Journal of Medicinal Plants Research Vol. 5(15), pp. 3537-3544, 4 August, 2011
Available online at http://www.academicjournals.org/JMPR
ISSN 1996-0875 ©2011 Academic Journals

Full Length Research Paper

Physicochemical composition of hydro-distilled essential oil from coriander (*Coriandrum sativum* L.) seeds cultivated in Pakistan

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Accepted 3 May, 2011

This experiment describes the physiochemical composition of the essential oil derived from the seeds of coriander (*Coriandrum sativum*) cultivated in Pakistan. Hydrodistilled essential oil content from coriander seeds was found to be 0.15%. The physicochemical properties namely density (25°C), refractive index (25°C), acid value, ester value, and optical rotation (25°C) determined for the essential oil were found to be 0.8310, 1.4592, 4.0, 23.7, and +11.5 g/cm^3, respectively. A total of 48 chemical constituents representing 90% of the essential oil tested were identified using Gas chromatography-flame ionization detector (GC-FID) and Gas chromatography-mass spectroscopy (GC-MS). Linalool with contribution of 69.60% was found to be the principal constituent. Other important components identified were: geranyl acetate (4.99%), γ-terpinene (4.17%), α-pinene (1.63%), anethol (1.15%) and *p*-cymene (1.12%). The analyzed essential oil mainly comprised of oxygenated monoterpene hydrocarbons (80.83%), followed by monoterpene hydrocarbons (8.00%), sesquiterpene hydrocarbons (0.47%) and oxygenated sesquiterpene hydrocarbons (0.35%). Overall, the physicochemical attributes and chemical profile of the tested essential oil from Pakistan were reasonably comparable with those investigated for coriander seed essential oils from other regions of the world suggesting its potential for functional foods and cosmetics applications.

Key words: Hydrodistillation, coriander seed, essential oil, physicochemical attributes, gas chromatography-mass spectroscopy (GC-MS), linalool, γ-terpinene, oxygenated monoterpenes.

INTRODUCTION

Coriander (*Coriandrum sativum* L.), a medicinal and culinary plant from the Umbelliferae (also known as Apiaceae) family, is one of the important spice crops (Gupta et al., 1991). A native of eastern Mediterranean region, coriander is now widely cultivated in many other parts of the world for its leaves, seeds and essential oil production. It is commonly grown in India, Pakistan, Bangladesh, Russia, Central Europe, Morocco, and China (Bhuiyan et al., 2009). India is the world's largest coriander producer, where the seeds and leaves of this spice are widely used for various food applications and essential oil extraction (Coskuner and Karababa, 2007). The seeds of coriander are small, almost ovate globular, approximately 3 to 5 mm in diameter; when dried, are usually brown colored, but in some cases may be off-white or straw-colored. The seeds, in whole form, or the powder, possessing a mild, sweet, and slight pungent odor, are extensively used as condiments as well in the preparation of curry powder, pickling spices, sausages

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and seasonings (Bhuiyan et al., 2009). The seeds are also used as a flavoring agent in different foods namely pastries, cookies, buns, cakes and breads (Akgul, 1993; Coskuner and Karababa, 2007; Bhuiyan et al., 2009). In addition to the traditional food uses, these have been widely used in the folk medicine system as carminative, spasmolytic, digestive, and galactagogue (Ghani, 2003; Bhuiyan et al., 2009). Chemically, coriander seed comprises two important constituents: the essential oil and the fatty oil. Depending upon varietals and agroclimatic fators, the essential oil content and fatty oil content from dried coriander seeds varies from 0.03 to 2.60% and 9.9 to 27.3%, respectively (Ramadan and Morsel, 2002; Coskuner and Karababa, 2007; Eikani et al., 2007). On commercial basis, coriander dried seeds are mostly subjected to hydrodistillation to produce an essential oil. Some other techniques such as supercritical fluid extraction (SCFE), using CO_2 and microwave-assisted hydrodistillation (MWHD) have also been investigated (Kosar et al., 2005).

Coriander seed essential oil as well as seed extract possessed antibacterial, antioxidant, anticancer and antimutagenic activities (Msaada et al., 2007; Bakkali et al., 2008; Mataysoh et al., 2009; Zoubiri and Baaliouamer, 2010). The isolated essential is used as an ingredient in cosmetics, creams, lotions, emulsifiers, soaps, shampoos and detergents imparting a distinctive essence to the products (Dogan and Akgul, 1987; Kaya et al., 2000; Misharina, 2001; Aburjai and Natsheh, 2003; Bhuiyan et al., 2009). The yield and chemical composition of coriander seed essential oil varies both qualitatively and quantitatively in relation to the method of extraction, type of the cultivar and the area of harvest (Kosar et al., 2005; Bhuiyan et al., 2009). Coriander seed essential oil is mainly composed of linalool, together with some other oxygenated monoterpenes and monoterpene hydrocarbons.

The concentration of linalool, the major component of essential oil, varies mostly between 50 and 70% (Argonosa et al., 1998; Illes et al., 2000; Coskuner and Karababa, 2007; Zoubiri and Baaliouamer, 2010). Of the other chemical constituents of the essential oil, geranyl acetate, α-pinene, γ-terpenine, myrcene, β-pinene and *p*-cymene are prominent (Coskuner and Karababa, 2007; Bhuiyan et al., 2009; Zoubiri and Baaliouamer, 2010). The knowledge of the chemical composition of an essential oil is of key importance for determining its potential industrial or medicinal applications. As far as we know, there are no reports available on the detailed physicochemical attributes of the hydrodistilled coriander seed essential oil from Pakistan. Therefore, the present research work was under taken with the main objectives to appraise the yield and physicochemical characteristics and chemical composition of the essential oil isolated from the seeds of coriander (*C. sativum*) cultivated in Pakistan. Gas chromatography-mass spectroscopy (GC-MS) analysis of the essential oil was performed to authenticate the profile of chemical constituents.

MATERIALS AND METHODS

Plant material

The coriander (*C. sativum* L.) seeds were harvested from the Botanical Research Garden of the University of Agriculture Faisalabad (UAF), Faisalabad, Pakistan. The specimens were further authenticated by Dr. Mansoor (a taxonomist), working at the Department of Botany, UAF, Faisalabad, Pakistan.

Isolation of volatile oil

The essential oil was isolated from the crushed dried coriander seeds (200 g) using 3 h hydrodistillation process. A Clevenger-type apparatus was used for this purpose. The isolated essential oil was dried over sodium sulphate (Na_2SO_4), filtered using Millipore filter paper (45 µm pore size) and stored at -4°C, until analyzed.

Physicochemical properties

The coriander seed essential oil was analyzed for physicochemical characteristics namely refractive index (25°C), density (25°C), color, optical rotation (25°C), solubility, acid number and ester number following AOAC standard methods (AOAC, 1990). A Lovibond Tintometer (Tintometer Ltd., Salisbury, UK) was used for reading the color of the isolated oil using one-inch cell. The refractive index of the oil was checked by using a digital refractometer (model, 7000α Atago Company Ltd. Japan) (Hussain et al., 2008).

Chemical composition

Gas chromatography

For analysis of the chemical constituents of the coriander seed essential oil, a gas chromatograph (Perkin-Elmer model 8700), fitted with a flame ionization detector (FID) was used. A HP-5MS capillary column (30 m × 0.25 mm, film thickness 0.25 µm) was used for separation purposes. The initial column temperature was set at 80°C and then raised to 220°C by the rate of 4°C/min. The initial and final column temperatures were held for 3 and 10 min, respectively. The operating temperatures for detector and injector were 220 and 290°C, respectively. The mobile phase used was helium at a flow rate of 1.5 ml/min. A 1.0 µl sample was injected using split mode (split ratio 100:1). All the quantitative measurements were made using a built-in data-handling program of the gas chromatograph (Perkin-Elmer, Norwalk, CT, USA). The composition of oil chemical constituents was reported as a relative percentage of the total peak area.

Gas chromatography/mass spectrometry analysis

The essential oil was also analyzed and authenticated for chemical composition using an Agilent-Technologies 6890N network gas chromatographic (GC) system (Little Falls, California, USA), equipped with 5975 inert XL mass selective detector and 7683B series auto injector (Agilent-Technologies). A sample volume of 1.0 µl was injected, applying split mode (split ratio 100:1), into HP-5 MS capillary column (30 m x 0.25 mm, film thickness 0.25 µm; Little Falls, CA, USA) using the same column temperature and gas flow rate as selected previously for GC analysis. An electron ionization (EI) system, with ionization energy (70 eV), was used for GC/MS detection. Mass scanning range was varied over 50 to 550 m/z. The injector and MS transfer line temperature were 220 and 290°C, respectively. The essential oil chemical compounds were identified

Table 1. Yield and physiccochemical properties of coriander seed essential oil.

Characteristic	Present study	Literature data	Reference
Yield (g/100g)	0.15 ± 0.10	0.1–0.35%	(Burdock and Carabin, 2008; Msaada et al., 2007)
Density (g/cm^3, 25°C)	0.831 ± 0.02	0.863-0.875	(Burdock and Carabin, 2008)
Refractive index (25°C)	1.4592 ± 0.004	1.4620-1.4720	(Burdock and Carabin, 2008)
Physical color and appearance	Pale yellow liquid	Colorless to pale yellow liquid	(Burdock and Carabin, 2008)
Color (Tintometer)			
Yellow unit	4.50 ± 0.50	Not found	Not available
Red unit	1.90 ± 0.50	Not found	Not available
Optical rotation (25°C)	+11.5 ± 0.2	+ 8 to +15	(Burdock and Carabin, 2008; Parthasarathy et al., 2008)
Acid number	4.0 ± 0.2	Up to 5.0	(Burdock and Carabin, 2008; Parthasarathy et al., 2008)
Ester number	23.7 ± 1.3	3.0-22.7	(Burdock and Carabin, 2008; Parthasarathy et al., 2008)
Solubility	Soluble in 2.5 volumes of 70% alcohol	Soluble in 2-3 volumes of 70% alcohol	(Burdock and Carabin, 2008; Parthasarathy et al., 2008)

Values are mean ± SD for triplicate determinations.

on the basis of matching their retention indices in relation to *n*-alkanes (C_9-C_{24}) and moreover with those of authentic compounds or published data (Minica-Dukic et al*.,* 2003; Vagionas et al*.,* 2007). Besides, the comparison of MS spectral data of the compounds with those from NIST mass spectral library was also applied to authenticate the compounds (Masada, 1976; Adams, 2001).

RESULTS AND DISCUSSION

Percent oil yield

In the present work hydrodistilled essential oil isolated from coriander (*C. sativum*) seeds, native to Pakistan, were tested for physicochemical properties and chemical composition. The data in Table 1 shows the yield and some important physicochemical characteristics of the essential oil isolated. The hydrodistilled essential oil yield from coriander seed was found to be 0.13 /100 g dry weight basis. Coriander seed essential oil yield from Pakistan, although smaller in magnitude, was in line to that reported in the literature (0.03 to 2.60% dry seed weight basis) from some other regions of the world (Kaya et al., 2001; Coskuner and Karababa, 2007).

Literature revealed that the yield of coriander essential oil differs in relation to the origin and cultivars of seeds as well as due to agroclimatic and geographical variations (Weiss, 2002; Telci et al., 2006; Hussain et al., 2008). Kiralan et al., (2009) reported that coriander seeds contained 0.3 to 1.2% essential oil, 60 to 70% of which was made up of linalool. Bhuiyan et al. (2009) investigated the content of essential oil from coriander seeds, grown in Bangladesh, to be 0.42% (fresh weight basis). The essential oil content studied in the two coriander varieties (vulgare and microcarpum) from Turkey varied between 0.15 to 0.25% and 0.31 to 0.43%, respectively (Telci et al., 2006). According the investigation of Zheljazkova et al. (2008) the essential oil content from different cultivars of coriander seeds native to Atlantic Canada was ranged from 0.8 to 2.2%.

Coriander seed can be categorized into two basic types: large, and small-sized. Small-sized cultivars, mainly grown in temperate regions, including European have generally higher oil yield (> 0.4%). The large-sized cultivars, mainly distributed in the tropical and subtropical regions, usually exhibit low oil content, 0.1 to 0.35%. Small-sized coriander seeds cultivated in the former USSR and most of the European countries usually contain 1.0 to 2.0% essential oil. Moroccan and Indian coriander seeds usually have oil content less than 0.4% (Weiss, 2002).

Physicochemical characteristics of oil

The values of density (25°C) and refractive index (25°C) of coriander seed essential oil were found to be 0.831 and 1.4592 g/cm^3, respectively (Table 1). Both the refractive index and density are important physical properties that can be used as a diagnostic criterion for evaluating the purity of the oils. The values of refractive

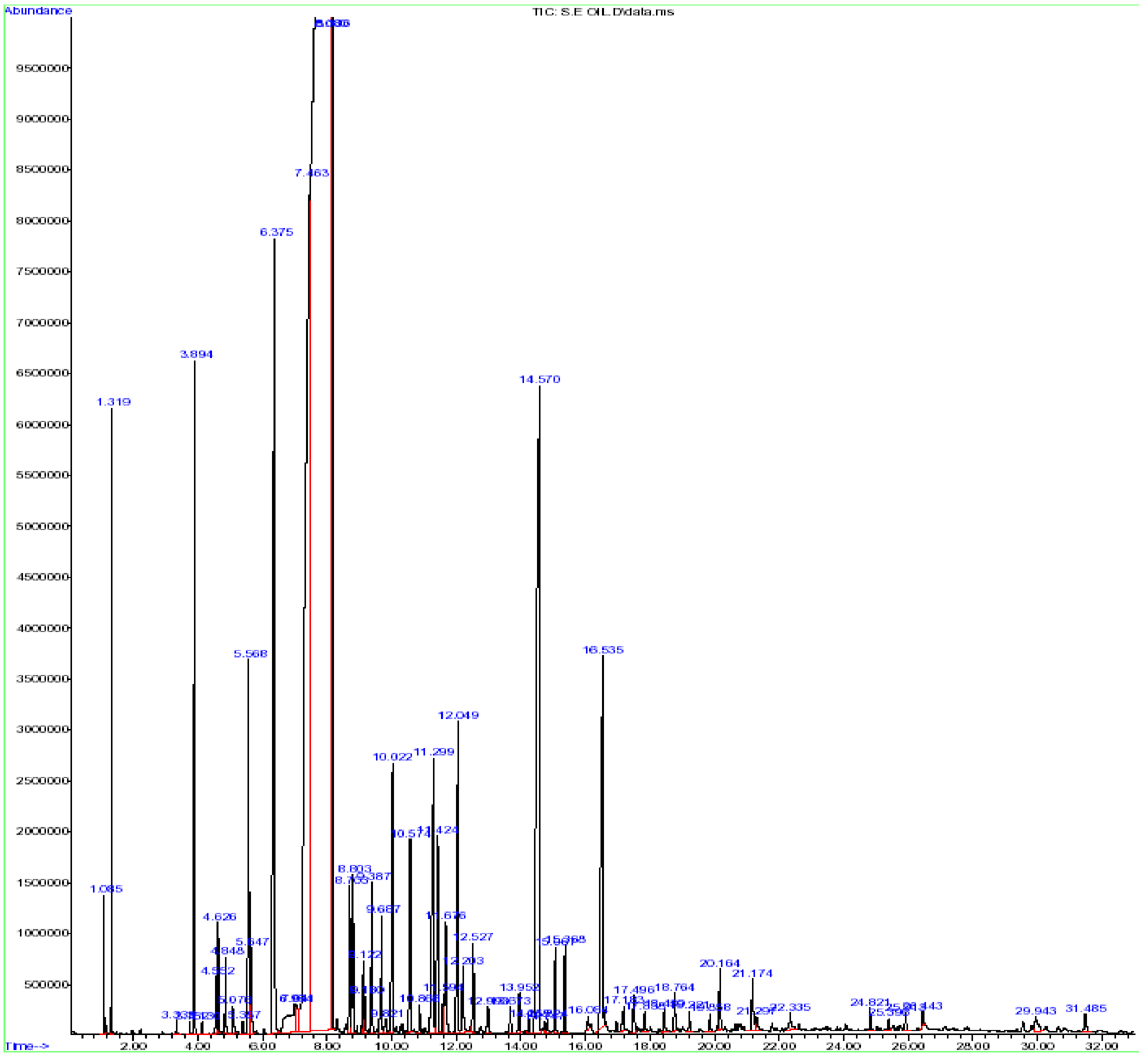

Figure 1. GC-MS chromatogram of coriander (*Coriandrum sativum*) seed essential oil.

index and density in the present analysis of coriander seed essential oil were found to slightly lower than those reported by Burdock and Carabin (2008), 1.462 and 1.472 and 0.863 to 0.875, respectively. When visually inspected, the tested oil showed a pale yellow color with liquid like appearance. While the tintometric color measurement showed the color intensity of the oil to be 4.5 in yellow and 1.9 in red units. The extraction procedure, extent of processing, seed quality and maturity at harvest, and storage conditions are some of the key factors, which might influence the color of the isolated oils. The present values (Table 1) of some other characteristics namely acid number (4.0), ester number (23.7), optical rotation (+11.5) and solubility (soluble in 2.5 volumes of 70% alcohol) of the tested essential oil were noted to be rather within the limits of the standard specifications given in the literature (Burdock and Carabin, 2008; Parthasarathy et al., 2008).

Considerable variations are reported in the physicochemical characteristics of coriander seed essential oils across the countries since factors such as type and origin of cultivar, seed maturity at harvest, storage conditions and method of extraction can influence such properties. For example, fruit immaturity and impurity due to inclusion of leaf or stalk material can lead to decrease the values of specific gravity, optical rotation and linalool content (Parthasarathy et al., 2008). European coriander seed essential oils are often characterized by an optical rotation value between +9 and +13 and ester value of *ca*. 22 while Moroccan-based oils generally have an optical rotation of +10 and ester number around 30. Similarly in some cases essential oils from Indian-grown coriander seeds have shown quite low value for refractive index (1.4000) while a high ester value (Weiss, 2002; Parthasarathy et al., 2008).

Chemical composition of oil

The tested coriander seed essential oil was analyzed for

Table 2. Chemical composition of coriander seed essential oil as analyzed by GC-MS.

Component	Retention time	Composition (%)
Monoterpene hydrocarbons		
α –Terpinene	5.38	0.03 ± 0.03
γ –Terpinene	6.37	4.17 ± 0.04
Sabinene	4.55	0.12 ± 0.07
β-Pinene	4.62	0.23 ± 0.06
β-Myrcene	4.84	0.18 ± 0.04
α –Thujene	3.74	0.02 ± 0.05
α –Pinene	3.89	1.63 ± 0.05
Camphene	4.12	0.02 ± 0.04
p-Cymene	5.56	1.12 ± 0.02
D-Limonene	5.64	0.26 ± 0.01
Terpinolene	6.98	0.53 ± 0.01
Subtotal		8.00
Oxygenated monoterpene hydrocarbons		
Octanal	5.07	0.10 ± 0.03
Heptanal	3.33	0.03 ± 0.05
Linalool	8.08	69.60 ± 0.2
Citronellal	8.80	0.45 ± 0.02
Terpinene-4-ol	9.38	0.39 ± 0.02
Borneol	9.12	0.18 ± 0.04
Camphor	8.70	0.38 ± 0.02
Menthadien-1-ol	9.68	0.39 ± 0.02
Estragole	9.82	0.08 ± 0.01
Anethol	12.04	1.15 ± 0.03
Decanal	11.59	0.14 ± 0.02
β-Citronellol	10.57	0.65 ± 0.02
Cuminaldehyde	10.86	0.07 ± 0.01
1-Undecanol	11.67	0.41 ± 0.01
Thymol	12.20	0.28 ± 0.02
Tetradecanal	12.52	0.25 ± 0.02
2,6-Octadiene	13.67	0.09 ± 0.02
Geranyl acetate	14.56	4.99 ± 0.02
Dodecanal	15.06	0.24 ± 0.02
cis-Nerolidol	18.76	0.12 ± 0.02
Tetradecanal	19.85	0.07 ± 0.03
Subtotal		
Sesquiterpene hydrocarbons		
α –cubebene	14.26	0.05 ± 0.01
β-caryophyllene	19.22	0.07 ± 0.03
Caryophyllene	15.36	0.28 ± 0.02
Δ –Cadinene	17.84	0.07 ± 0.02
Subtotal		0.47
Oxygenated sesquiterpene hydrocarbons		
Apiol	20.16	0.20 ± 0.01
α-Elemol	18.43	0.09 ± 0.03
Santalol	21.29	0.06 ± 0.04
Subtotal		0.35

Table 2. Contd.

Others		
Tridecanoic acid	22.33	0.09 ± 0.02
2-Pentadecanone	24.82	0.08 ± 0.03
Z-5-Nonadecene	25.39	0.05 ± 0.02
Nonadecane	25.91	0.06 ± 0.01
Hexadecanoic acid	26.44	0.04 ± 0.01
Heneicosane	29.94	0.12 ± 0.01
Subtotal		0.44
Grand total		90.09%

Values are mean ± SD for triplicate determinations.

its chemical constituents using GC and GC-MS. A typical GC-MS chromatogram showing the separation of the tested essential oil chemical constituents, together with their actually recorded retention times, is presented as Figure 1. The corresponding qualitative and quantitative chemical compositional data is given in Table 2. A total of 48 compounds were identified in the essential oil, accounting for 90.09% of the total oil. The essential oil tested contained high amount of linalool (69.60%) followed by geranyl acetate (4.99%), γ-terpinene (4.17%), α-pinene (1.63%), anethol (1.15%) and *para*-cymene (1.12%). Some minor compounds including D-limonene (0.26%), terpinolene (0.53%), citronellal (0.45%), terpinene-4-ol (0.39%), camphor (0.38%), menthadien-1-ol (0.39%), *β*-citronellol (0.65%), 1-undecanol (0.41%), thymol (0.28%), tetradecanal (0.25%), dodecanal (0.24%), and caryophyllene (0.28%) were also detected. As far as the composition of chemical groups is concerned, the analyzed essential oil mainly comprised of oxygenated monoterpene hydrocarbons representing 80.83% of the oil. Linalool was the major component in this group contributing 86.10% of the total oxygenated monoterpenes. The amounts of other three groups of chemicals namely monoterpene hydrocarbons, sesquiterpene hydrocarbons and oxygenated sesquiterpene hydrocarbons were established be at levels of 8.00, 0.47 and 0.35%, respectively.

In Table 3, a comparison of the main chemical constituents of coriander seed essential oils from different regions of the world, together with the values determined for the present study is given. The chemical composition of coriander seed essential oil from Pakistan was somewhat comparable with that examined by Singh et al. (2006) who identified 52 components in Indian coriander seed essential oil, accounting for 98.45% of the total oil. In agreement with our present data, the major chemical components which they detected in the essential oil were: linalool (75.30%), geranyl acetate (8.12%) and α-pinene (4.09%). In another study, Zoubiri and Baaliouamer (2010) identified 17 compounds in the essential oil from coriander seeds cultivated in Algeria. In this study linalool amounting to 73.1% was found to be the principle component in the oil. Other main components detected in the Algerian oil were *p*-mentha-1,4-dien-7-ol (6.51%), *α*-pinene (3.41%) and neryl acetate (3.22%). According to the findings of Bhuiyan et al. (2009), the essential oil from the fruits of coriander harvested in Bangladesh revealed the presence of 53 compounds, where the concentration of major compounds linalool (37.7%), geranyl acetate (17.6%) and γ-terpinene (14.4%), was considerably varied to those determined in our present analysis. Similarly, in contradictory to our present oil composition as well as to other literature reports, coriander seed essential oil from Kenya had entirely different chemicals profile revealing the presence of 2E-decenal (15.90%), decanal (14.30%), 2E-decen-1-ol (14.20%), n-decanol (13.60%), 2E-tridecen-1-al (6.75%), docecanal (4.36%) and undecanol (3.37%) as the main components. Such qualitative and quantitative variations in the chemical composition of coriander seed essential oil across the regions might be linked to the varied nature and origin of the seed cultivar, as well as to the differences in the harvesting and fruits growing regimes including the agroclomatic conditions (Telci et al., 2006; Hussain et al., 2008; Zheljazkova et al., 2008).

Besides the tabulated (Table 2) literature comparison, many other studies also revealed the chemical composition of coriander seed essential oils. For example, Msaada et al. (2007) investigated linalool (87.54%) and c*is*-dihydrocarvone (2.36%) as the two main components in the coriander seeds essential oil from Tunisia. Telci et al. (2006) studied the yield and chemical composition of essential oil from *C. sativum* seeds of two varieties (var. vulgare Alef and var. microcarpum DC) grown in different regions of Turkey. They found that the oils isolated mainly consisted of oxygenated monoterpenes, representing ~73 to 82% in microcarpum and ~50 to 65% in vulgare variety. There were large variations observed with regard to the content of linalool, the principal component of the oils, between the two varieties. The var. microcarpum had higher linalool content (63.5 to 71.0%) than vulgare (42.1 to 52.7%). The content of linalool (69.6%) in our analysis was within the range of var. microcarpum. In contrast to

Table 3. Comparison of the chemical composition (%) of coriander seed essential oil main components (present study Vs different countries data).

Component	Present study*	India (Singh et al., 2006)	Bangladesh (Bhuiyan et al., 2009)	Algeria (Zoubiri and Baaliouamer, 2010)	Kenya (Matasyoh et al., 2009)
γ-Terpinene	4.17 ± 0.04	Tr	14.42	4.17	nd
β-Pinene	0.23 ± 0.06	0.86	1.82	0.78	nd
Geraniol	nd	0.81	1.87	nd	nd
α-Pinene	1.63 ± 0.05	4.09	nd	3.41	0.04
p-Cymene	1.12 ± 0.02	0.45	nd	1.76	nd
Limonene	0.26 ± 0.01	0.63	0.40	1.23	nd
α-Cedrene	nd	Nd	3.87	nd	nd
Linalool	69.60 ± 0.2	75.30	37.65	73.11	0.32
Citronellal	0.45 ± 0.02	0.10	1.31	nd	nd
Camphor	0.38 ± 0.02	0.14	nd	1.85	nd
Decanal	0.14 ± 0.03	nd	0.14	0.43	14.30
2E-Decenal	nd	nd	nd	nd	15.90
2E-Decen-1-ol	nd	nd	nd	nd	14.20
n-Decanol	nd	nd	nd	nd	13.60
Undecanal	nd	nd	nd	nd	3.23
Udecanol	nd	nd	nd	nd	3.37
Trans-2-Undecen-1-ol	nd	nd	nd	nd	2.12
n-Undecanol	nd	nd	nd	nd	2.38
Docecanal	nd	nd	nd	nd	4.36
2E-Tridecen-1-al	nd	nd	nd	nd	6.75
Geranyl acetate	4.99 ± 0.02	8.12	17.57	nd	nd
Neryl acetate	nd	nd	nd	3.22	nd
Dodecanal	0.24 ± 0.02	nd	nd	nd	nd
P-mentha-1,4-dien-7-ol	nd	nd	nd	6.51	nd

* Values are mean ± SD for triplicate determinations; nd: not detected.

our findings, the oil from var. vulgare contained a considerable amount of hexadecanoic acid (11.3 to 15.9%) and tetradecanoic acid (7.9 to 10.5%). Geranyl acetate, geraniol γ-terpinene, (Z)-isoapiole dillapiole and *p*-cymene were some other important components detected in Turkish oils. The essential oils isolated from coriander seeds, produced in Atlantic Canada, alsoexhibited a high level of linalool (64 to 84.6%) (Zheljazkova et al., 2008). While among the other constituents of the oils, camphor, α-pinene, phellandrene, linalyl acetate, limonene, *para*-cymene and geranyl acetate with contribution 3.4 to 6.2%, 1.2 to 3.2%, 1.7 to 4.1%, 2.4 to 3.3%, 0.7 to 1.8%, 0.5 to 1.3%, and 0.9 to 1.6, respectively were the prominent compounds, showing both qualitative and quantitative variations from our present analysis.

Generally, it is observed that European coriander seed essential oils are high in linalool in comparison to the oils from Asian regions. European oils show monoterpene hydrocarbon content between 16 to 30%, linalool 60 to 75%, whereas a considerable amount of other oxygenated monoterpenes is also present. The main monoterpene hydrocarbon components detected in these oils are γ-terpinene (upto 10%), and limonene, *p*-cymene, α-pinene upto 7% each. The most prominent non-linalool oxygenated monoterpenes reported are geranyl acetate upto levels of 5%, borneol upto 7%, camphor and geranial upto 4% each and geraniol upto 2%. Russian oils offer a high content of linalool, 69 to 75%. The oils from coriander species native to Indian region differ from European and Russian oils in having a lower amount of linalool and relatively a higher ester number (Weiss, 2002; Parthasarathy et al., 2008).

Conclusions

In consistent with the chemical profiles of coriander seed essential oils from most of the studied regions of the world, the essential oil isolated from Pakistani coriander seeds was found to be a rich source of oxygenated monoterpenes representing linalool as the principal constituent. Overall, this study showed that physic-chemical attributes and chemical composition of the coriander seed essential oil from Pakistan, with few exceptions, were quite comparable with those reported in the literature suggesting its potential uses for food, pharmaceutical and cosmetic applications. An in-depth research work on the antioxidant principles and biological bioactivities of coriander seed essential oil is further recommended.

REFERENCES

Aburjai T, Natsheh FM (2003). Plants used in cosmetics. Pytother. Res., 17: 987-1000.

Adams RP (2001). Identification of Essential Oils Components by Gas Chromatography/Quadrupole Mass Spectroscopy. Allured Publishing Corporation, Carol Stream, IL., p. 456.

Akgul A (1993). Spice Science and Technology, Food Technology Dernegei Publishing publications, no. 15, Ankara, pp. 113-114.

AOAC (1990). Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC), 15th edn. AOAC Inc., Virginia.

Argonosa GC, Sosulski FW, Slikard AE (1998). Seed yields and essential oil of northern-grown coriander (*Coriandrum sativum* L.). J. Herbs Spices Med. Plants, 6: 23-32.

Bakkali F, Averbeck S, Averbeck D, Idaomar M (2008). Biological effects of essential oils, A review. Food Chem. Toxicol., 46: 446-475.

Bhuiyan MNI, Begum J, Sultana M (2009). Chemical composition of leaf and seed essential oil of *Coriandrum sativum* L. from Bangladesh. Bangladesh J. Pharmacol., 4: 150-153.

Burdock GA (2001). Coriander oil. In: *Fenaroli's Handbook of Flavor Ingredients* (4th Edition), CRC Press, New York, pp. 344-345.

Coşkuner Y, Karababa E (2007). Physical properties of coriander seeds (*Coriandrum sativum* L.). J. Food Eng., 80: 408-416.

Dogan A, Akgul A (1987). Production of Coriander, and the use of composition. Turk. J. Agric. For. Dog, 11(2): 326-333.

Ghani A (2003). Medicinal plants of Bangladesh*:* Chemical constituents and uses. 2nd ed. Asiatic Society of Bangladesh, Dhaka, p. 183.

Gupta K, Thakral KK, Arora SK, Wagle DS (1991). Studies on growth, structural carbohydrates and phytate in coriander (*Coriandrum sativum*) during seed development. J. Sci. Food Agric., 54: 43-46.

Hussain AI, Anwar F, Sherazi STH, Przybylski R (2008). Chemical composition, antioxidant and antimicrobial activities of basil (*Ocimum basilicum*) essential oils depends on seasonal variations. Food Chem., 108: 986-995.

Illes V, Daood HG, Perneczki S, Szokonya L, Then M (2000). Extraction of coriander seed oil by CO_2 and propane at super and subcritical conditions. J. Supercrit. Fluid, 17: 177-186.

Kaya N, Yylmaz G, Telci I (2000). Different times, planted coriander (*Coriander sativum* L.) populations agronomic and technological properties. Turkish J. Agric. For., 24: 355-364.

Kiralan M, Calikoglu E, Ipek A, Bayrak A, Gurbuz B (2009). Fatty acid and volatile oil composition of different coriander (*Coriandrum sativum*) registered varieties cultivated in Turkey. Chem. Nat. Compd., 45(1): 100-102.

Kosar M, Ozek T, Goger F, Kurkcuoglu M, Baser KHC (2005). Comparison of microwave assisted hydrodistillation and hydrodistillation methods for the analysis of volatile secondary metabolites. Pharm. Biol., 43(6): 491-495

Masada Y (1976). Analysis of essential oil by gas chromatography and mass spectometry, John Wiley and Sons Inc., New York, pp. 118-120.

Minica DN, Bozin B, Sokovic M, Simin N (2004). Antimicrobial and antioxidant activities of *Melissa officinalis* L. (Lamiaceae) essential oil. J. Agric. Food Chem., 52(7): 2485-2489.

Misharina TA (2001). Influence of the duration and conditions of storage on the composition of the essential oil from coriander from coriander seeds. Appl. Biochem. Microbiol., 37(6): 622-628.

Msaada K, Hosni K, Taarit MB, Chahed T, Kchouk ME, Marzouk B (2007). Changes on essential oil composition of coriander (*Coriandrum sativum* L.) fruits during three stages of maturity. Food Chem., 102(4): 1131-1134.

Mataysoh JC, Maiyo ZC, Ngure RM, Chepkorir R (2009). Chemical composition and antimicrobial activity of the essential oil of *Coriandrum sativum*. Food Chem., 113: 526-529.

Parthasarathy VA, Zachariah TJ (2008). Coriander In: Chemistry of Spices, Parthasarathy VA, Chempakam B, Zachariah TJ (Eds.), CABI Publishing (CAB International), Nosworthy Way Wallingford Oxfordshire OX10 8DE UK, pp. 190-210.

Ramadan MF, Mörsel JT (2002). Oil composition of coriander (*Coriandrum sativum*) fruit seeds. Eur. Food Res. Tech., 36: 273-276.

Singh G, Maurya S, De LMP, Catalan CAN (2006). Studies on essential oils, Part 41. Chemical composition, antifungal, antioxidant and sprout suppressant activities of coriander (*Coriandrum sativum*) essential oils and its oleoresin. Flav. Frag. J., 21(3): 472-479.

Telci I, Gul TO, Sahbaz N (2006). Yield, essential oil content and composition of *Coriandrum sativum* varieties (var. *vulgare* Alef and var. *microcarpum* DC.) grown in two different locations. J. Essent. Oil Res., 18: 189-193.

Vagionas K, Graikou K, Chinou IB, Runyoro D, Ngassapa O (2007). Chemical analysis and antimicrobial activity of essential oils from the aromatic plants *Artemisia afra* Jacq. and *Leonotis ocymifolia* (Burm. F.) *Iwarsson* var. *raineriana* (Vision 1) Iwarsson growing in Tanzania. J. Essent. Oil Res., 19: 396-400.

Weiss EA (2002). Spice Crops, CABI Publishing (CAB International), NY, USA.

Zoubiri S, Baaliouamer A (2010). Essential oil composition of *Coriandrum sativum* seed cultivated in Algeria as food grains protectant. Food Chem., 122: 1226-1228.

Zheljazkova VD, Pickett KM, Caldwell CD, Pincock, JA, Roberts JC, Mapplebeck L (2008). Cultivar and sowing date effects on seed yield and oil composition of coriander in Atlantic Canada. Ind. Crops Prod., 28: 88-94.