International Journal of Advances in Pharmacy Medicine and Bioallied Sciences

An International, Peer-reviewed, Indexed, Open Access, Multi-disciplinary Journal

www.biomedjournal.com

ISSN 2348-2109

International Journal of Advances in Pharmacy Medicine and Bioallied Sciences

www.biomedjournal.com

International, Peer-reviewed, Indexed, Open Access, Multi-disciplinary Journal

Original Research Article

Gas chromatographic investigation of essential oil composition of coriander (*Coriandrum sativum* L.) collected from Saudi Arabian market

Md Tanwir Athar

Scientific Research Center, Prince Sultan Military Medical City, Riyadh, Kingdom of Saudi Arabia.

ARTICLE INFO

Article History:
Received 10 Sept 2018
Revised 25 OCt 2018
Accepted 10 Nov 2018

Keywords:
Coriandrum sativum,
GC/MS

ABSTRACT

Background: The present study is focused on the analysis of chemical constituents of the *Coriandrum sativum* L. (Locally known as "Kamoon") which is available in the market of Saudi Arabia.
Material and methods: The coriander oil was analyzed by Gas chromatography/mass spectrometry (GC/MS). The mass spectra were compared with the standard spectra available in National Institute Standard and Technique (NIST) library.
Results: The results indicated that the coriander oil is composed of a number of chemical compounds including alpha -pinene, linalool, and geraniol which are biologically active.
Conclusion: It can be concluded that the *Coriandrum sativum* L. due to the presence of many bioactive compounds can be used as a new potential source of medicine for the treatment of various type of illness.

*AUTHOR FOR CORRESPONDENCE
E-mail address: tantab001@gmail.com

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is an annual herbaceous plant originally from southern Europe, Asia and Caucasus belong to family Apiaceae. It is categorized under aromatic, medicinal and condimental plant list (Khalid, 2015). The leaf of this plant contains essential oil with an unpleasant odor. The essential oil of dried fruits (sometimes said as seeds) of this plant has a pleasant smell.

The dried fruit has been used as a drug for indigestion, against worms, and as a component of embrocation for rheumatism and pains in the joints. It has also been widely used in the food industry to prepare liqueur, sweets, and condiment as well as perfume and cosmetics. The essential oil present in the fruit is rich in linalool and it is used in pharmaceutical production to improve the flavor and aroma of some medicines. Ripe fruits of coriander are widely and popularly used in infusion preparation as an analgesic, antispasmodic, febrifuge, carminative and diuretic agent. The fruits of coriander are alternative, antibilious, antispasmodic, aphrodisiac, appetizer, aromatic, carminative, diaphoretic, diuretic, refrigerant, stimulant, stomachic, tonic (Pande et al., 2010). Fresh leaves are pungent and aromatic. The essential oil of coriander stimulates the secretion of gastric juices and is carminative and spasmolytic; *in vitro*, it has antibacterial and antifungal effects (Anonymous, 1997; 2000).

Chemically, coriander fruits contain an essential oil (up to 1%) constituted of linalool (main, 60–70%), other monoterpenoids (citronellol, geraniol, myrcene) gamma -terpinene, limonene, D-phellandrene and E-phellandrene, p-cymene, and E-pinene, borneol, and

camphor), and fatty acids (oleic, linolenic, and palmitic acids etc.). Linalool (59.6-71.6%) has been reported as the main constituent of the essential oil of coriander fruits (Hussain et al., 1988; Pino et al., 1996).

This work aimed to evaluate the chemical composition of coriander seeds (Coriandrum sativum L.) available in the local market of Saudi Arabia.

Keeping in view the past published work (Caputo et al., 2016; El-Zaeddi et al., 2016), on this medicinally important plant, we evaluated the chemical composition of coriander fruit oil. The rationale of this work is to compare in the bioactive components of coriander seed marketed in Saudi Arabia and the rest of the world. Since quality control of herbal and dietary supplement is one of the major concern in these days (Musthaba et al., 2011), the data obtained by this studies may be used as a tool to assess the quality of coriander.

It's worth noting that the coriander is not necessarily grown in the kingdom of Saudi Arabia. Mostly it is being imported from another part of the world. This study will help to demonstrate the presence of bioactive components in coriander that is available in the Saudi Arabian market.

MATERIALS AND METHODS

Chemicals and Reagents

Methanol (MS grade Fluka), and inert helium gas (99.999% purity) were used for the analysis.

Plant material

The dried fruit of the *Coriandrum sativum* was collected from the local market in Riyadh, Saudi Arabia. It was identified by Dr. Abuzer Ali, Kingdom of Saudi Arabia and the voucher specimen (voucher number P/M/015) has been stored in the Herbal Unit, Prince Sultan Military Medical City, Saudi Arabia. The fruit was coarsely powdered and used for extraction.

Extraction of volatile oil by steam distillation

The volatile oil from the fruits of the coriander was extracted by Clevenger apparatus as previously done by the author for the clove (Athar et al., 2013) and thyme oil (Al-Asmari et al., 2017). Sixty grams of coarsely ground dried fruits were taken in a 1000-mL round-bottom flask, and water was added to approximately three-fourths full. The flask was heated using a heating mantle in order to boil the water. The volatile oil along with the water vapor condensed in the condenser and accumulated in a graduated sidearm of the Clevenger apparatus. Distillation was continued until there was no difference in successive readings of the oil volume. The oil was drained, dried over anhydrous sodium sulfate, filtered through 0.22-μM filter paper, and kept at 4 °C in sealed vials in dark.

Sample preparation

The sample was prepared in the LC-MS grade hexane. An amount of 1000 μL.L-1 of the coriander sample was prepared by dissolving the 10μL of the coriander oil in 9.990 mL of hexane. The prepared sample was used for the analysis.

Instrumentation

Gas chromatograph-Mass spectrophotometric analysis of the coriander oil was carried out on a GC-MS system (Agilent 7890A series, Germany) equipped with split/splitless injector and auto-sampler attached to an apolar HP-5MS (5% phenyl polymethyl siloxane) capillary column (30 m×0.25 mm i.d. and 0.25-μm film thickness) and fitted to a mass detector as reported earlier (Al-Asmari et al., 2015a; Al-Asmari et al., 2015b). One μL sample of thousand ppm coriander oil in hexane was injected for analysis. Carrier gas flow rate (He) was kept constant at 1 mL/min, split ratio 1:20; injector temperature at 250◦C, detector temperature at 300°C. The column temperature was programmed at 40°C for 1 min followed by linear programming from 40° to 220°C (at 8°C/min, and kept isothermal for 2 min; then 220° to 260°C (at 10°C/min). Transfer line was heated at 280°C. Mass spectra were acquired in EI mode (70 eV); in the range 50 to 550 m/z, and 1 μL of the sample in methanol was injected. The total run time was 29 minute. The components of the oil were identified by comparison of mass spectra to those from NIST libraries, using search engines.

Identification of components

Interpretation of mass spectrum GC-MS was conducted using the database of National Institute Standard and Technique (NIST) having more than 62,000 patterns. The spectrum of the unknown component was compared with the spectrum of the known components stored in the NIST library. The Name, Molecular weight, Structure of the component of the test material was ascertained.

RESULTS AND DISCUSSION

Physical characteristics of the oil

The seeds of the coriander yielded 0.7% (w/w) of the oil. The oil is yellow in color with a pleasant and characteristic aroma.

GC optimization

For analysis of the coriander oil, GC system was optimized by varying the temperature and the split ratio. HP-5MS column was selected for the study due to

its good results in the previous analysis (Al-Asmari, Albalawi, 2015a; Al-Asmari, Athar, 2017; Al-Asmari, Athar, 2015b; Athar, Tamboli, 2013). used in previous works. The temperate program and the split ratio which has given the higher resolution in less time were selected for the study.

Oil analysis

Compositional analysis of extracted oil of coriander revealed a number of the compounds in its volatile fraction. The result showed the presence of the 16 different types of constituent (Figure 1, Table 1). The compounds were identified by comparing the mass spectra. The oil was found to be rich in oxygenated monoterpenes, monoterpene hydrocarbons, and monoterpene alcohol. Eighteen compounds were found in the oil that includes alpha-pinene, beta-myrcene, limonene, gamma-terpinene, linalool, alpha-campholenal, citronellal, endo-borneol, alpha-terpineol, decanal, citronellol, geraniol, crotonyl bromide, undecanal, citronellyl butyrate, geranyl acetate, dodecanal, and caryophyllene. Most of the compounds have a significant reported pharmacological activity. The major compounds found were linalool, geranyl acetate, alpha-pinene, geraniol, and undecanal. The results of the analysis along with the retention time and the percentage area of each compound are reported in table 1. The chromatogram is presented in figure 1. Chemical constituent, molecular formula, molecular weight, and reported pharmacological activity are documented in Table 2.

Table 1. List of the compound present in the Coriander oil analyzed by GC-MS to show the retention time and the area percentage of each compound.

S. No.	Compound	RT	Peak Area %
1.	**Alpha-Pinene**	6.164	5.61
2.	Beta-Myrcene	7.261	0.18
3.	Limonene	7.988	0.22
4.	Gamma-Terpinene	8.577	0.27
5.	**Linalool**	9.409	65.39
6.	Alpha-Campholenal	9.887	0.12
7.	Citronellal	10.351	0.36
8.	Endo-Borneol	10.654	0.31
9.	Alpha-terpineol	11.077	0.22
10.	Decanal	11.295	0.23
11.	Citronellol	11.718	0.50
12.	**Geraniol**	12.182	0.73
13.	Crotonyl Bromide	12.474	0.17
14.	Undecanal	13.057	0.56
15.	Citronellyl butyrate	13.824	0.55
16.	**Geranyl Acetate**	14.336	9.53
17.	Dodecanal	14.728	0.24
18.	Caryophyllene	15.020	0.23

Coriander is one of the oldest herbs that have been used for over 3000 years! It is used for culinary as well as medicinal purposes (Ishikawa et al., 2003). The oil of coriander is used in cosmetics, body care products, and perfumes. This is also a plant of high economic value since it is widely used in the food and cosmetic industry (Sahib et al., 2013). Gas chromatography and Mass spectrometry have become a robust, practical and popular tool to analyze the volatile oil components of the herbal medicine. In the last few decades, these techniques became one of the most commonly used techniques in the scientific world. Selectivity and sensitivity of the method with an added advantage of easy identification of the compounds through a number of reference libraries made these techniques versatile and popular. In this study library from the National Institute, Standard and Technique (NIST) have been used for the identification of the compounds. Another advantage of this method is that the sample preparation requires minimal preliminary requirements. Sometimes it can also be directly injected into the instrument at suitable temperatures (Bhuiyan et al., 2009; Matasyoh et al., 2009; Singh et al., 2006; Sriti et al., 2009).

Based on the above-mentioned advantages, GC/MS techniques were used to characterize the coriander oil. We found a number of pharmacologically active ingredients in this oil. This result is in accordance with the results as previously done by the authors (Bhuiyan, Begum, 2009; Zeković et al., 2011).

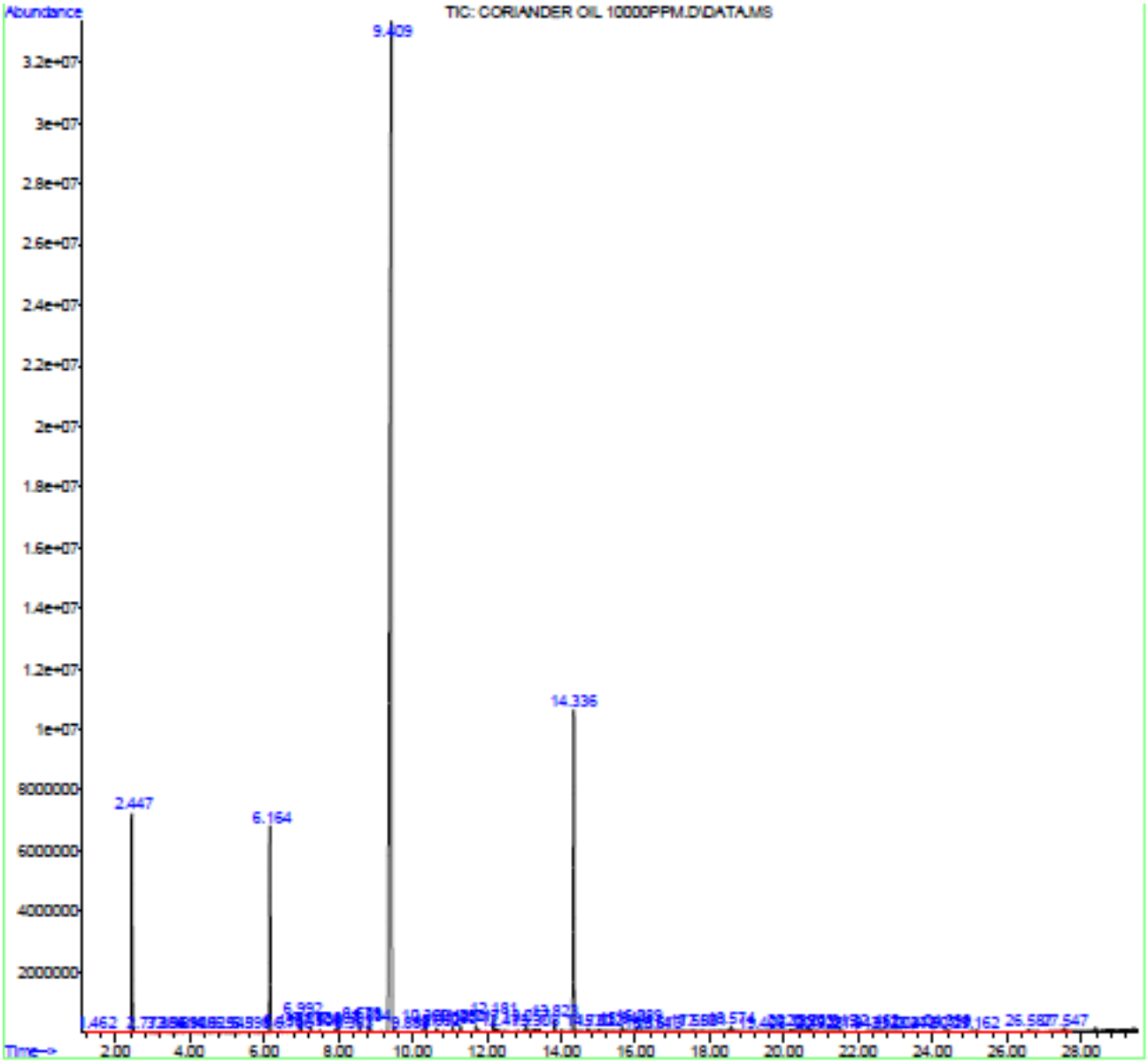

Figure 1. GCMS spectra showing different constituents of Coriander oil.

The three most pharmacologically active compounds found are as follows:

Linalool

Linalool (3,7-dimethyl-1,6-octadiene-3-ol) is a common floral volatile compound with two distinct enantiomers (Raguso, 2016). Over two hundred of plant species produce linalool, mainly from the families Lamiaceae (mint) (Joshi, 2014), Lauraceae (laurels, cinnamon, rosewood) (Salleh et al., 2016) and Rutaceae (citrus fruits) (Azadi et al., 2012; Rabehaja et al., 2016). Research showed that linalool has a strong fragrance that causes stress relief in the experimental rat (Nakamura et al., 2009).

Geranyl acetate

It is a natural monoterpene that is present in the flavored plant. It is used in perfumes industry, cosmetic and creams preparation, as a flavoring agent, household cleaning products and also in the fragrance industry (Bakkali et al., 2008). It also has a reported anti-microbial (Chang et al., 2001) and antioxidant (Malhotra et al., 2016) activity on the experimental animals.

Alpha-pinene

Alpha-Pinene is an organic compound of the terpene class and chemically it is alkene. Pharmacologically alpha pine is having anti-inflammatory, memory enhancing and bronchodilator activity (Russo, 2011). It has a modulating effect of GABA receptors acting on benzodiazepine binding site (Yang et al., 2016).

Table 2. Details of the bioactive compounds present in the Coriander oil after the GC-MS analysis along with formula molecular weight and reported activity of each bioactive compound.

S. No.	Chemical Name	MF	Mol. Wt.	Reported activity	Reference
1.	Alpha-Pinene	$C_{10}H_{16}$	136.23	Gastro-protective, Anti-inflammatory	(de Almeida Pinheiro et al., 2015; Kummer et al., 2015)
2.	Beta-Myrcene	$C_{10}H_{16}$	136.23	Analgesic, Anticancer	(Kauderer et al., 1991; Lorenzetti et al., 1991)
3.	Limonene	$C_{10}H_{16}$	136.23	Anticancer, Spasmolytic	(de Sousa et al., 2015; Elson et al., 1988; Haag et al., 1992; Okabe et al., 1989)
4.	Gamma-Terpinene	$C_{10}H_{16}$	136.23	Antimicrobial, Anti-inflammatory	(de Oliveira Ramalho et al., 2015; Rota et al., 2008)
5.	Linalool	$C_{10}H_{18}O$	154.25	Antimicrobial, Anti-inflammatory	(Huo et al., 2013; Park et al., 2012)
6.	Alpha-Campholenal	$C_{10}H_{16}$	152.23	Antioxidant	(Mahmoudabady et al., 2017)
7.	Citronellal	$C_{10}H_{18}O$	154.25	Anticancer	(Maberg et al., 2015)
8.	Endo-Borneol	$C_{10}H_{18}O$	154.25	Immunomodulator, Antioxidant	(Jeon et al., 2011)
9.	Alpha-terpineol	$C_{10}H_{18}O$	154.25	Anticancer	(Hassan et al., 2010)
10.	Decanal	$C_{10}H_{20}O$	156.25	Anticancer, Antioxidant and Antimicrobial	(Liu et al., 2012)
11.	Citronellol	$C_{10}H_{20}O$	156.25	Antioxidant, Antifungal	(Jagdale et al., 2015; Pereira et al., 2015)
12.	Geraniol	$C_{10}H_{18}O$	154.25	Cardiovascular, Antifungal,	(Kshirsagar et al., 2015; Pereira, Mendes, 2015; Wittig et al., 2015)
13.	Crotonyl Bromide	C_4H_5BrO	148.98	Anti-scabies	(Horvarth, 1950)
14.	Undecanal	$C_{11}H_{22}O$	170.29	Perfumes	(Bauer et al., 2008)
15.	Citronellyl butyrate	$C_{14}H_{26}O_2$	196.29	Antioxidant, Antimicrobial	(Dorman et al., 2000; Morris et al., 1979)
16.	Geranyl Acetate	$C_{12}H_{20}O_2$	196.29	Antibacterial	(Chang, Chen, 2001)
17.	Dodecanal	$C_{12}H_{24}O$	184.32	Flavoring agent	(Coleman and Shaw, 1971)
18.	Caryophyllene	$C_{15}H_{24}$	204.35	Local anesthetic, anticancer, antioxidant, analgesic and Anti-inflammatory	(Chavan et al., 2010; Ghelardini et al., 2001; Legault and Pichette, 2007)

CONCLUSION

Based on the analysis, linalool, geranyl acetate, and the alpha-pinene were found as the major contents of the oil. The present study also revealed that the coriander oil which is isolated from the Saudi market is similar to those that are available in different parts of the world. At the same time, there is also variation in the composition of either constituent which confirms that there is a variation in the composition due to geographical changes.

On the basis of the results, it is concluded that the coriander fruit available in the Saudi market is having all the necessary constituents and it can be used for its medicinal and the dietary purposes. It is also recommended that there should be a quality control parameter for the assessment of the herbs available in the market.

CONFLICT OF INTEREST

None declared.

REFERENCES

Al-Asmari AK, Albalawi SM, Athar MT, Khan AQ, Al-Shahrani H, Islam M. Moringa oleifera as an Anti-Cancer Agent against Breast and Colorectal Cancer Cell Lines. PloS one. 2015a;10:e0135814.

Al-Asmari AK, Athar MT, Al-Faraidy AA, Almuhaiza MS. Chemical composition of essential oil of Thymus vulgaris collected from Saudi Arabian market. Asian Pacific Journal of Tropical Biomedicine. 2017;7:In press.

Al-Asmari AK, Athar MT, Al-Shahrani HM, Al-Dakheel SI, Al-Ghamdi MA. Efficacy of Lepidium sativum against carbon tetra chloride induced hepatotoxicity and determination of its bioactive compounds by GC–MS. Toxicology Reports. 2015b;2:1319-1326.

Anonymous. British Pharmacopoeia. Bernan Press (PA). British Pharmacopoeia Commission, Great Britain. Medicines Commission, & General Medical Council (Great Britain). ; 2000.

Anonymous. European pharmacopoeia: European Pharmacopoeia Commission, and European Directorate for the Quality of Medicines & Healthcare. Council of Europe; 1997.

Athar MT, Tamboli ET, Ansari S, Ahmad S. Quantification of Eugenol in Hydro-Distilled Clove Oil (Eugenia caryophyllus) and Its Marketed Products by Validated GC-MS Method. Journal of Herbs, Spices & Medicinal Plants. 2013;19:365-376.

Azadi B, Nickavar B, Amin G. Volatile constituents of the peel and leaf of Citrus aurantium L. cultivated in the north of Iran. J Pharm Health Sci. 2012;1:37-41.

Bakkali F, Averbeck S, Averbeck D, Idaomar M. Biological effects of essential oils–a review. Food and chemical toxicology. 2008;46:446-475.

Bauer K, Garbe D, Surburg H. Common fragrance and flavor materials: preparation, properties and uses: John Wiley & Sons; 2008.

Bhuiyan MNI, Begum J, Sultana M. Chemical composition of leaf and seed essential oil of Coriandrum sativum L. from Bangladesh. Bangladesh Journal of Pharmacology. 2009;4:150-153.

Caputo L, Souza LF, Alloisio S, Cornara L, De Feo V. Coriandrum sativum and Lavandula angustifolia Essential Oils: Chemical Composition and Activity on Central Nervous System. Int J Mol Sci. 2016;17.

Chang S-T, Chen P-F, Chang S-C. Antibacterial activity of leaf essential oils and their constituents from Cinnamomum osmophloeum. Journal of Ethnopharmacology. 2001;77:123-127.

Chavan M, Wakte P, Shinde D. Analgesic and anti-inflammatory activity of Caryophyllene oxide from Annona squamosa L. bark. Phytomedicine. 2010;17:149-151.

Coleman RL, Shaw PE. Analysis of Valencia orange essence and aroma oils. Journal of agricultural and food chemistry. 1971;19:520-523.

de Almeida Pinheiro M, Magalhães RM, Torres DM, Cavalcante RC, Mota FSX, Coelho EMAO, et al. Gastroprotective effect of alpha-pinene and its correlation with antiulcerogenic activity of essential oils obtained from Hyptis species. Pharmacognosy magazine. 2015;11:123.

de Oliveira Ramalho TR, de Oliveira MTP, de Araujo Lima AL, Bezerra-Santos CR, Piuvezam MR. Gamma-terpinene modulates acute inflammatory response in mice. Planta medica. 2015;81:1248-1254.

de Sousa DP, Mesquita RF, de Araújo RL, de Lima JT. Spasmolytic Activity of Carvone and Limonene Enantiomers. Natural product communications. 2015;10:1893-1896.

Dorman HD, Surai P, Deans SG. In vitro antioxidant activity of a number of plant essential oils and phytoconstituents. Journal of essential oil Research. 2000;12:241-248.

Elson CE, Maltzman TH, Boston JL, Tanner MA, Gould MN. Anti-carcinogenic activity of d-limonene during the initiation and promotion/progression stages of DMBA-induced rat mammary carcinogenesis. Carcinogenesis. 1988;9:331-332.

El-Zaeddi H, Martinez-Tome J, Calin-Sanchez A, Burlo F, Carbonell-Barrachina AA. Volatile Composition of Essential Oils from Different Aromatic Herbs Grown in Mediterranean Regions of Spain. Foods. 2016;5.

Ghelardini C, Galeotti N, Mannelli LDC, Mazzanti G, Bartolini A. Local anaesthetic activity of β-caryophyllene. Il Farmaco. 2001;56:387-389.

Haag JD, Lindstrom MJ, Gould MN. Limonene-induced regression of mammary carcinomas. Cancer research. 1992;52:4021-4026.

Hassan SB, Gali-Muhtasib H, Göransson H, Larsson R. Alpha terpineol: a potential anticancer agent which acts through suppressing NF-κB signalling. Anticancer Research. 2010;30:1911-1919.

Horvarth PN. Streptomycin therapy of granuloma inguinale1950.

Huo M, Cui X, Xue J, Chi G, Gao R, Deng X, et al. Anti-inflammatory effects of linalool in RAW 264.7 macrophages and lipopolysaccharide-induced lung injury model. journal of surgical research. 2013;180:e47-e54.

Hussain A, Virmani OP, Sharma A, Kumar A, and Misra LN. Major Essential Oil-Bearing Plants of India, Central Institute of Medicinal and Aromatic Plants. Lucknow, India1988.

Ishikawa T, Kondo K, Kitajima J. Water-soluble constituents of coriander. Chemical and Pharmaceutical Bulletin. 2003;51:32-39.

Jagdale AD, Kamble SP, Nalawade ML, Arvindekar AU. Citronellol: A potential antioxidant and aldose reductase inhibitor from Cymbopogon citratus. International Journal of Pharmacy and Pharmaceutical Sciences. 2015;7:203-209.

Jeon S, Hur J, Jeong H, Koo B, Pak S. SuHeXiang Wan essential oil alleviates amyloid beta induced memory impairment through inhibition of tau protein phosphorylation in mice. The American journal of Chinese medicine. 2011;39:917-932.

Joshi RK. Chemical composition and antimicrobial activity of the essential oil of Ocimum basilicum L.(sweet basil) from Western Ghats of North West Karnataka, India. Ancient science of life. 2014;33:151.

Kauderer B, Zamith H, Paumgartten FJ, Speit G, Holden H. Evaluation of the mutagenicity of β-myrcene in mammalian cells in vitro. Environmental and Molecular Mutagenesis. 1991;18:28-34.

Khalid KA. Effect of macro and micro nutrients on essential oil of coriander fruits. Journal of Material and Environmental Sciences. 2015;6:2060-2065.

Kshirsagar R, Reddy G, Bakshi V, Diwan P. Geraniol a major component of essential oil ameliorates endothelial

dysfunction induced by high-fat diet fed rats. Atherosclerosis. 2015;241:e154-e155.

Kummer R, Estevão-Silva CF, Bastos RL, Rocha BA, Spironello RA, Yamada AN, et al. Alpha-pinene reduces in vitro and in vivo leukocyte migration during acute inflammation. International Journal of Applied Research in Natural Products. 2015;8:12-17.

Legault J, Pichette A. Potentiating effect of β-caryophyllene on anticancer activity of α-humulene, isocaryophyllene and paclitaxel. Journal of Pharmacy and Pharmacology. 2007;59:1643-1647.

Liu K, Chen Q, Liu Y, Zhou X, Wang X. Isolation and biological activities of decanal, linalool, valencene, and octanal from sweet orange oil. Journal of Food Science. 2012;77.

Lorenzetti BB, Souza GE, Sarti SJ, Santos Filho D, Ferreira SH. Myrcene mimics the peripheral analgesic activity of lemongrass tea. Journal of Ethnopharmacology. 1991;34:43-48.

Maberg D, Simon A, Häussinger D, Keitel V, Gisselmann G, Conrad H, et al. Monoterpene (−)-citronellal affects hepatocarcinoma cell signaling via an olfactory receptor. Archives of biochemistry and biophysics. 2015;566:100-109.

Mahmoudabady M, Lashkari M, Niazmand S, Soukhtanloo M. Cardioprotective effects of Achillea wilhelmsii on the isolated rat heart in ischemia–reperfusion. Journal of Traditional and Complementary Medicine. 2017.

Malhotra S, Shukla R, Kulshrestha S, Siddiqui A. Chemical Composition and Antioxidant Activity of Citrus Medica Var Acidica Essential Oil. Journal of Chemical, Biological and Physical Sciences (JCBPS). 2016;6:574.

Matasyoh J, Maiyo Z, Ngure R, Chepkorir R. Chemical composition and antimicrobial activity of the essential oil of Coriandrum sativum. Food Chemistry. 2009;113:526-529.

Morris J, Khettry A, Seitz E. Antimicrobial activity of aroma chemicals and essential oils. Journal of the American Oil Chemists' Society. 1979;56:595-603.

Musthaba SM, Athar MT, Baboota S, Ahmed S. HPTLC Analysis of Neem oil Extract in Herbal Dosage Form. Asian Journal of Chemistry. 2011;23:385-387.

Nakamura A, Fujiwara S, Matsumoto I, Abe K. Stress repression in restrained rats by (R)-(−)-linalool inhalation and gene expression profiling of their whole blood cells. Journal of agricultural and food chemistry. 2009;57:5480-5485.

Okabe H, Takayama K, Ogura A, Nagai T. Effect of limonene and related compounds on the percutaneous absorption of indomethacin. Drug design and delivery. 1989;4:313-321.

Pande KK, Pande L, Pande B, Pujari A, Sah P. Gas chromatographic investigation of Coriandrum sativum L. from Indian Himalayas. New York Sciences Journal. 2010;3:43-47.

Park S-N, Lim YK, Freire MO, Cho E, Jin D, Kook J-K. Antimicrobial effect of linalool and α-terpineol against periodontopathic and cariogenic bacteria. Anaerobe. 2012;18:369-372.

Pereira FdO, Mendes JM, Lima IO, Mota KSdL, Oliveira WAd, Lima EdO. Antifungal activity of geraniol and citronellol, two monoterpenes alcohols, against Trichophyton rubrum involves inhibition of ergosterol biosynthesis. Pharmaceutical biology. 2015;53:228-234.

Pino JA, Rosado A, Fuentes V. Chemical composition of the seed oil of Coriandrum sativum L. from Cuba. . Journal of essential oil Research. 1996;8:97-98.

Rabehaja DJ, Garcia G, Charmillon J-M, Désiré O, Paoli M, Ramanoelina PA, et al. Chemical composition of Melicope belahe (Baill.) TG Hartley (Rutaceae) leaf essential oil from Madagascar. Natural Product Research. 2016:1-4.

Raguso RA. More lessons from linalool: insights gained from a ubiquitous floral volatile. Current Opinion in Plant Biology. 2016;32:31-36.

Rota MC, Herrera A, Martínez RM, Sotomayor JA, Jordán MJ. Antimicrobial activity and chemical composition of Thymus vulgaris, Thymus zygis and Thymus hyemalis essential oils. Food control. 2008;19:681-687.

Russo EB. Taming THC: potential cannabis synergy and phytocannabinoid-terpenoid entourage effects. British journal of pharmacology. 2011;163:1344-1364.

Sahib NG, Anwar F, Gilani AH, Hamid AA, Saari N, Alkharfy KM. Coriander (Coriandrum sativum L.): A potential source of high-value components for functional foods and nutraceuticals-A review. Phytotherapy Research. 2013;27:1439-1456.

Salleh WMNHW, Ahmad F, Yen KH, Zulkifli RM. Essential Oil Compositions of Malaysian Lauraceae: A Mini Review. 2016.

Singh G, Maurya S, De Lampasona M, Catalan CA. Studies on essential oils, Part 41. Chemical composition, antifungal, antioxidant and sprout suppressant activities of coriander (Coriandrum sativum) essential oil and its oleoresin. Flavour and fragrance journal. 2006;21:472-479.

Sriti J, Talou T, Wannes WA, Cerny M, Marzouk B. Essential oil, fatty acid and sterol composition of Tunisian coriander fruit different parts. Journal of the Science of Food and Agriculture. 2009;89:1659-1664.

Wittig C, Scheuer C, Parakenings J, Menger MD, Laschke MW. Geraniol suppresses angiogenesis by downregulating vascular endothelial growth factor (VEGF)/VEGFR-2 signaling. PloS one. 2015;10:e0131946.

Yang H, Woo J, Pae AN, Um MY, Cho N-C, Park KD, et al. α-Pinene, a major constituent of pine tree oils, enhances non-rapid eye movement sleep in mice through GABAA-benzodiazepine receptors. Molecular Pharmacology. 2016;90:530-539.

Zeković Z, Adamović D, Ćetković G, Radojković M, Vidović S. Essential oil and extract of coriander (Coriandrum sativum L.). Acta Periodica Technologica. 2011;42:281-288.