibamoto. 2007. Antioxidant activities and volatile constituents of various essential oils. J. Agric. Food Chem. 55: 1737-1742.

51. Wohlmuth, H., D. N. Leach, M. K. Smith and S. P. Myers. 2005. Gingerol content of diploid and tetraploid clones of ginger (*Zingiber officinale* Roscoe). J. Agric. Food Chem. 53: 5772-5778.

52. Yen G.C. and H.Y. Chen. 1995. Antioxidative activity of various tea extracts in relation to their antimutagenecity. J. Agric. Food Chem. 43:27-32.

53. Zancan, K. C., M. O. M. Marques, A. J. Petenate and M. A. A. Meireles. 2002. Extraction of ginger (*Zingiber officinale* Roscoe) oleoresin with CO_2 and co-solvents: a study of the antioxidant action of the extracts. J. Supercritical Fluids 24: 57-76.

54. Zia-ur-Rehman, A. M. Salariya and F. Habib. 2003. Antioxidant activity of ginger extract in sunflower oil. J. Sci. Food Agric. 83: 624-629.

55. Zohary, D. and M. Hopf. 2000. Domestication of plants in the Old World. 3rd Ed. Oxford University Press, p. 206.