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**INFLUENCE OF GAMMA IRRADIATION AND  
MICROWAVE ON THE CAPSAICIN AND THE VOLATILE  
COMPOUNDS OF RED CHILLI (*CAPSICUM ANNUM*)**

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M.K.E. Youssef<sup>a</sup>, S.M. El-Bendary<sup>b</sup>,

N.T. El-Melegy<sup>c</sup>, R.M. Ahmed<sup>d</sup>

<sup>a</sup> *Faculty of Agriculture, Food Science & Technology Dept., Assiut University,  
71516 Assiut, Egypt*

<sup>b</sup> *Faculty of Specific Education, Home Economic Dept., Ain Shams University,  
Cairo, Egypt*

<sup>c</sup> *Faculty of Medicine, Medical Biochemistry Dept., Assiut University, 71516  
Assiut, Egypt*

<sup>d</sup> *Faculty of Specific Education, Home Economic Dept., Assiut University, 71516  
Assiut, Egypt*

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**Abstract**

Red chilli was irradiated with two types of radiations; gamma and microwave. The effects were evaluated in the changes in the capsaicin concentration, and the volatile oil composition through the methods: micellar electrokinetic chromatography and gas chromatography/mass spectrophotometry (GC/MS). Gamma irradiation used at a dose of 10 kGy. Microwave radiation was performed by continues supply of 50 W/Kg of red chilli for 15 min. Capsaicin decreased 63.17% by gamma irradiation and 21.29% by microwave treatment. Forty-four volatile oils have been identified, most of them reported for the first time. The total amount was 898 mg/kg and decreased by irradiation: 566 mg/kg and after microwave: 524 mg/kg. Some aromatic hydrocarbons such as heptadecane, tetramethylhexadecane and octadecane were disappeared completely after both treatments. Other organic compounds like ethyl benzene persisted in the same level after treatments. The precision and accuracy was investigated by standard deviation for reproducible measurements and recovery, respectively. Statistical analysis was performed by using Student's t-test. Differences were considered significant at  $P \leq 0.05$ .

**Keywords:** Red chilli, Gamma, Microwave, Capsaicin, Volatile oil

<sup>a</sup> Faculty of Agriculture, Food Science & Technology Dept., Assiut University, 71516 Assiut, Egypt

<sup>b</sup> Faculty of Specific Education, Home Economic Dept., Ain Shams University, Cairo, Egypt

<sup>c</sup> Faculty of Medicine, Medical Biochemistry Dept., Assiut University, 71516 Assiut, Egypt

<sup>d</sup> Faculty of Specific Education, Home Economic Dept., Assiut University, 71516 Assiut, Egypt

## **1. Introduction:**

Protecting the safety of our food supply always has a high priority and is a great challenge. Food irradiation and microwave are two technologies very useful to resolve this challenge. Irradiation technology can be used to treat many types of foods, by exposing them to appropriate levels of radiation doses. The United States Department of Agriculture (USDA) and the United States Food and Drug Administration (FDA) since 1963 had approved the use of gamma irradiation on a variety of food products for different purposes like control of mould in wheat flour and the elimination of microbial contamination in poultry, meat, herbs and spices. Irradiation is an effective technology and is preferred by many processors because the good penetration of the ionizing radiation, permit the food treat once is already packaged to irradiate industrial pallets or totes, reducing the need for material handling. The directive 1999/3/EC (European Community) established a community list of foods and food ingredients that might be treated with ionizing radiation and maximum overall average absorbed dose might be 10 kGy for dried aromatic herbs and spices. The FDA limit for culinary herbs and spices is not to exceed 30 kGy ([21CFR part 179 Code for Federal Regulation, 2004](#)). Several studies also indicated the importance to use microwaves for the sanitization spices. The effectiveness of the microwaves to treat spices depends of the high penetration power of radiation in spices which have lower water content usually 80-150 g/kg. This also causes a moderate and uniform heating which is lethal ([Emam, Farag and Aziz, 1995](#)).

Red chilli (*Capsicum annuum*) is an annual herbaceous plant from the Solanaceae family ([Mosquera and Mendez, 1994](#)) and is used extensively as spice and staple in the diet. It is extensively imported and regarded as the most highly demanded kinds of spices in global markets. For the consumer, organoleptic quality is important and often decisive in the purchase. The odour and taste sensations take a particular place when they are eating. The ‘hot’ taste of red chilli is due to the presence of non-volatile capsaicinoids, particularly capsaicin ([Reineccius, 1994](#)). Current research is also focusing on the volatile compounds as an important parameter for the quality of fresh red chilli ([Cremer and Eichner, 2000](#); [Guadayol, Caixach, Ribe’, Cabanas and Rivera, 1997](#); [Luning, de Rijk, Wichers and Roozen, 1994](#)).

Capsaicin (CAPS) is the main pungent component of red chilli, constituting 90% or more of the total capsaicinoids. Previous high performance liquid chromatographic methods have been reported for analytical separation, quantitation and identification of naturally capsaicinoids (Heresh, and Jurenitsch, 1979; Jurenitsch, and Kampelmuhler, 1980; Suresh, Manjunatha and Srinivasan, 2007). Thin-layer chromatography (Suzuki, Kawada and Iwai, 1980). Krajewska and Powers (1986) described a reversed-phase low-pressure liquid chromatographic method also for isolation naturally occurring capsaicinoids. These methods, though attaining sometimes low detection limits, are very laborious, long-lasting and expensive. Therefore, the current work used micellar electrokinetic chromatography, has several advantages than such techniques (Andromaque, 1999), for the determination of capsaicin.

The analysis of volatile compounds has been a challenge to many researchers. Different analytical methods have been developed to determine fresh chilli flavour, such as; solvent extraction-simultaneous distillation extraction (Chitwood, Pangborn, Jennings, 1983; Wu, and Liou, 1986; Korany, Kocsis, Amtmann and Mednyanszky, 2002) and dynamic headspace (Luning et al., 1994). However, these methods are time-consuming, expensive and likely to introduce artifact resulting from sample preparation and solvent interaction steps. Besides they cannot represent the total composition of the volatile chemical compounds. Since the main complexity is to distinguish the feature of the essential oil constituents. The aroma profiles are characteristic of the spices. It is important to find an specific method focuses on the aroma structures. For this purpose, gas chromatography/mass-spectrometry (GC/MS) is one of the best methods (Kameoka, 1986).

Numerous studies for spices have determined that irradiation or microwave is safe technologies (Mitchell, McLauchlan, Isaacs, Williams and Nottingham, 1992; Emam et al., 1995; Lee, Sung, Lee and Kim, 2004; Kim, Byung, Kim and Seung, 2005). Nevertheless, questions on changes in the composition of volatile oils and capsaicin after treatment of red chilli using gamma radiation or microwave technologies are still in debated in the scientific field. Therefore, the aim of the present work is to evaluate the influence of gamma radiation and microwave radiation within the allowable doses in the capsaicin and the volatile oil composition of red chilli.

## **2. Materials and Methods**

### **2.1. Materials**

Nine kilograms of three samples (3.0 kg/sample) of Assiut red chilli procured freshly from the Faculty of Agriculture, Assiut University. The samples were cultivated in the same field in Assiut city and harvested in the same period (January/February 2008). The samples were kept at 5 °C in aroma-tight bags excluding light. The whole sample was homogenized and was grind in a mill type Lab. Mill-1 QC-114.

Capsaicin (8-methyl-N-vanillyl-6-nonenamide) 98% purity degree was purchased from Sigma. Sodium dodecylsulphate (SDS), sodium dihydrogenphosphate ( $\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$ ) and sodium tetraborate ( $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ ) were analytical grade from Aldrich. The standards to analyze volatile compounds were purchased from Aldrich with a purity higher to 98%. Organic solvents from Aldrich or Fluka company were used without prior purification.

### **2.2. Treatment of red chilli**

One sample of raw red chilli (about 3.0 kilograms) was irradiated at Egyptian Atomic Energy Authority using a  $^{60}\text{Co}$  gamma source at an average dose of 10 kGy which is the average dose recommended by [the Codex Alimentarius commission \(1990\)](#), to reduce microbial load or to reduce the number of pathogenic microorganisms for spices and herbs. Another sample of raw red chilli (about 3.0 kilograms) was treated by microwave radiation. The treatment using microwave radiation (MS143SCE, Samsung Electronics, Korea) was performed by continues supply of red chilli in the pasteurization chamber at 50 W/Kg of red chilli for 15 min., where microwave oscillators allow the sanitization with drastic reduction of the microbic contamination (Less than  $10^3$  microorganisms per gram).

### **2.3. Determination of capsaicin by capillary electrophoresis**

Capillary electrophoresis (CE) separation was carried out in Analytical Chemistry Special Unit (Assiut University) following method described by [Andromaque \(1999\)](#) with a minor modification. A capillary electrophoresis system (Agilent Technologies, Germany) equipped with a photodiode array detector was used. The data were collected on a personal computer using the ChemStation software. An uncoated fused-silica capillary; 64.5 cm total length (56.0 cm effective length), 650  $\mu\text{m}$  outer

diameter and 50  $\mu\text{m}$  internal diameter were used. The CE sampling was performed by hydrodynamic injection at 25 mbar for 5 s; detection wavelength was 214 nm; voltage was maintained at +20 kV and temperature at 25 °C. Each solution was filtered through a 0.22  $\mu\text{m}$  membrane filter before injection into the CE system. At the beginning of day, the CE capillary was flush for 10 min with 0.10 mol/L NaOH, 10 min with H<sub>2</sub>O and 10 min with running the buffer; between runs it was left 2 min running buffer; at the end of day it was for 5 min with 1.00 mol/L NaOH and 15 min with H<sub>2</sub>O. A phosphate–borate running buffer was prepared by mixing an appropriate volume of 15 mmol/L sodium tetraborate solutions with a 15 mmol/L sodium dihydrogenphosphate solution in order to obtain a pH 9.0. When the pH was adjusted, SDS was added to the solution, so that at the end 67.5 mmol/L SDS concentration. Finally, methanol was added in order to obtain 15% (v/v). Capsaicin solutions at a concentration of 2.5 mmol/L were prepared daily in a 50% water/methanol (v/v). Appropriate dilutions of this initial solution were prepared to obtain the calibration curve. Ultrapure, type I, reagent grade water was obtained by a Milli-Q plus purification system (Millipore, USA). Extraction of capsaicin from red chilli samples was simply performed by weighing the appropriate weight of sample and dissolved in water-methanol (1:1) solution. The solution was sonicated for 5 min at ambient temperature and filtered through 0.22  $\mu\text{m}$  membrane prior to injection into CE system. When it was necessary, appropriate dilutions were carried in order to match within the calibration range of the standard solution. The extraction was performed in duplicate and each CE measurement was repeated three times.

#### ***2.4.Determination of volatile compounds by Gas Chromatography/Mass Spectrophotometry***

GC/MS separation was carried out in Analytical Chemistry Special Unit (Assiut University) following method described by **Jorge, Enrique and Rolando (2006)**. GC/MS used to analyse the samples was a Hewlett–Packard model 6890N GC equipped with a 5973 mass-selective detector (Agilent Technologies, USA). It was fitted with a HP-5MS fused silica capillary column (30 m x 0.25 mm x 0.25  $\mu\text{m}$ ). The temperatures at the injector and detector were 250 °C. The oven was held at 50 °C for 2 min and then increased to 280 °C at 4 °C min<sup>-1</sup> and held for 10 min. The flow rate of carrier gas (helium) was 1 ml min<sup>-1</sup>. The detector operated in electron impact mode (70 eV) at 230 °C. Detection was performed in the scan mode between

30 and 400 Da. Components were identified by comparison of their mass spectra with those at National Institute of Standards and Technology (NIST) or Wiley data base, and confirmed, in many compounds, by their relative retention indices.

Isolation of volatile compounds was done by blending appropriate weight of red chilli sample for 1 min with 500 mL of distilled water. Immediately the resultant puree was treated in a simultaneous steam-distillation-solvent extraction apparatus for 1 h. Dichloromethane (40 mL) was used as an extracting solvent and the condenser was cooled at 10 °C. The volatile concentrate was dried over anhydrous sulfate and concentrated to 0.6 mL on a Kuderna–Danish evaporator and then, to 0.2 mL with a gentle nitrogen stream. Extractions were made by in duplicate for the three red chilli samples.

### ***2.5. Statistical analysis***

Data were expressed as means  $\pm$  SD. Statistical analysis was performed by using Student's t-test. Differences were considered significant at  $P \leq 0.05$ . Recovery was calculated by dividing the detector response of analyte in the sample to the response of analyte reference material. All statistical data obtained using MiniTab statistical program (USA).

## ***3. Results and Discussion***

### ***3.1. Determination of Capsaicin by Capillary Electrophoresis***

The system used for the determination of capsaicin in red chillis of raw and in samples treated by microwave and gamma radiations was optimized to be simple, rapid and reliable. The extraction of capsaicin was simplified by dissolving samples in a little volume of methanol and sonicating for 10 minutes. The results have been more than satisfactory where the lost of capsaicin was less than 0.5% quantified with a standard solution before and after the sonication. As well, the other instrumental parameters such as applied voltage, injection time, injection pressure, etc were optimized as described in the experimental section. The reliability of the proposed system was evaluated by checking precision of the measurements. Twenty consecutive runs with standard solution (2000 mg/L) of capsaicin were performed within the same day (repeatability) and three consecutive days (reproducibility). The relative standard deviations (RSDs) were calculated and found to be 0.95% and 1.75% for repeatability and reproducibility, respectively. These values indicate the high precision of the



proposed system. The method detection limit was also checked and was found to be 5.15 mg/L which is about three times the detection limit calculated in previous method (Andromaque, 1999). Therefore, the slight modification of the parameters increased the sensitivity of the proposed method and was consistent with our objectives.

Quantitation of capsaicin was obtained by comparison of capsaicin peak areas of known concentration. The detector response was linear over the range of 0.5 mg/L to 20 mg/L. Correlation coefficient was greater than 0.99 for the standard curve. The mean of slope (n=5) was 0.0213 (S.D.  $\pm$  0.0004). The y-intercept was determined to be not significantly different from zero ( $p > 0.05$ ). The results obtained for the quantification of capsaicin in red chillis are presented in Table 1. The electropherograms of the three samples displayed in Fig. 1. The results obtained correspond very well to different levels of capsaicin obtained in each sample. The electropherogram (a) for "raw red chilli" which has the highest capsaicin concentration, (b) for "gamma irradiated red chilli" in which capsaicin decreased significantly (about half of raw red chilli) and (c) for "microwaved red chilli" which has approximately equal capsaicin content to raw red chilli. The above results indicated that gamma radiation has a great influence on the capsaicin composition in comparison to the results obtained with microwave. Capsaicin decreased 63.17% by gamma irradiation and 21.29% by microwave treatment.

#### ***Beneficial and adverse effects of capsaicin***

It was well-known that capsaicin inhibits the arylhydrocarbon hydroxylase responsible for the metabolism of carcinogenic polycyclic aromatic hydrocarbons. Capsaicin was also found to suppress the metabolism and covalent DNA binding of polycyclic aromatic hydrocarbons in human and mouse keratinocytes (Modly, Das, Don, Marcelo, Mukhtar and Bickers, 1986). In addition, it has been demonstrated that capsaicin modulates the microsomal cytochrome P450 enzymes *CYP3A1*, *2A2*, *2B1*, *2B2*, *2C6*, and *2C11*, thereby affecting the metabolism of carcinogens and other xenobiotics (Teel, 1991). Capsaicin can affect the initiating activities of aflatoxin B1 by modulating its metabolism and inhibiting the covalent DNA binding of aflatoxin B1 (Teel, 1991). Capsaicin also inhibited the tumorigenicity of vinyl carbamate and dimethylnitrosamine which are activated by cytochrome P450 2E1 (Surh, Lee, Park, Mayne, Liem and Miller, 1995), and repressed the growth of some transformed cells of human

origin, including ovarian carcinoma, mammary adenocarcinoma, and human promyelocytic leukemia cells in culture. The capsaicin-induced growth inhibition and apoptosis shown by the aforementioned cell lines was correlated with the inhibition of plasma membrane NADH oxidase activity. An early Italian case-control study revealed that chili consumption was protective against stomach cancer (Buiatti et al, 1989). However, an epidemiologic study showed that chilli pepper consumers have a greater risk to develop stomach cancer than non-consumers (Toth, and Gannett, 1992). A small number of studies have been conducted to assess the carcinogenic potency of capsaicin and of chilli extract. Initial work showed that rats fed diets containing 10% chilli pepper developed liver tumors (Hoch-Ligeti, 1952), and the dietary administration of capsaicin produced duodenal tumors in Swiss albino mice (Toth, and Gannett, 1992; Toth, Rogan and Walker, 1984). Other studies suggested that capsaicin may act as a co-carcinogen or tumor promoter (Agrawal, Wiessler, Hecker and Bhide, 1986; Surh, and Lee, 1995). Therefore, capsaicin seems to promote or inhibit chemically induced carcinogenesis and mutagenesis. Although a minute amount of capsaicin has little or no deleterious effects, heavy ingestion of this compound might be associated with necrosis, ulceration and even carcinogenesis. Capsaicin metabolites mediated by cytochrome P450 may interact with target cell DNA in an irreversible manner, thereby triggering mutagenicity and malignant transformation. In contrast, capsaicin can alter the metabolism of chemical carcinogens. At lower doses, the electrophilic toxic metabolites of capsaicin are probably effectively removed either by cellular nucleophiles, such as reduced glutathione, or by other conjugation reactions including sulfation and glucuronidation. If such defensive processes are saturated by a high dosage of malfunctioning capsaicin, toxic metabolites of capsaicin will accumulate and consequently may lead to carcinogenesis. Therefore, from the point of human health based on our observations, the sanitization of red chilli using gamma irradiation could be more beneficial than that using microwave technology.

### ***3.2. Determination of volatile compounds by GC/MS***

The volatile composition in red chillis of raw and in the samples treated by microwave and gamma radiations were obtained by simultaneous steam-distillation-solvent extraction and analyzed by GC/MS using fused silica capillary columns. Tables 2, 3 and 4 show the majority of volatile compounds found in the three samples. In total, forty four volatile

compounds were identified in the raw sample, all of them reported for the first time in Egyptian red chillis. The total amount was 898 mg/kg. and decreased by irradiation: 566 mg/kg and after microwave: 524 mg/kg. The volatile compounds that characterize red chillis can be classified into aromatic hydrocarbons, esters, phenolic, sulfur, ketone, naphthalene and benzene derivatives compounds. Esters and benzene derivative volatile compounds are the most effective compounds on the odour of red chilli. It is interesting the presence of so many aromatic hydrocarbons in raw sample; the total amount was found to be 360 mg/kg (Table 2). The abundance of such compounds decreased obviously after sanitization by gamma radiation (171 mg/kg) as presented in Table 3 and microwave (144 mg/kg) as cited in Table 4. Nonane, hexadecane, trimethylcyclohexane, dimethylhexadecane, tricosane, tetracosane and docosane were the major ones in the raw red chilli. It was interesting that all these compounds disappeared after sanitization except Nonane, trimethylcyclohexane and dimethyldecane. In addition, other aromatic hydrocarbons existed in low amounts in raw red chilli such as heptadecane (3 mg), tetramethylhexadecane (11 mg), octadecane (13 mg), nonadecane (10 mg), eicosane (6 mg), heneicosane (10 mg) and octadecane (8 mg) as cited in Table 2 were disappeared completely in gamma irradiated and microwaved red chilli.

Esters presented in small number of compounds in raw red chilli such as tetradecanoic acid (9 mg) and hexanoic acid (31 mg), their contribution to the odour is considerable. Interestingly, these esters reported in raw red chilli were not detected in gamma and microwaved treated samples. The same behaviour was observed for the phenolic compounds (e.g. m-ter-butylphenol, 2-(1,1-dimethylethyl)-5-methyl phenol and 2,4-bis(1,1-dimethylethyl) phenol), the sulfur compound (p,p'- dichlorosulfone) and the ketone compounds (e.g. 1,1-dimethyl-5-hydroxy-1,3-dihydro-isobenzofuran-3-one and 1,2-diphenyl ethanone). Interestingly, the naphthalene compounds (e.g. naphthalene and 2-methyl naphthalene) were detected in raw red chilli (Table 2) and in gamma irradiated red chilli (Table 3) but disappeared completely in microwaved red chilli (Table 4).

One of the benzene derivatives volatile compounds namely ethyl benzene existed in high level in raw chilli (61 mg), gamma irradiated chilli (60 mg) and microwaved chilli (57 mg), this compound contributes to the odour of red chilli samples. Other benzene derivatives such as isopropyl benzene and 3,5-dimethyl-1-ethylbenzene were detected in the studied

samples at approximately the same level as indicated in [Tables 2, 3 and 4](#). On the other hand, 1,2,3-trimethylbenzene was quantified in raw and gamma irradiated chillis at the same concentration (21 mg) and its level decreased significantly in microwaved red chilli (8 mg). While, 1,2,3,4-tetramethylbenzene was measured in raw and gamma irradiated chillis at the same level (1 mg) and disappeared completely in microwaved red chilli. 1,4-dimethyl-2-ethylbenzene was detected at 2 mg in raw red chilli and disappeared in both other studied samples. The explanation for the disappearance of some compounds by gamma radiation and others by microwave is not clear for us and may need some other physical analysis for samples after both treatments. Only we can say that this behavior could be attributed to the effect of gained energy by microwave or gamma radiation on the degree of volatilization of these aromatic compounds.

#### ***Beneficial and adverse effects of volatile compounds***

The cytotoxic capacity of the volatile oils based on prooxidant activity can make them excellent antiseptic and antimicrobial agents for personal use. A big advantage of volatile oils shows a very clear antimutagenic capacity which could well be linked to anticarcinogenic activity. Recent studies have demonstrated that the prooxidant activity of volatile oils or some of their constituents, as also that of some polyphenols, is very efficient in reducing local tumor volume or tumor cell proliferation by apoptotic and/or necrotic effects ([Buhagiar, Podesta, Wilson, Micallef and Ali, 1999](#); [Salim and Fukushima, 2003](#); [Kloog and Cox, 2004](#); [Paik, Koh, Beak, Paek and Kim, 2005](#); [Yoo et al., 2005](#); [Kachadourian and Day, 2006](#)). [Sylvestre, Legault, Dufour and Pichette \(2005\)](#) & [Sylvestre, Pichette, Longtin, Nagau and Legault \(2006\)](#) also have shown that volatile oils have an anticancerogenic activity on the lung and colon cancer cell lines. [Salim and Fukushima \(2003\)](#) have shown an antiproliferative activity and inhibition of 1,2-dimethylhydrazine-induced cancer in the rat by volatile oil. Therefore, the sanitization of red chilli by gamma irradiation is more beneficial from the human health point of view than that by microwave where the decreasing amount level of volatile oils is less.

#### ***4. Conclusion***

The main objective of this study is to evaluate the use of two different kinds of radiations (gamma and microwave) in the quality of the red chilli and this evaluation was in function to determine the effect in the

concentration of capsaicin and the profile of the volatile compounds. The use of micellar electrokinetic chromatography and gas chromatography/mass spectrometry to detect capsaicin and volatile oils in raw and treated red chilli samples was investigated. It was found that gamma irradiation decreased the level of capsaicin (63.17%) more than microwave radiation (21.29%). The total of volatile compounds in the raw chilli are 45 compounds, with a quantity of 898 mg/kg, in microwave appeared 18 compounds with a quantity of 524 mg/kg and with gamma radiation appeared 24 compounds with a quantity of 566 mg/kg. Some volatile compounds disappeared by gamma radiation and others by microwave, this could be attributed to the type of gained energy and its effect on the degree of volatilization of such compounds. From the point of beneficial and adverse effects of capsaicin and volatile oils based on its concentration, the treatment of red chilli by gamma irradiation could be preferred than that by microwave.

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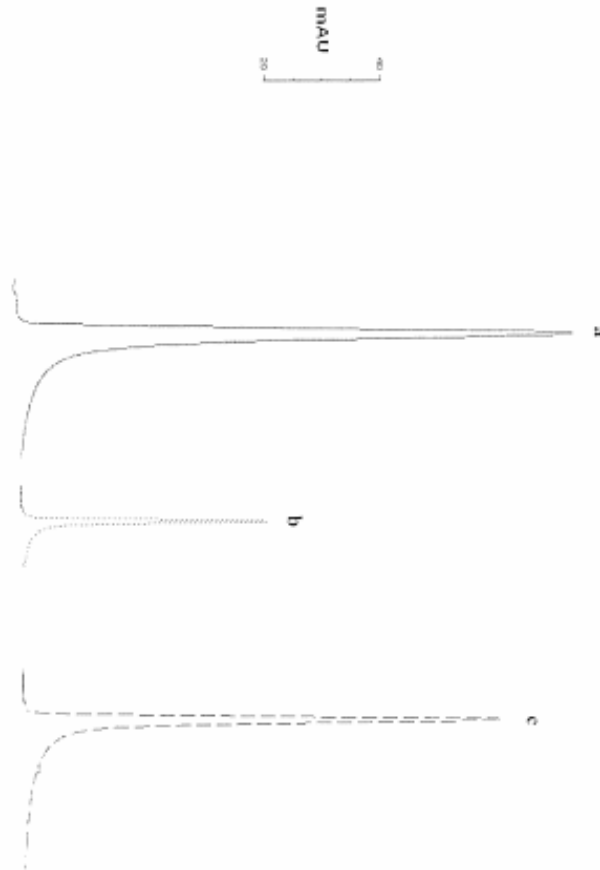
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**Figure Legend:**

**Fig. 1:** Comparison between the micellar electrokinetic chromatograms of a) raw red chilli; b) gamma irradiated red chilli and c) microwaved red chilli (1.5 g of each sample in 10 mL methanol) under the experimental conditions as cited in the text.



**Table 1:**

Amount of capsaicin (mg/kg) in raw, microwaved and gamma irradiated red chillis

Sample	Amount of Capsaicin, mg/kg ( $\pm$ S.D. <sup>a</sup> )
Raw red Chilli	92.60 ( $\pm$ 0.53, n= 6)
Gamma irradiated red chilli	34.10 ( $\pm$ 0.45, n= 6)
Microwaved red chilli	72.89 ( $\pm$ 0.79, n= 6)

<sup>a</sup>S.D.: Standard Deviation

**Table 2: Volatile compounds found in raw red chilli sample and their concentrations (mg/kg)**

Compound	Concentration, mg/kg ( $\pm$ S.D. <sup>a</sup> )	R <sup>b</sup>
1,2,4-Trimethyl cyclohexane	34.00 ( $\pm$ 0.31)	105.38
5,6-Dimethyl decane	28.00 ( $\pm$ 0.18)	98.13
Ethylbenzene	61.00 ( $\pm$ 0.29)	110.05
p-Xylene	281.00( $\pm$ 0.19)	99.03
1-Ethyl-4-methylcyclohexane	15.00 ( $\pm$ 0.30)	101.55
Styrene	32.00 ( $\pm$ 0.27)	90.29
Nonane	68.00 ( $\pm$ 0.17)	112.08
Isopropyl benzene	5.00 ( $\pm$ 0.10)	98.33
Propyl cyclohexane	6.00 ( $\pm$ 0.15)	88.55
m-Ethyl toluene	6.00 ( $\pm$ 0.13)	100.38
1,2,3-Trimethyl benzene	21.00 ( $\pm$ 0.25)	111.89
Decane	4.00 ( $\pm$ 0.11)	100.21
m-Propyl toluene	2.00 ( $\pm$ 0.07)	101.16
1,4-Dimethyl-2-ethyl benzene	2.00 ( $\pm$ 0.08)	99.98
2-Ethyl-p-xylene	1.00 ( $\pm$ 0.02)	88.94
Undecane	4.00 ( $\pm$ 0.12)	100.16
3,5-Dimethyl-1-ethylbenzene	3.00 ( $\pm$ 0.19)	100.23
1,2,3,4-Tetramethyl benzene	1.00 ( $\pm$ 0.04)	89.98
Naphthalene	2.00 ( $\pm$ 0.03)	101.13
Dodecane	3.00 ( $\pm$ 0.08)	99.97
2-Methyl naphthalene	2.00 ( $\pm$ 0.03)	89.56
m-ter-butyl phenol	5.00 ( $\pm$ 0.16)	100.18
Tridecane	7.00 ( $\pm$ 0.21)	99.38
2-(1,1-Dimethylethyl)-5-methyl phenol	2.00 ( $\pm$ 0.09)	88.13
Tetradecane	9.00 ( $\pm$ 0.29)	100.05
1,1-Dimethyl-5-hydroxy-1,3-dihydro- Isobenzofuran-3-one	3.00 ( $\pm$ 0.09)	99.03
Hexadecane	47.00 ( $\pm$ 0.30)	101.55
Pentadecane	3.00 ( $\pm$ 0.07)	80.29
2,4-bis(1,1-dimethylethyl) phenol	2.00 ( $\pm$ 0.03)	112.08
Heptadecane	16.00 ( $\pm$ 0.20)	98.33
2,6,11,15-Tetramethyl hexadecane	11.00 ( $\pm$ 0.15)	98.55
1,2-Diphenyl ethanone	8.00 ( $\pm$ 0.23)	105.38
Octadecane	13.00 ( $\pm$ 0.25)	101.89
Tetradecanoic acid-1-methyl ethyl ester	9.00 ( $\pm$ 0.13)	99.03
Nonadecane	10.00 ( $\pm$ 0.16)	101.55
Eicosane	6.00 ( $\pm$ 0.30)	89.29
Heneicosane	10.00 ( $\pm$ 0.24)	102.08
Docosane	20.00 ( $\pm$ 0.19)	98.33
p,p'-Dichlorodiphenyl sulfone	23.00 ( $\pm$ 0.32)	98.55
Tricosane	26.00 ( $\pm$ 0.22)	100.38

Compound	Concentration, mg/kg ( $\pm$ S.D. <sup>a</sup> )	R <sup>b</sup>
Tetracosane	25.00 ( $\pm$ 0.15)	101.89
2-Ethyl hexadecyl ester hexanoic acid	31.00 ( $\pm$ 0.33)	99.56
Octacosane	8.00 ( $\pm$ 0.11)	110.21
Bis(2-ethylhexyl) phthalate	23.00 ( $\pm$ 0.23)	98.99

<sup>a</sup>S.D.: Standard Deviation

<sup>b</sup>R: Per cent recovery

**Table 3: Volatile compounds found in gamma irradiated red chilli sample and their concentrations (mg/kg)**

Compound	Concentration, mg/kg ( $\pm$ S.D.)	R
1,2,4-Trimethyl cyclohexane	34.00 ( $\pm$ 0.31)	100.21
5,6-Dimethyl decane	27.00 ( $\pm$ 0.18)	101.16
Ethylbenzene	60.00 ( $\pm$ 0.29)	99.98
p-Xylene	266.00 ( $\pm$ 0.49)	98.94
1-Ethyl-4-methylcyclohexane	12.00 ( $\pm$ 0.30)	105.16
Styrene	27.00 ( $\pm$ 0.27)	100.23
Nonane	63.00 ( $\pm$ 0.77)	99.98
Isopropyl benzene	5.00 ( $\pm$ 0.15)	111.13
Propyl cyclohexane	6.00 ( $\pm$ 0.18)	99.97
m-Ethyl toluene	5.00 ( $\pm$ 0.13)	99.56
1,2,3-Trimethyl benzene	21.00 ( $\pm$ 0.25)	100.18
Decane	4.00 ( $\pm$ 0.03)	101.13
m-Propyl toluene	2.00 ( $\pm$ 0.02)	90.15
1,4-Dimethyl-2-ethyl benzene	2.00 ( $\pm$ 0.04)	99.38
2-Ethyl-p-xylene	1.00 ( $\pm$ 0.02)	80.13
Undecane	4.00 ( $\pm$ 0.09)	100.05
3,5-Dimethyl-1-ethylbenzene	3.00 ( $\pm$ 0.03)	99.03
1,2,3,4-Tetramethyl benzene	1.00 ( $\pm$ 0.02)	111.55
Naphthalene	1.00 ( $\pm$ 0.02)	109.29
Dodecane	3.00 ( $\pm$ 0.04)	105.08
2-Methyl naphthalene	1.00 ( $\pm$ 0.02)	88.33
Tridecane	7.00 ( $\pm$ 0.25)	88.55
Tetradecane	9.00 ( $\pm$ 0.18)	90.38
Pentadecane	2.00 ( $\pm$ 0.04)	81.89

**Table 4: Volatile compounds found in microwaved red chilli sample and their concentrations (mg/kg)**

Compound	Concentration, mg/kg ( $\pm$ S.D.)	R
1,2,4-Trimethyl cyclohexane	28.00 ( $\pm$ 0.31)	99.38
5,6-Dimethyl decane	27.00 ( $\pm$ 0.18)	98.13
Ethylbenzene	57.00 ( $\pm$ 0.29)	100.05
p-Xylene	265.00 ( $\pm$ 0.49)	99.03
1-Ethyl-4-methylcyclohexane	12.00 ( $\pm$ 0.13)	111.55
Styrene	27.00 ( $\pm$ 0.27)	99.29
Nonane	62.00 ( $\pm$ 0.57)	102.08
Isopropyl benzene	5.00 ( $\pm$ 0.13)	88.33
Propyl cyclohexane	6.00 ( $\pm$ 0.15)	88.55
m-Ethyl toluene	5.00 ( $\pm$ 0.13)	90.38
1,2,3-Trimethyl benzene	8.00 ( $\pm$ 0.25)	91.89
Decane	2.00 ( $\pm$ 0.06)	99.56
Undecane	1.00 ( $\pm$ 0.03)	80.21
3,5-Dimethyl-1-ethylbenzene	1.00 ( $\pm$ 0.02)	80.99
Dodecane	3.00 ( $\pm$ 0.16)	91.02
Tridecane	6.00 ( $\pm$ 0.19)	95.23
Tetradecane	7.00 ( $\pm$ 0.26)	96.60
Pentadecane	2.00 ( $\pm$ 0.08)	82.97

## تأثير أشعة جاما و الميكروويف على الكابيسين و الزيوت الطيارة بالشطة الحمراء

أ.د/ محمد كمال السيد يوسف

أستاذ علوم وتكنولوجيا الأغذية بكلية الزراعة- جامعة أسيوط وعضو أكاديمية العلوم الأمريكية

أ.د/ سناء محمد البندارى

أستاذ التغذية بكلية التربية النوعية- جامعة عين شمس

د/ نجلاء طه حنفي المليجي

أستاذ مساعد الكيمياء الحيوية الطبية بكلية الطب- جامعة أسيوط

أ/ رشا موسى أحمد موسى

مدرس مساعد بقسم الاقتصاد المنزلي- جامعة أسيوط

### المستخلص

تم تشيع الشطة الحمراء بنوعين من الأشعة: أشعة جاما وأشعة الميكروويف. وتم دراسة تأثيرهما على تركيزات الكابيسين والزيوت الطيارة باستخدام طريقتين هما على وجه التحديد: كروماتوجرافيا الالكتروكائنايكية الغروية وكروماتوجرافيا الغاز/الطيف الكتلي. وتم تشيع العينة بأشعة جاما عند جرعة مقدارها ١٠ كيلو/جراي ، وبأشعة الميكروويف من مصدر اشعاعى مستمر عند معدل ٥٠ وات/كجم من الشطة الحمراء لمدة ١٥ دقيقة. ولوحظ حدوث إنخفاض فى تركيز الكابيسين بنسبة ٦٣.١٧% بعد التعرض لأشعة جاما و بنسبة ٢١.٢٩% بعد التعرض لأشعة الميكروويف. كما تم التعرف على ٤٤ نوعا من الزيوت الطيارة معظمها تم إكتشافها وفصلها و التعرف عليها لأول مرة. وكان التركيز الكلى للزيوت الطيارة هو ٨٩٨ ملجرام/كيلو جرام إنخفض إلى ٥٦٦ ملجرام /كيلو جرام بعد المعالجة بأشعة جاما و ٥٢٤ ملجرام/ كيلو جرام بعد المعالجة بأشعة الميكروويف. ووجد أن بعض المركبات الهيدروكربونية الأروماتية مثل هيبثاديكان وتيترا ميثيل هيكساديكان وأوكتاديكان قد إختفت تماماً بعد التعرض للإشعاع، فى حين أن بعض المركبات الأخرى مثل إيثيل بنزين بقيت بنفس التركيز. ولقد تم اختبار دقة النتائج بحساب قيمة الانحراف المعياري للقيم الناتجة من تكرار القياس. وتم اجراء التحليل الاحصائى باستخدام اختبار الطالب " t ". وأوضحت النتائج وجود اختلافات ذات دلالة احصائية عند مستوى  $P \leq 0.05$ .

### الكلمات المفتاحية:

الشطة الحمراء - جاما - ميكروويف - كابيسين - الزيوت الطيارة