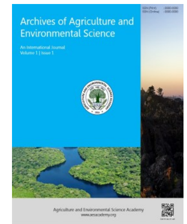
Archives of Agriculture and Environmental Science 1 (1): 22-36 (2016)

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: www.aesacademy.org

e-ISSN: 2456-6632



ORIGINAL RESEARCH ARTICLE

Quantitative evaluation of essential oils for the identification of chemical constituents by gas chromatography/mass spectrometry

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ARTICLE HISTORY

Received: 18 Sept. 2016
Revised received: 22 Sept. 2016
Accepted: 25 Sept. 2016

Keywords

Chemical constituents
Essential oils
Gas chromatography
Mass Spectrometry

ABSTRACT

Essential oils are greatly strenuous aromatic materials having various constituents. They are used in the preparation of various precious substances like making perfumes, medicines, cleaning agent, and aromatic treatment etc. The purpose of the present investigation was to identify the major and minor chemical constituent in eighteen essential oils *viz.,* amyris, basil, black pepper, camphor, catnip, chamomile, cinnamon, citronella, dill, frankincense, galbanum, jasmine, juniper, lavender, peppermint, rosemary, tagetes and thyme with the help of gas chromatography /mass spectrometry (GC/MS). In eighteen essential oils the identified compounds studied by GC-MS contain various types of high and low molecular weights of chemical ingredients. Therefore, GC/MS efficiently and speedily screened all the volatile elements present in the essential oils for the quantitative use of these identified chemical constituents for various reasons.

Citation of this article: Uniyal, A., Tikar, S.N., Agrawal, O.P., Sukumaran, D. and Veer, V. (2016). Quantitative evaluation of essential oils for the identification of chemical constituents by gas chromatography/mass spectrometry. *Archives of Agriculture and Environmental Science,* 1(1): 22-36.

INTRODUCTION

Essential oils are natural secondary plant products contain highly volatile liquid contain many chemicals. Most of the essential oils grouped into major chemical categories like alkaloids, phenolics and terpenoids are major constituents of essential oils. Essential oils are extracted from various parts of plants with the help of distillation methods such as hydro distillation, steam distillation hydro-steam distillation and solvent extraction. A variety of biological activities including behavioural responses have been recorded towards such essential oils in different living organisms. The response of biological agents comprises all activities that these volatile compounds or their mixtures exert on humans, animals, and other plants (Marcelle Gonny *et al.,* 2006; Suleiman Afsharypuor and Nahid Azarbayejany, 2006; Baser and Buchbauer, 2010).

The important oil producing plants are represented in more than thirty families of plants, comprising some ninety species. The majority of spices (cardamom, clove, nutmeg, ginger etc.) originate from tropical countries. Conversely the majority of herbs (bay, cumin, dill, marjoram, fennel, lavender, rosemary, thyme, etc.) grow in temperate climates. The same plant grown in different regions and under different conditions can produce essential oils of widely diverse characteristics, which are known as "chemotypes". Common thyme (*Thymus vulgaris*) for example produces several chemotypes depending on the conditions of its growth and dominant constituent, notably the citral or linalool types, and the thymol or carvacrol type. It is therefore important not only to know the botanical name of the plant from which an oil has been produced, but also its place of origin and main constituents which are concerned to define its qualities (Lawless, 1992).

Essential oils are extracted from almost every conceivable plant part, such as flowers like rose and chamomile, leaves as peppermint and rosemary, fruits of orange and lemon, seeds as in coriander and fennel, grasses like lemongrass and ginger grass, roots and rhizomes as ginger, wood of cedar wood and sandalwood, bark like in cinnamon, gum as in frankincense (Tisserand, 1990). There are also essential oil from bulbs like garlic, dried flower buds like clove, and from stems or twig like clove stem. Usually they are liquid but can also be solid or semisolid, according to temperature such as rose. The majority of essential oils are clear or pale yellow in color, although a few are deeply colored like German chamomile (blue). They are damaged by the effects of light, heat, air and moisture, and should always be kept in a cool environment, in tightly Stoppard dark glass bottles. Essential oils are dissolved in pure alcohol, fats and are not soluble in water (Tisserand, 1990; Suleiman Afsharypuor and Nahid Azarbayejany, 2006). The chemical constituents present in the different essential oils are used in perfumes, cosmetics, soaps, for flavoring foods, drinks and household cleaning products and various essential oils have been used in medical formulations. Keeping above in view, the present investigation was carried out this study, to determine the various chemical constituents present in the different essential oils using gas chromatography /mass spectrometry (GC/MS) and identified with their retention time and molecular weight.

MATERIALS AND METHODS

Collection of essential oils: Eighteen essential oils namely amyris (*Amyris balsamifera*), basil (*Ocimum basilicum*), black pepper (*Piper nigrum*), camphor (*Cinnamomum camphora*), catnip (*Nepeta cataria*), chamomile (*Anthemis nobilis*), cinnamon (*Cinnamamomus zeylanicum*), citronella (*Cymbopogon winterianus*), dill (*Anethum graveolens*), frankincense (*Boswellia carteri*), galbanum (*Ferula galbaniflua*), jasmine (*Jasminum grandiflorum*), juniper (*Juniperus communis*), lavender (*Lavendula angustifolia*), peppermint (*Mentha piperita*), rosemary (*Rosmarinus officinalis*), tagetes (*Tagetes minuta*), thyme (*Thymus serpyllum*) were obtained from the authentic source of trade/ Fragrance and Flavour Development Center (FFDC), Kannuj (Uttar Pradesh) for the identification of essential oils and chemical constituents.

Gas chromatography /Mass spectrometry analysis: Gas chromatography /mass spectrometry are standard equipment used to analyze different chemical components present in essential oil. GC/MS is a method that combines the features of gas-liquid chromatography and mass spectrometry to identify different substances within a sample. The identification of component in 23 essential oils was analyzed by gas chromatography/ mass spectrometry (GC/MS). GC/MS analysis of the oil was carried out on an Agilent gas chromatograph (2880A) with a (30 m × 0.32mm × 0.25 µ ID) equipped with an Agilent mass selective detector in the electron impact mode (Ionization energy: 70 eV). Helium gas was used as the carrier gas at constant flow rate 2 ml/minute and an injection volume of 1 µl was employed (Split ratio of 100:1) injector temperature 250°C; ion-source temperature 260°C, capillary: 30 m × 230µm, film thickness 0.25 µm, average velocity 44.6 cm/s, pressure 1.9 psi, purge flow 3 ml/minute, purge time 0.20 minute. The oven temperature was programmed from 50 to 325°C (isothermal for 2 minutes) with an increase of 5°C/minute to 160°C, then 20°C/minute to 260°C, equilibration time 1 minute, ramp 5°C/min, ending with a 30 minutes isothermal at 290°C. Total GC running time was 30 minutes. The volume of injected specimen of 1µl of diluted oil in methanol solution (1%).

Identification of chemical constituents: The chemical constituents of essential oils were identified in comparison with their retention indices. Identification of components of essential oil was based on retention indices (RI) and computer matching with the PBM libraries.

RESULTS AND DISCUSSION

Essential oils are highly concentrated aromatic substances found in plants contain numbers of organic constituents including hormones, vitamin and other natural elements. Therefore, it is important to identification the components of essential oils using gas chromatography /mass spectrome-

Table 1. Major chemical components of different essential oils identified by GC/MS.

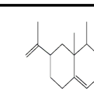
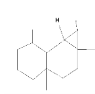
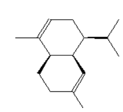
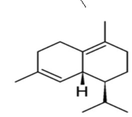
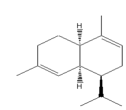
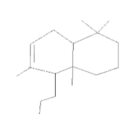
Oil	Chemical Name	R.T.	IUPAC Name	Molecular Formula	M.W.	Qual. %	Structure
	eremophilene	20.917	4a,5-dimethyl-3-prop-1-en-2-yl-2,3,4,5,6,7-hexahydro-1H-naphthalene	$C_{15}H_{24}$	204	90	
	β-maaliene	22.593	1,1,3a,7-tetramethyl-1a,2,3,3a,4,5,6,7b-octahydro-1H-cyclopropa(a)naphthalene	$C_{15}H_{24}$	204	95	
	β-amorphene	22.666	2-Isopropyl-5-methyl-9-methylene-bicyclo-1-decene(4.4.0)	$C_{15}H_{24}$	204	93	
Amyris	*β*- cadinene	22.824	4-isopropyl-1,6-dimethyldecahydronaphthalene	$C_{15}H_{24}$	204	97	
	(+)-calarene	23.296	1,1,7,7a-tetramethyl-2,3,5,6,7,7b-hexahydro-1aH-cyclopropa(a)naphthalene	$C_{15}H_{24}$	204	97	
	driminol	24.928	2,5,5,8a-tetramethyl-1,4,4a,6,7,8-hexahydronaphthalen-1-yl)	$C_{15}H_{26}O$	222	94	

Table 1. *Contd.*

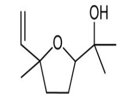
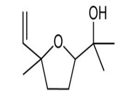
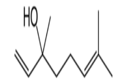
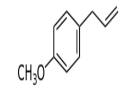
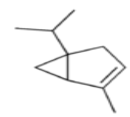
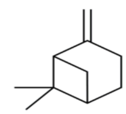
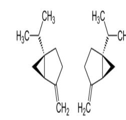
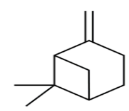
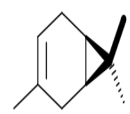
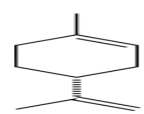
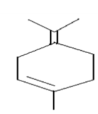
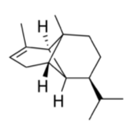
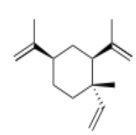
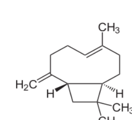
	linalool oxide	8.483	2-Methyl-2-vinyl-5-(1-hydroxy-1-methylethyl)tetrahydrofuran	$C_{10}H_{18}O_2$	170	80	
	linalool oxide	8.926	2-Methyl-2-vinyl-5-(1-hydroxy-1-methylethyl)tetrahydrofuran	$C_{10}H_{18}O_2$	170	90	
Basil	linalool	9.277	3, 7-dimethylocta-1, 6-dien-3-ol	$C_{10}H_{18}O$	154	93	
	estragole	11.949	1-allyl-4-methoxybenzene	$C_{10}H_{12}O$	148	98	
	α-thujene	4.854	4-methyl-1-propan-2-ylbicyclo(3.1.0) hex-3-ene	$C_{10}H_{16}$	136	93	
	β-pinene	5.007	6,6-Dimethyl-2-methylenebicyclo (3.1.1)heptanes	$C_{10}H_{16}$	136	97	
	sabinene	5.91	4-methylene-1-(1-methylethyl)bicycle (3.1.0)hexane	$C_{10}H_{16}$	136	97	
	β-pinene	6.019	6,6-Dimethyl-2-methylenebicyclo (3.1.1)heptanes	$C_{10}H_{16}$	136	97	
Black Pepper	*δ* -3-carene	6.781	3,7,7-trimethylbicyclo(4.1.0)hept-3-ene	$C_{10}H_{16}$	136	97	
	DL-limonene	7.371	1-Methyl-4-(1-methylethenyl)-cyclohexene	$C_{10}H_{16}$	136	99	
	P-mentha 1-,4(8)-dine	15.598	1-methyl-4-propan-2-ylidenecyclohexene	$C_{10}H_{16}$	136	91	
	(-)-*α*-copaene	16.663	8-isopropyl-1,3-dimethyltricyclo (4.4.0.0^{2,7})dec-3-ene	$C_{15}H_{24}$	204	99	
	β-elemene	17.005	2,4-Disopropenyl-1-methyl-1-Venylcyclohexane	$C_{15}H_{24}$	204	99	
	β- caryo-phyllene	17.733	4, 11, 11-trimethyl-8-methylene-bicyclo (7.2.0) undec-4-ene	$C_{15}H_{24.}$	204	99	

Table 1. *Contd.*

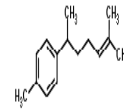
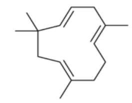
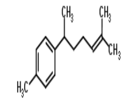
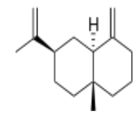
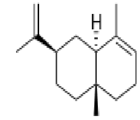
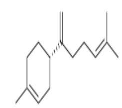
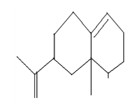
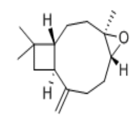
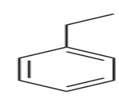
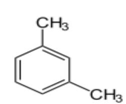
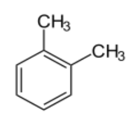
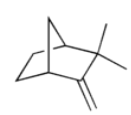
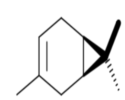
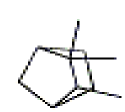
	α-bergamotene	18.103	2,6-dimethyl-6-(4-methylpent-3-en -1-yl)bicycle(3.1.1)hept-2-ene	$C_{15}H_{24}$	204	91	
	α-humulene	18.63	2,6,6,9-Tetramethyl-1,4-8-cycloundecatriene	$C_{15}H_{24}$	204	97	
	curcumene	19.308	1-Methyl-4-(6-methyl-5-hepten-2-yl)benzene	$C_{15}H_{22}$	204	96	
	β-selinene	19.447	Eudesma-4(14),11-diene	$C_{15}H_{24}$	204	99	
Black Pepper	α-selinene	19.623	Eudesma-3,11-diene	$C_{15}H_{24}$	204	97	
	β-bisabolene	19.658	1-Methyl-4-(6-methylhepta-1,5-dien-2-yl)cyclohex-1-ene	$C_{15}H_{24}$	204	97	
	eremophilene	20.942	4,5-dimethyl-3-prop-1-en-2-yl-2,3,4,5,6,7-hexahydro-1H-naphthalene	$C_{15}H_{24}$	204	90	
	caryophyllene oxide	21.676	4,12,12-trimethyl-9-methylene-5-oxatricyclo(8.2.0.04,6)dodecane	$C_{15}H_{24}O$	220	94	
	ethylbenzene	3.16	Ethylbenzene	C_8H_{10}	106	94	
	m-xylol	3.765	1,3-Dimethylbenzol	C_8H_{10}	106	97	
	O-xylene	4.17	1,2-Dimethylbenzol	C_8H_{10}	106	97	
Camphor	camphene	5.366	2,2-dimethyl-3-methylene-bicyclo (2.2.1)heptanes	$C_{10}H_{16}$	136	97	
	δ -3-carane	5.549	3,7,7-trimethylbicyclo(4.1.0)hept-3 -ene	$C_{10}H_{16}$	138	58	
	isocamphane	5.865	2,2,3-Trimethylbicyclo(2.2.1) heptanes	$C_{10}H_{18}$	138	97	
	norbornane	6.045	Bicyclo(2.2.1)heptanes	C_7H_{12}	138	96	

Table 1. *Contd.*

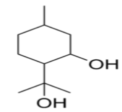
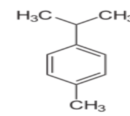
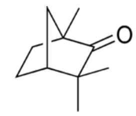
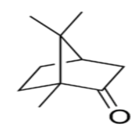
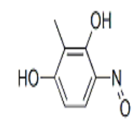
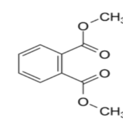
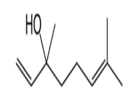
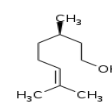
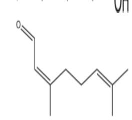
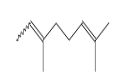
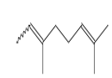
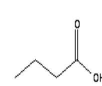
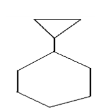
	p-menthane-3,8-diol	6.364	2-(1-Hydroxy-1-methylethyl)-5-methylcyclohexanol	$C_{10}H_{20}O_2$	140	74	
	p-cimene	7.198	1-Methyl-4-(1-methylethyl) benzene	$C_{10}H_{14}$	134	97	
	fencone	8.944	1,3,3-Trimethylbicyclo(2.2.1) heptan-2-one	$C_{10}H_{16}O$	154	95	
Camphor	acetaldehyde	9.422	Ethanal	C_2H_4O	152	90	
	camphor	10.547	1,7,7-Trimethylbicyclo(2.2.1) heptan-2-one	$C_{10}H_{16}O$	152	98	
	2-methyl-4-nitrosoresorcinol	15.828	2-Methyl-4-nitrosoresorcinol	$C_7H_7NO_3$	153	50	
	dimethyl phalate	18.508	dimethyl benzene-1,2-dicarboxylate	$C_{10}H_{10}O_4$	194	94	
	linalool	9.268	3, 7-dimethylocta-1, 6-dien-3-ol	$C_{10}H_{18}O$	154	91	
	β-citronellol	12.794	3,7-Dimethyloct-6-en-1-ol	$C_{10}H_{20}O$	156	98	
	geraniol	13.434	3,7-Dimethyl-2,6-octadien-1-ol	$C_{10}H_{18}O$	154	94	
	neral	14.012	3,7-dimethylocta-2,6-dienal	$C_{10}H_{16}O$	152	49	
Catnip	2,6-Octadine,2,6-Dimethyl	15.816	2,6-Octadine,2,6-Dimethyl	$C_{10}H_{18}$	138	92	
	2,6-Octadine,2,6-Dimethyl	16.058	2,6-Octadine,2,6-Dimethyl	$C_{10}H_{18}$	138	98	
	butanoic acid	16.282	Butanoic acid	$C_4H_8O_2$	224	91	
	4-cyclopropyl cyclohexane	16.702	4-Cyclopropyl Cyclohexane	C_9H_{16}	112	58	

Table 1. *Contd.*

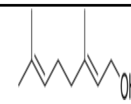
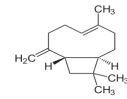
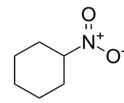
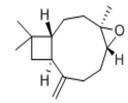
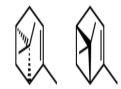
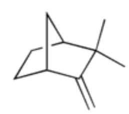
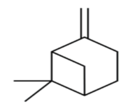
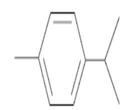
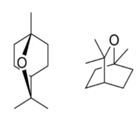
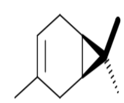
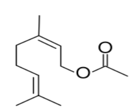
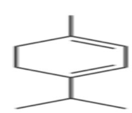
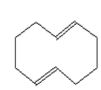
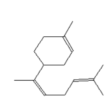
	geraniol ester	16.807	2,6-Octadien-1-ol, 3,7-dimethyl-, acetate	$C_{10}H_{18}O$	196	91	
	caryophyllene	17.718	4, 11, 11-trimethyl-8-methylene-bicyclo (7.2.0) undec-4-ene	$C_{15}H_{24}$	204	99	
Catnip	1-nitrocyclohexene	19.459	Nitrocyclohexane	$C_6H_{11}NO_2$	127	50	
	β-caryophyllene oxide	21.668	4,12,12-trimethyl-9-methylene-5 oxatricyclo(8.2.0.04,6)dodecane	$C_{15}H_{24}O$	220	94	
	tricyclene	4.768	1,4,7,10-tetrazacyclododecane	$C_{10}H_{16}$	136	50	
	α-pinene	5.003	2, 6, 6-Trimethyl bicycle (3.1.1) hept-2-ene	$C_{10}H_{16}$	136	86	
	camphene	5.366	2,2-dimethyl-3-methylene-bicyclo (2.2.1)heptanes	$C_{10}H_{16}$	136	94	
	β-pinene	6.016	6,6-Dimethyl-2-methylenebicyclo (3.1.1)heptanes	$C_{10}H_{16}$	136	94	
Chamo-mile	cymene	7.193	1-Methyl-4-(1-methylethyl) benzene	$C_{10}H_{14}$	134	87	
	1,8-cineole	7.428	1,3,3-Trimethyl-2-oxabicyclo (2,2,2)octane	$C_{10}H_{18}O$	154	98	
	δ -3-carene	7.781	3,7,7-trimethylbicyclo(4.1.0)hept-3-ene	$C_{10}H_{16}$	136	50	
	neryl acetate	9.274	3,7-Dimethyl-2,6-octadien-1-yl acetate	$C_{12}H_{20}O_2$	196	53	
	α- terpinene	11.882	4-Methyl-1-(1-methylethyl)-1,3-cyclohexadiene	$C_{10}H_{16}$	136	60	
	β-farnesene	18.633	3,7,11-trimethyldodeca-1,3,6,10-tetraene	$C_{15}H_{24}$	204	96	
	1,6-cyclodecadine	19.252	1,6-Cyclodecadiene	$C_{10}H_{16}$	204	94	
	Cis *α*-bisabolene	19.784	4-[(1Z)-1,5-Dimethyl-1,4-hexadienyl]-1-methyl-1-cyclohexene	$C_{15}H_{24}$	204	90	

Table 1. *Contd.*

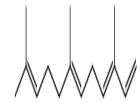
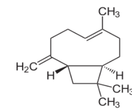
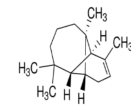
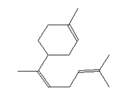
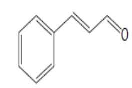
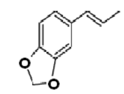
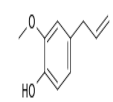
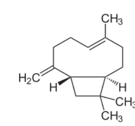
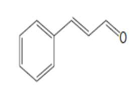
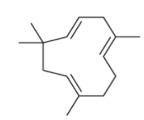
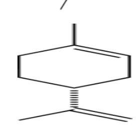
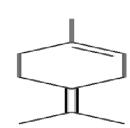
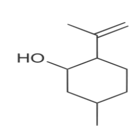
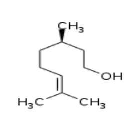
	α-franesene	19.892	3,7,11-trimethyldodeca-1,3,6,10-tetraene	$C_{15}H_{24}$	204	91	
Chamomile	*Trans*- caryo-phyllene	19.948	4,11,11-trimethyl-8-methylene-bicycle(7.2.0)undec-4-ene	$C_{15}H_{24}$	204	72	
	α-longipinene	20.01	2,6,6,9-Tetramethyltricyclo (5.4.0.0$^{2.8}$)undec-9-ene	$C_{15}H_{24}$	204	64	
	Cis *α*-bisabolene	20.73	4-[(1Z)-1,5-Dimethyl-1,4-hexadienyl]-1-methyl-1-cyclohexene	$C_{15}H_{24}$	204	93	
	cinnamal	13.966	2-Propenal, 3-phenyl	$C_{15}H_{20}O$	132	98	
	β-isosafrole	14.403	5-[(1*E*)-Prop-1-en-1-yl]-1,3-benz	$C_{10}H_{10}O2$	162	49	
	p-eugenol	16.054	2-methoxy-4-prop-2-enylphenol	$C_{10}H_{12}O_2$	164	98	
	β-caryophyllene	17.721	4, 11, 11-trimethyl-8-methylene-bicyclo (7.2.0) un-dec-4-ene	$C_{15}H_{24.}$	204	90	
	cinnamaldehyde	18.191	(2*E*)-3-phenylprop-2-enal	C_9H_8O	230	93	
Cinnamon	2-propen-1-ol	18.446	2-Propen-1-ol	C_3H_6O	176	53	
	α-humulene	18.621	2,6,6,9-Tetramethyl-1,4-8-cycloundecatriene	$C_{15}H_{24}$	204	39	
	DL-limonene	7.306	1-Methyl-4-(1-methylethenyl)-cyclohexene	$C_{10}H_{16}$	136	99	
	α-terpinolene	9.297	1-Methyl-4-(propan-2-ylidene) cyclohex-1-ene	$C_{10}H_{16}$	136	91	
Citronella	isopulegol	10.602	5-methyl-2-prop-1-en-2-ylcyclohexan-1-ol	$C_{10}H_{18}O$	154	98	
	citronella	10.712	3,7-dimethyloct-6-enal	$C_{10}H_{18}O$	154	98	

Table 1. *Contd.*

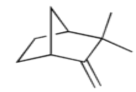
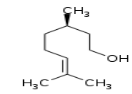
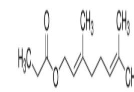
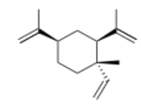
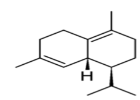
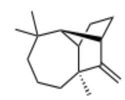
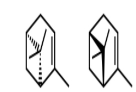
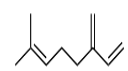
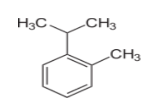
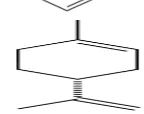
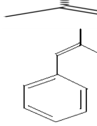
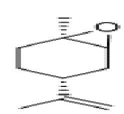
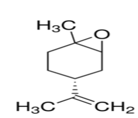
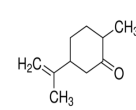
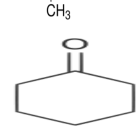
	camphene	10.859	2,2-dimethyl-3-methylene-bicyclo(2.2.1)heptanes	$C_{10}H_{16}$	136	91	
	β-citronellol	12.799	3,7-Dimethyloct-6-en-1-ol	$C_{10}H_{20}O$	156	98	
	geraniol	13.44	3,7-Dimethyl-2,6-octadien-1-ol	$C_{10}H_{18}O$	154	87	
Citronella	farnesol L	15.631	3,7,11-trimethyldodeca-2,6,10-trien-1-ol	$C_{15}H_{26}O$	222	49	
	geranyl propionate	16.803	2,6-Octadien-1-ol, 3,7-dimethyl-, propanoate	$C_{15}H_{24}$	210	90	
	β-elemene	17.001	2,4-Disopropenyl-1-methyl-1-Venylcyclohexane	$C_{15}H_{24}$	204	95	
	δ -cadinene	20.175	4,7-dimethyl-1-(propan-2-yl)-1,2,3,5,6,8a-hexahydronaphthalene	$C_{15}H_{24}$	204	99	
	(+)-longifolene	20.928	3,3,7-trimethyl- 8-methylenetricyclo- (5.4.0.0) undecane	$C_{15}H_{24}$	204	95	
	α-pinene	4.981	2, 6, 6-Trimethyl bicycle (3.1.1) hept-2-ene	$C_{10}H_{16}$	136	95	
	β-myrcene	5.856	7-Methyl-3-methylene-1,6-octadiene	$C_{10}H_{16}$	134	94	
	O-cymol	7.177	1-methyl-2-propan-2-ylbenzene	$C_{10}H_{14}$	134	97	
	DL-limonene	7.298	1-Methyl-4-(1-methylethenyl)-cyclohexene	$C_{10}H_{16}$	136	99	
Dill	2-Methyl-1-propenyl, benzene	8.928	2-methylprop-1-enylbenzene	$C_{10}H_{12}$	132	97	
	limonene epoxide	10.264	6-methyl-3-prop-1-en-2-yl-7-oxabicyclo(4.1.0) heptanes	$C_{10}H_{16}O$	152	76	
	limonene oxide	10.527	6-methyl-3-prop-1-en-2-yl-7-oxabicyclo(4.1.0) heptanes	$C_{10}H_{16}O$	134	78	
	(+)-dihydrocarvone	11.95	(2R,5R)-5-Isopropenyl-2-methylcyclohexanone	$C_{10}H_{16}O$	152	99	
	cyclohexanone	12.124	Cyclohexanone	$C_6H_{10}O$	152	98	

Table 1. *Contd.*

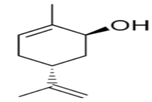
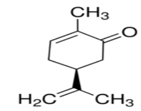
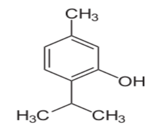
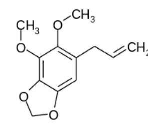
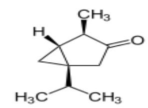
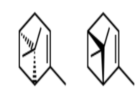
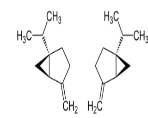
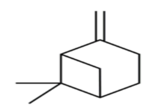
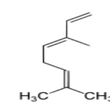
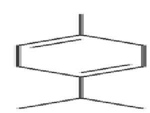
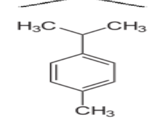
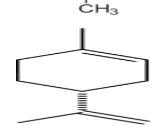
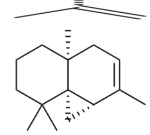
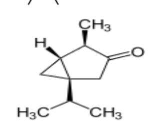
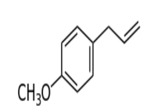
Dill	carveol	12.524	2-Methyl-5-(1-methylethenyl)-2-cyclohexen-1-ol	$C_{10}H_{16}O$	152	55	
	(+)-carvone	13.211	5-Isopropenyl-2-methyl-2-cyclohexenone, *p*-Mentha-6,8-dien-2-one	$C_{10}H_{14}O$	150	97	
	thymol	14.489	2-Isopropyl-5-methylphenol	$C_{10}H_{14}O$	150	95	
	dillapiole	22.536	1-Allyl-2,3-dimethoxy-4,5-(methylenedioxy)benzene	$C_{12}H_{14}O_4$	222	97	
Frankin-cense	*α*-thujene	4.85	4-Methyl-1-(propan-2-yl) bicycle(3.1.0)hexan-3-one	$C_{10}H_{16}O$	134	93	
	α-pinene	5.006	2, 6, 6-Trimethyl bicycle (3.1.1) hept-2-ene	$C_{10}H_{16}$	136	97	
	sabinene	5.907	4-methylene-1-(1-methylethyl) bicycle(3.1.0) hexane	$C_{10}H_{16}$	136	96	
	β-pinene	6.06	6,6-Dimethyl-2-methylenebicyclo(3.1.1) heptanes	$C_{10}H_{16}$	136	96	
	β-ocimene	6.312	3,7-dimethylocta-1,3,6-triene	$C_{10}H_{16}$	136	45	
	γ-terpinene	6.778	1-Isopropyl-4-methyl-1,4-cyclohexadiene	$C_{10}H_{16}$	136	87	
	p-cimene	7.197	1-Methyl-4-(1-methylethyl) benzene	$C_{10}H_{14}$	134	90	
	DL-limonene	7.306	1-Methyl-4-(1-methylethenyl)-cyclohexene	$C_{10}H_{16}$	136	93	
	thujopsene	8.765	2,4a,8,8-Tetramethyl-1,1a,4,4a,5,6,7,8-octahydrocyclopropa(d) naphthalene	$C_{15}H_{24}$	204	38	
	α-thujone	9.74	Methyl-1-(propan-2-yl) bicycle(3.1.0)hexan-3-one	$C_{10}H_{16}O$	134	90	
	p-allylanisole	11.934	1-allyl-4-methoxybenzene	$C_{10}H_{12}O$	148	96	

Table 1. *Contd.*

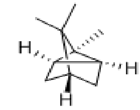
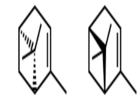
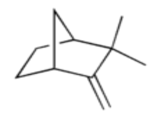
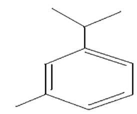
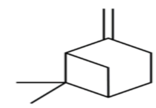
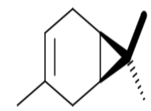
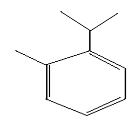
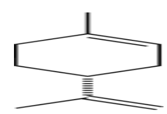
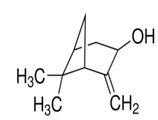
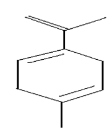
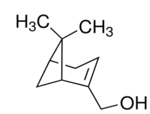
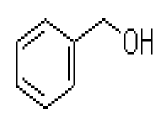
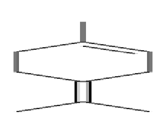
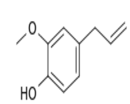
	tricyclene	4.755	6,7,7-trimethyl-2,3,4,5-tetrahydro-1H-tricyclo (2.2.1.02,6)heptanes	$C_{10}H_{16}$	136	96	
	α-pinene	4.991	2, 6, 6-Trimethyl bicycle (3.1.1)hept-2-ene	$C_{10}H_{16}$	136	97	
	camphene	5.357	2,2-dimethyl-3-methylene-bicyclo(2.2.1)heptanes	$C_{10}H_{16}$	136	98	
	β-cimene	5.856	1-methyl-3-propan-2-ylbenzene	$C_{10}H_{14}$	134	94	
	β-pinene	6.005	6,6-Dimethyl-2-methylenebicyclo (3.1.1) hep-tane	$C_{10}H_{16}$	136	97	
Galbanum	*δ* -3-carene	6.765	3,7,7-trimethylbicyclo(4.1.0) hept-3-ene	$C_{10}H_{16}$	136	97	
	o-cimene	7.182	1-Menthyl-2-isopropylbenzene	$C_{10}H_{14}$	134	97	
	DL-limonene	7.298	1-Methyl-4-(1-methylethenyl)-cyclohexene	$C_{10}H_{16}$	136	99	
	pinocarveol	10.355	6,6-Dimethyl-2-methylenebicyclo(3.1.1)heptan-3-ol	$C_{10}H_{16}O$	152	56	
	mentha-1,4,8-triene	10.527	1-methyl-4-prop-1-en-2-ylcyclohexa-1	$C_{10}H_{14}$	134	78	
	(-) myrtenol	11.895	6,6-Dimethylbicyclo(3.1.1) hept-2-ene-2-methanol	$C_{10}H_{16}O$	152	97	
Jasmine	α-toluenol	7.496	Phenylmethenol	C_7H_8O	108	97	
	α-terpinolene	9.227	1-Methyl-4-(propan-2-ylidene) cyclohex-1-ene	$C_{10}H_{16}$	136	90	
	eugenol	16.5	4-Allyl-2-methoxyphenol	$C_{10}H_{12}O_2$	164	98	

Table 1. *Contd.*

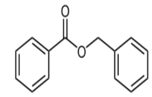
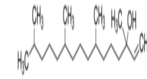
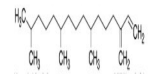
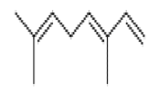
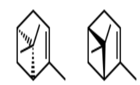
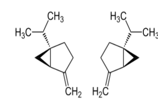
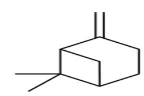
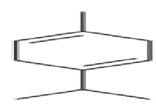
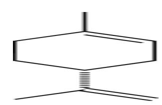
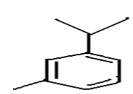
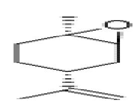
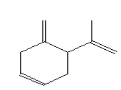
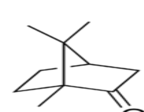
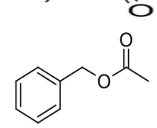
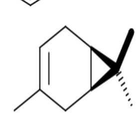
	ascabin	24.899	Benzyl benzoate	$C_{14}H_{12}O_2$	212	98	
	palmatic acid	26.2772	hexadecanoic acid	$C_{16}H_{32}O_2$	270	96	
Jasmine	isophytol	26.417	3,7,11,15-Tetramethyl-1-hexadecen-3-ol	$C_{20}H_{40}O$	296	86	
	phytol	27.407	3,7,11,15-tetramethyl-2-hexadecen-1-ol	$C_{20}H_{40}O$	290	43	
	neophytadiene	27.937	7,11,15-trimethyl-3-methylidenehexadec-1-ene	$C_{20}H_{38}$	278	90	
	p- ocimene	4.838	3,7-Dimethyl-1,3,6-Octatriene	$C_{10}H_{16}$	138	83	
	α-pinene	5.00	2, 6, 6-Trimethyl bicycle (3.1.1) hept-2-ene	$C_{10}H_{16}$	136	97	
Juniper	sabinene	5.898	4-methylene-1-(1-methylethyl) bicycle(3.1.0)hexane	$C_{10}H_{16}$	136	91	
	β-pinene	6.011	6,6-Dimethyl-2-methylenebicyclo(3.1.1) heptanes	$C_{10}H_{16}$	136	97	
	γ-terpinene	6.769	1-Isopropyl-4-methyl-1,4-cyclohexadiene	$C_{10}H_{16}$	136	90	
	DL-limonene	7.309	1-Methyl-4-(1-methylethenyl)-cyclohexene	$C_{10}H_{16}$	136	98	
	β-Cymene	7.188	1-1-methyl-3-propan-2-ylbenzene	$C_{10}H_{14}$	134	87	
	limonene oxide	9.199	6-methyl-3-prop-1-en-2-yl-7-oxabicyclo(4.1.0)heptane (Click)	$C_{10}H_{16}O$	152	53	
Lavender	para- mentha-triene	9.505	1-methyl-4-prop-1-en-2-ylcyclohexa-1,3-diene	$C_{10}H_{14}$	134	22	
	camphor	10.536	1,7,7-Trimethylbicyclo(2.2.1) heptan-2-one	$C_{10}H_{16}O$	152	72	
	benzyl acetate	10.978	Benzyl acetate	$C_9H_{10}O_2$	150	64	
	δ -3-carene	13.395	3,7,7-trimethylbicyclo(4.1.0) hept-3-ene	$C_{10}H_{16}$	136	94	

Table 1. *Contd.*

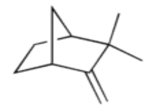
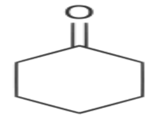
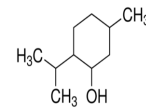
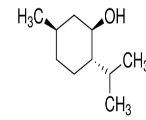
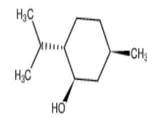
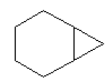
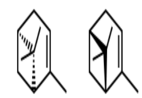
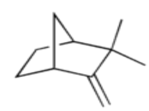
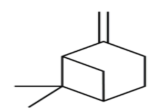
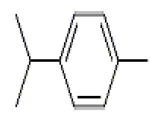
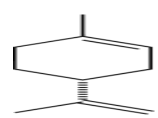
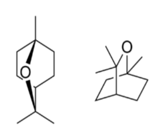
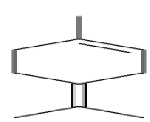
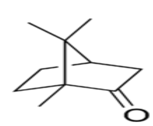
Peppermint	camphene	10.597	2,2-dimethyl-3-methylene-bicyclo(2.2.1)heptanes	$C_{10}H_{16}$	136	93	
	cyclohexanone	10.794	Cyclohexanone	$C_6H_{10}O$	154	98	
	DL-menthol	11.182	2-Isopropyl-5-methylcyclohexanol	$C_{10}H_{20}O$	156	91	
	L-(-) menthol	11.419	2-Isopropyl-5-methylcyclohexanol, 5-Methyl-2 -(1-methylethyl)cyclohexanol	$C_{10}H_{20}O$	156	91	
	3-p-menthanol	11.685	3-p-Menthanol	$C_{10}H_{20}O$	156	91	
	norcarane	14.468	Bicyclo(4,1,0)heptanes	C_7H_{12}	136	96	
Rosemary	*α*-pinene	5.004	2, 6, 6-Trimethyl bicycle (3.1.1) hept-2-ene	$C_{10}H_{16}$	136	97	
	camphene	5.37	2,2-dimethyl-3-methylene-bicyclo(2.2.1)heptane	$C_{10}H_{16}$	136	98	
	β-pinene	6.011	6,6-Dimethyl-2-methylenebicyclo(3.1.1) heptanes	$C_{10}H_{16}$	136	96	
	cymol	7.197	2,6-dimethyl-3-propan-2-ylpheno	C10H14	134	95	
	DL-limonene	7.31	1-Methyl-4-(1-methylethenyl)-cyclohexene	$C_{10}H_{16}$	136	99	
	1,8-cineole	7.441	1,3,3-Trimethyl-2-oxabicyclo (2,2,2)octane	$C_{10}H_{18}O$	154	99	
	α-terpinolene	9.274	Methyl-4-(propan-2-ylidene) cyclohex-1-ene	$C_{10}H_{16}$	136	78	
	camphor	10.55	1,7,7-Trimethylbicyclo(2.2.1) heptan-2-one	$C_{10}H_{16}O$	152	98	

Table 1. *Contd.*

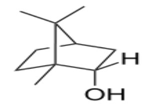
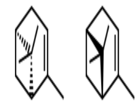
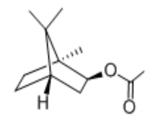
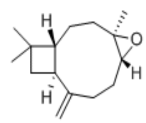
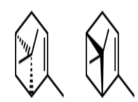
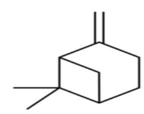
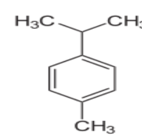
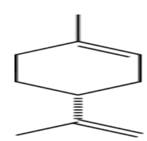
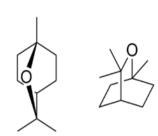
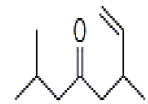
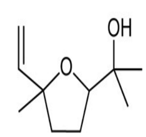
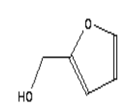
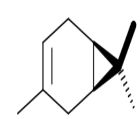
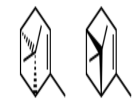
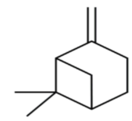
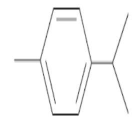
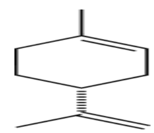
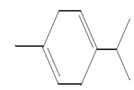
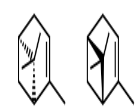
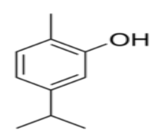
Rosemary	isobroneol	10.993	4,7,7-trimethylbicyclo(2.2.1) heptan-3-ol	$C_{10}H_{16}O$	154	86	
	α-pinene	11.892	2, 6, 6-Trimethyl bicycle (3.1.1) hept-2-ene	$C_{10}H_{16}$	136	87	
	pichtosine	14.359	Bicyclo(2.2.1)heptan-2-ol, 1,7,7 -trimethyl-, acetate	$C_{12}H_{20}O_2$	196	91	
	β-caryo-phyllene oxide	21.667	4,12,12-trimethyl-9-methylene-5-oxatricyclo(8.2.0.04,6) dodecane	$C_{15}H_{24}O$	220	87	
Tagetes	*α*-pinene	4.999	2, 6, 6-Trimethyl bicycle (3.1.1) hept-2-ene	$C_{10}H_{16}$	136	95	
	β-pinene	6.001	6,6-Dimethyl-2-methylenebicyclo(3.1.1) heptanes	$C_{10}H_{16}$	136	94	
	p-cymene	7.188	1-Methyl-4-(1-methylethyl) benzene	$C_{10}H_{14}$	134	86	
	DL-limonene	7.311	1-Methyl-4-(1-methylethenyl)-cyclohexene	$C_{10}H_{16}$	136	99	
	1,8-cineole	7.428	1,3,3-Trimethyl-2-oxabicyclo (2,2,2)octane	$C_{10}H_{18}O$	154	52	
	dihydro-tagetone	7.959	2,6-Dimethyloct-7-en-4-one	$C_{10}H_{18}O$	154	78	
	linalool oxide trans	8.483	2-Methyl-2-vinyl-5-(1-hydroxy -1-methylethyl)tetrahydrofuran	$C_{10}H_{18}O_2$	170	72	
	furfuryl alcohol	8.921	2-Furanmenthanol	$C_5H_6O_2$	170	49	
	δ -3-carene	9.274	3,7,7-trimethylbicyclo(4.1.0) hept-3-ene	$C_{10}H_{16}$	136	87	

Table 1. *Contd.*

	α-pinene	4.986	2, 6, 6-Trimethyl bicycle (3.1.1) hept-2-ene	$C_{10}H_{16}$	136	97	
	β-pinene	5.997	6,6-Dimethyl-2-methylenebicyclo(3.1.1)heptanes	$C_{10}H_{16}$	136	97	
	cymene	7.188	1-Methyl-4-(1-methylethyl) benzene	$C_{10}H_{14}$	134	97	
Thyme	DL-limonene	7.297	1-Methyl-4-(1-methylethenyl)-cyclohexene	$C_{10}H_{16}$	136	97	
	moslene	8.075	1,4-Cyclohexadiene, 1-methyl-4-(1-methylethyl)	$C_{10}H_{16}$	136	97	
	α-pinene	11.092	2, 6, 6-Trimethyl bicycle (3.1.1) hept-2-ene	$C_{10}H_{16}$	136	42	
	carvacrol	14.709	5-isopropyl-2-methylphenol 2-Methyl-5-(1-methylethyl)-phenol	$C_{10}H_{14}O$	150	94	

try (GC/MS) for detection of major and trace constituents. In the present study, the identification of highly volatile chemical components present in essential oils with the help of GC/MS showed many monoterpenes such as hydrocarbons (α-Pinene), alcohol (geraniol, menthol, linalool), ethers (1,8-cineol), aldehydes (cinnamaldehyde) etc. The composition of essential oils is highly diverse in different plant species and chemical components present in essential oils and some chemical constituents are common in few essential oils. The chemical compositions of essential oil are different in different stages of plant development and the chemical components of essential oils especially monoterpenes directly depend on temperature, weather condition and soil acidity as earlier reported by Clark and Manery (1981).

The components of essential oils were analyses and identified by GC-MS using DB-5 fused silica capillary column (Table 1). The major constituent α-Pinene (97%) of Juniper was dominant monoterpine (Gonny *et al.,* 2005). A monocyclic monoterpene DL-Limonene 98 (R.T-7.311) is a major constituent of tagetes oil (Chamorro *et al.,* 2008) and Linalool 93% (RT- 9.277) is an acyclic monoterpene alcohol also known as 3, 7-dimethylocta-1, 6 -dien-3-ol (Benedec *et al.,* 2009). Cinnamon essential oil contains Cinnamaldehyde 93% (RT- 18.191) as a major component and it is a monocyclic monoterpene alcohol and also known as Cinnamic aldehyde or trans Cinnamaldehyde (98%) (Adams, 1989) and the dominant chemical constituent of chamomile oil is 1, 8-Cineole 98% (RT-7.428). 1, 8-Cineole or Eucalyptol is a bicyclic monoterpene alcohol also called 1, 8-Epoxy-*p*-menthane (Adams, 1989). In frankincense oil *α*-Pinene 97% (RT- 5.006) a bicyclic monoterpene is the dominant constituent. It is an alkene and it contains a reactive four-membered ring (Woolley *et al.,* 2012). Moreover, Linalool (96%) is the main component of lavender oil (Afsharypuor and Azarbayejany, 2006) and the major component in amyris essential oil is *β*- Cadinene 97% (RT- 22.824) also called Cadina-3,9-diene.

Chemically, the Cadinenes are bicyclic sesquiterpenes (Lawrence, 1990). However, from the dominant constituent of dill oil is (+)-Carvone 97% (RT- 13.211) (Radulescu *et al.,* 2010) also called *p*-Mentha-6,8-dien-2-one a monocyclic monoterpene ketone and DL-Limonene 99% (7.298) is the dominant constituents in galbanum oil a monocyclic monoterpene hydrocarbon (Adams, 1995). The major dominant component identified in catnip oil is Caryophyllene 99% (RT- 17.718). Caryophyllene or *β* Caryophyllene is a natural bicyclic sesquiterpene (Wesolowska *et al.,* 2011) and Thymol 95% (RT- 14.514) is the dominant constituent of thyme oil. Thymol is a monocyclic monoterpine alcohol (Ahmad *et al.,* 2006). The major component of black pepper oil is *β*- Caryophyllene (99%) (Jirovetza *et al.,* 2012) and the major component of citronella oil is citronella (98%), citronella oil contains two derivatives such as alcohol citronellol and the aldehyde citronellal (Cassel and Vargas, 2006). Rosemary essential oil contains Camphene 98% (RT- 5.370) as a dominant constituent identified by GC/MS is a bicyclic monoterpene (Martinez *et al.,* 2009) and jasmine contain Eugenol (98%) (Adams, 1989). Moreover, menthol (91%) is the dominant chemical constituent in peppermint also known as 3-*p*-menthanol is a monocyclic monoterpene alcohol (Derwich *et al.,* 2010) and camphor oil contains camphor 98% (RT- 10.547) is abicyclic monoterpene as a main constituent (Guenther, 1950).

Therefore, the essential oils were analyzed using GC/MS to get some major constituents with their retention time and molecular weight with quality percentage but some constituents are common in some essential oils with slightly difference in retention time such as Linalool present in lavender and basil as dominant component with retention time ranging from 9.271RT to 9.277RT.

Conclusions

The present study concluded that several major chemical constituents were identified from different essential oils like amyris (*A. balsamifera*), basil (*O. basilicum*), black pepper (*P. nigrum*), camphor (*C. camphora*), catnip (*N. cataria*), chamomile (*A. nobilis*), cinnamon (*C. zeylanicum*), citronella (*C. winterianus*), dill (*A. graveolens*), frankincense (*B. carteri*), galbanum (*F. galbaniflua*), jasmine (*J. grandiflorum*), juniper (*J. communis*), lavender (*L. angustifolia*), peppermint (*M. piperita*), rosemary (*R. officinalis*), tagetes (*T. minuta*), thyme (*T. serpyllum*) using GC/MS. These essential oils have several chemical constituents and can be used for multiple purposes such as use in national and international market of flavor and fragrances, cosmetic industries, agricultural industries, household insecticides, pharmacy, alternative medicine, integrated pest management, etc. Therefore, GC/MS can be effectively used for the identification of different chemical constituents present in the various essential oils.

ACKNOWLEDGEMENTS

The authors are grateful to Prof. (Dr.) M.P. Kaushik, former Director, Defence Research & Development Establishment (D.R.D.E), Gwalior and all the colleagues in the Department of Vector Management Division for their help and support while carrying out this investigation on essential oils. Fragrance and Flavor Development Center (FFDC), Kannuj, Uttar Pradesh, India is also kindly acknowledged by the authors for providing essential oils.

REFERENCES

Adams, R. P. (1989). Identification of essential oils by ion trap mass spectroscopy. Academic Press, New York, NY, USA.

Adams, R. P. (1995). Identification of essential oils components by gas chromatography/mass spectroscopy. Allured Publ. Corp., Illinois.

Ahmad, M. A., Khokhar, I., Ahmad. I., Kashmiri, A. M., Adnan, A. and Ahmad, M. (2006). Study of antimicrobial activity and composition by GC/MS spectroscopic analysis of the essential oil of *Thymus sperphyllum. Internet Journal of Food Safety*, 5: 56-60.

Baser, C. H. K. and Buchbauer, G. (2010). Hand book of essential oils: Science, technology and applications. Raton Florida: CRC Press, Boca Raton, New York.

Benedec, D., Oniga, I., Oprean, R. and Tames, M. (2009). Chemical composition of the essential oils of ocimum basilicum L. cultivated in Romania. *Farmica*, 57(5): 625-629.

Clark, R. J. and Menary, R. C. (1981). Variations in composition of peppermint oil in relation to production areas. *Economic Botany*, 35: 59-69.

Derwich, E., Benziane, Z., Taouil, R., Senhaji, O. and Touzani, M. (2010). Aromatic plants of Morocco: GC/MS analysis of the essential oils of leaves of *Mentha piperita*. *Advances in Environmental Biology*, 4(1): 80-85.

Gonny, M., Cavaleiro, C., Salgueiro, L. and Casanova, J. (2005). Analysis of *Juniperus communis* subsp. *alpina* needle, berry, wood and root oils by combination of GC, GC/MS and 13C-NMR. *Flavour Fragrance Journal*, 21: 99–106.

Guenther, E. (1950). 3RD Ed. *The Essential Oils*. D. Van Nostrand, New York.

Jirovetza, L., Buchbauera, G., Ngassoumb, B. M. and Geisslerc, M. (2012). Aroma compound analysis of *Piper nigrum* and *Piper guineense* essential oils from Cameroon using solid-phase microextraction–gas chromatography, solid-phase micro extraction GC/MS and olfactometry. *Journal of Chromatography*, 976: 265–275.

Lawrence, B. M. (1990). Amyris oil. Progress in essential oils. *Perfumer and Flavorist*, 15 (2): 78.

Lawless, J. (1992). The encyclopedia of essential oils. Shaftesbury, Dorset. Rockport, Massachusetts.

Marcelle Gonny, Carlos Cavaleiro, Ligia Salgueiro and Joseph Casanova (2006). Analysis of *Juniperus communis* subsp. *alpina* needle, berry, wood and root oils by combination of GC, GC/MS and 13C-NMR. *Flavour and Fragrance Journal*, 21: 99–106.

Martinez, A. L., Gonzalez-Trujano, M.E., Pellicer, F., Lopez-Munoz, F.J. and Navarrete, A. (2009). Antinociceptive effect and GC/MS analysis of *Rosmarinus officinalis* L. essential oil from its aerial parts. *Planta Medicine*, 75: 508–511.

Radulescu, V., Popescu, M. L. and Ilies, D. (2010). Chemical composition of the volatile oil from different plants parts of *Anthum gravelens* L. cultivated in Romania. *Farmica*, 58(5): 594-600.

Suleiman Afsharypuor and Nahid Azarbayejany (2006). Chemical constituents of the flower essential oil of *Lavandula officinalis* Chaix. from Isfahan (Iran). *Iranian Journal of Pharmaceutical Sciences*, 2(3): 169-172.

Tisserand, R. (1990). The essential oil safety data manual. Tisserand Aromatherapy Institute Brighton. Sussex. England.

Wesolowska, A., Jadczak, D. and Gerzeszczuk, M. (2011). MS analysis of lemon catnip (*Nepeta cataria* L. var. *citriodora* Balbis) essential oil. *Acta Chromatographica*, 1: 169-180.

Woolley, L.C., Suhailb, M. M., Smitha, B.L., Borena, E.K., Taylora, C.L., Schreudera, F.M., Chaia, K. J., Haqe, S.C.H., Linf, K.H., Al-Shahrig, A.A., Saif, Al-Hatmih and Younga, G. D. (2012). Chemical differentiation of *Boswellia sacra* and *Boswellia carterii* essential oils by gas chromatography and chiral GC/MS. *Journal of Chromatography*, 1261: 158-163.