Journal of Asian Scientific Research

journal homepage: http://aessweb.com/journal-detail.php?id=5003

ERYNGIUM FOETIDUM L. CORIANDRUM SATIVUM AND PERSICARIA ODORATA L.: A REVIEW

Mohammad Amin Shavandi[1]
Zahra Haddadian[2]
Mohd Halim Shah Ismail[3]

ABSTRACT

In this article, we present a review work on volatile compounds of three different aromatic plants, known in a group called as cilantro mimics, with cilantro flavors in which C10 and C12 aldehydes and alcohols have been found as the potent odor, together with the analytical techniques used to identify and/or quantify them. The work is distributed according to the different types of plant in this group (Eryngium foetidum L, corianderum satvuim and persicaria odorata) discussing the application, specification and analytical techniques employed for volatile compound determination. Emphasize is placed on major odorant compounds in mentioned plants.

Key Words: Coriander, Essential oil, Eryngium foetidum L., Coriandrum satvuim, Persicaria odorata Lour.

INTRODUCTION

The starting point for flavor industry was the extracts gained from aromatic plants. Volatile compounds encompass a small part of the plant, but play an important role in many industries such as food, fragrance and pharmaceutical manufacturing. The chemical composition of essential oils is complex and containing from a few dozens to several hundred constituents, especially hydrocarbons (terpenes and sesquiterpenes) and oxygenated compounds (alcohols, aldehydes, ketones, acids, phenols, oxides, lactones, acetalse, ethers and esters). Both hydrocarbons and

[1] Department of Environmental and Chemical Engineering, Faculty of Engineering, University Putra Malaysia. 43400, Selangor, Malaysia

[2] Department of Environmental and Chemical Engineering, Faculty of Engineering, University Putra Malaysia. 43400, Selangor, Malaysia

[3] Department of Environmental and Chemical Engineering, Faculty of Engineering, University Putra Malaysia. 43400, Selangor, Malaysia **E-mail:** mshalim@eng.upm.edu.my

oxygenated compounds are responsible for the characteristic odors and flavors. The proportion of individual compounds in the oil composition is different from trace levels to over 90% (δ-limonene in orange oil). The aroma's oil is the result of the combination of the aromas of all components. Trace components are important, since they give the oil a characteristic and natural odor. Thus, it is important that the natural proportion of the components is maintained during extraction of the essential oils from plants by any procedure (51). Eryngium foetidum L, along with Coriandrum sativum L. and persicaria odorata Lour., belong to a group namely cilantro mimics, which all have decanal and dodecanal as an important fragrance and flavor agents in common. Many studies have done on these plants regarding to theirs chemical properties and volatile components, despite the widespread use of these herbs for food and as ethno medicinal agents, Most of the investigations were on the extraction and identification of essential oil compounds. so There remains a lack of comprehensive, integral information on all constituents and the aroma profile similarities which exist in all three mentioned plants and also the methods employed to obtain essential oils of plants, like hydro distillation, steam distillation, solvent extraction and super critical Co2 extraction processes used. Whereas supercritical fluid application increased significantly due to its prominent characteristics in compare to other methods, this review is aimed at providing a critical analysis of the works published recently on cilantro mimic's plants, and different extraction methods applied to obtain essential oils, and other related products.

ERYNGIUM FOETIDUM L

Eryngium foetidum L., wild coriander, is a member of Umbelliferae family, and is known by several common names in different languages such as: shado beni (Trinidad), chadron benee (Dominica), fitweed (Guyana), coulante or culantro (Haiti), recao (Puerto Rico) langer koriander (German); ketumbar java (Malay); pak chi farang (Thai); ngo gai (Vietnamese); culantro, racao, recao (Spanish); bhandhanya (Hindi), jid yudn qidn in China and long leaf or spiny coriander (English) (41,57,19,59,13,45). The herb is indigenous to tropical America, tropical Africa and Caribbean islands, and was introduced around the 1880s by Chinese to the large parts of South-East Asia (Indochina, Malaysia, Indonesia), as a substitute condiment for the coriander due to its similar pungent smell(54,13,3). And today is often cultivated and widespread across the world like South Asia, the Pacific islands, some parts of Africa and Europe (1,54,3). Wild coriander comprises over 200 species(68). Most have long, evenly branched roots, by oblanceolated, toothed margins leaves that each of them has a small yellow spine, which are as much as 8-30 cm long and 4 cm broad. The harb have clustered flowers along with rounded fruits (13,45). Wild coriander is a biennial herb, by intense coriander like smelling grows naturally in shaded wet or moist conditions near cultivated areas. And propagate by means of seeds. The herb is sun like ones which tends to bolt and flower under hot high-light long days of summer months(19,59,13).

Common Applications and Uses

Wild coriander is most popular in culinary in Caribbean and in Asia, particularly in Malaysia, India, Korea, Thailand and Singapore where it's harvested leaves are commonly topped over soups, which the most famous one example is called salsa noodle dishes, and curries (13). In Latin America, recipes are enhanced with culantro. Its food applications also include as a seasoning material for the culinary purposes, such as its uses in vegetable, meat dishes, sauces, and snacks. The herb by having a different spicy aroma gives a unique characteristic flavor to the dishes and due to this, increasing demand for the herb among ethnic populations arises. For instance, cilantro has a large market in UK, Canada and US, because of the presence of large West Indian, Latin American, and Asian immigrant communities (54).

Besides its food application purposes, The traditional uses documented for this herb are mainly medicinal, which include, its leave and roots decoction use for flu, pneumonia, diabetes, and constipation, herb also has been used traditionally for treatment of fevers, vomiting, diarrhoea, .The crushed leaves are placed in the ear to treat pain, and are used for the local treatment of arthritic processes (25,21). It also has been used as a folk medicine for scorpion sting and stomach pains (13). The herb extracts is also used widely in herbal medicines. E. foetidum have been assessed for anti-convulsant, anthelmintic, and its extract is a potential source of natural products with topical anti inflammatory activity (55,21)**.** Also analgesic, antimalarial and antibacterial properties were reported from traditional use (55,21). Different ailment uses of this plant have been reported by Many researchers (69,54). includes hypertension rheumatism, asthma, eye disease, poisoning, venereal disease (VD), diabetes, as a vermifuge, fits, pain, malaria, snake bites and hypotensive and for digestive troubles (25,21,45). Culantro (Eryngium foetidum L.) has been acclaimed as health foods because of the significant amount of calcium, iron, carotene, riboflavin, proteins and vitamins A, B, and C and essential oils in the aerial parts (3). Apart from this, this herb by having important volatile compounds is a significant item perfumery in cosmetic industry (45).

Profile of Leave Constituents

Fresh leaves consist of 86–88% moisture, 3.3% protein, 0.6% fat, 6.5% carbohydrate, 1.7% ash, 0.06% phosphorus and 0.02% iron (54) Leaves are an excellent source of vitamin A (10,460 I.U./100 g), B2 (60 mg %), B1 (0.8 mg %), and C (150–200 mg %) On a dry weight basis. Leaves consist of 0.1–0.95% volatile oil, 27.7% crude fiber, 1.23% calcium, and 25 ppm boron(13).

Profile of Chemical Composition

In the scientific reports, there is a significant variation regarding to the obtained yield and identified compounds of essential oil from the leaves of wild coriander. Which can be due to differences in some factors like cultivar or population specific variation, climate and growth conditions, geographical origin, age of the herbs, or the different processing and analysis methods used by researchers (57,19). The reported yield of essential oil of E. foetidum is from 0.1 to 0.95% of dry weight of the leaves and is rich in aliphatic aldehyds (21,54), but E-2-dodecenal was reported as

the main components of the oil (36). The essential oil composition of E. foetidum has been evaluated widely from different origins, including Fiji (19), Bangladesh (13), Peru (6), Venezuela, India(45) Taiw , Vietnam, Cuba, Malaysia, and West Africa(19,45). Like Coriander sativum the essential oil of E. foetidum has been reported to mainly consist of aldehydes, ranging from 45.8% to 86.7% (19).

The highest recorded level of E-2- dodecenal in E. foetidum oil was from Malaysia (59.72%) and South Vietnam (58–67%)(45), This alkenal has been also documented in scientific literature in varying levels from different location like, India (45.9%), Vietnam (45.5%) , Bangladesh (37.4%), the Venezuelan Andes (27.5%) , Western Nepal (58.1%) , and in Western Africa (15.9–37.5%). It is a minor compound in the oil of plants growing in Cuba and Taiwan (<1.32%). No acids were identified in the study which was consistent with the oils conducted in Venezuela and West Africa (45). In comparison, Pino et al. and Leclercq et al. found carboxylic acids to make up 12.8% and 29.1%, respectively (19). Chowdhury et al, isolate the essential oil from leaves of E. foetidum by hydrodistillation method (13), and Sixty there compounds have been identified with 2- dodecenal (E) (37.4 %), dodecanoic acid (10.7 %), trans-2-dodecanoic acid (9.7 %), 2-tridecenal(E) (6.7 %), duraldehyde (5.1 %) and tetradecanal (4.4 %) as the major constituents. Other major constituents of above 1 % were 2-undecenal (1.7 %), 7-octadecenal (3.7 %), capric acid (1.9 %), caryophyllene oxide (1.2 %), capraldehyde (1.2 %), durylic acid (2.3 %), α-durenol (2 %) and limonene (2 %). Similar reports of presence of (E)-2-dodecenal as major constituent were reported by various authors (35,69,47,11,13). But isomers of trimethylbenzaldehyde were the largest contributors to the oils from the wild coriander leaves from, Venezuela (2,4,5-isomer) and another sample from West Africa (2,3,4- and 2,3,6-isomers) The essential oil of Taiwanese plant has been shown to have 2,4,5 trimethylbenzaldehyde, 5-dodecanone, and 4-hydroxy-3,5-dimethylacetphenone along with 9.1 % acid and 90.9 % neutral parts rich in (E)-2-dodecenal (19,45). Banout et al, employed hydrodistillation and reported that (E)-2- dodecenal being the main constituent of the culantro essential oil and averaging 61.8–62.2%, followed by n-dodecanal (10.9–15.5%), (E)-2- tetradecenal (6.7–7.6%) and 1-tetradecene (3.6–5.7%) (6). The Obtained Essential oil composition by him is in agreement with previous reports (37,11). the aldehydes such as decanal and dodecanal are very significant constituents of the volatile oil of E. foetidum, due to its vital application in flavor and fragrance industry . The results showed that the main "character-impact" odorants of the herb are E-2-dodecenal and Z-2-dodecenal (21,11).

Regarding to the essential oil can be obtained from the root; it is dominated mainly by unsaturated alicyclic or aromatic aldehydes (2,3,6-trimethylbenzaldehyd 40%, , 2-formyl-1,1,5-trimethyl cyclohexa-2,4-dien-6-ol 20%,) (45). In the essential oil from the seeds, sesquiterpenoids (carotol 20%, ß-farnesene 10%), phenylpropanoids (anethole) and monoterpenes (a-pinene) were found, but no aldehydes reported. (1,21,54) (1; 21; 54) [1]. The plant was analyzed for essential oils from different locations and around 36 to 60, compound reported, a summary of identified constituents is shown in table 1.

The most reported method for essential oil isolation and analysis of E.foetidum is hydro distillation followed by The GC and GC/MS analysis of the essential oil (13,62,6) and in particular, (E)-2-dodecenal, were most closely associated with characteristic aromas of C. sativum and E. foetidum herbs; whereas, decanal and dodecanal were the characterizing components of P. odoratum aroma(50).

CORIANDRUM SATVIUM L

Coriander (Coriandrum Sativum L.) is a member of Umbelliferae family, and its leaf is often called cilantro or Chinese parsley and is known as dhania in Fiji. Coriander is an annual popular culinary medicinal plant with a distinctive pungent, fatty, and aldehydic aroma (19), which has been cultivated since ancient times and is originally from the Mediterranean and Middle Eastern region and grows extensively in India, Russia, Central Europe, Asia and Morocco. It grows 25–60 cm (9–24 in.) in height. It has thin, spindle-shaped roots, erect stalk, alternate leaves and small, pinkish-white flowers. The plant flowers from June to July and yields round fruits consisting of two pericarps. The plant is cultivated for its aromatic leaves and seeds. There are two varieties of C. sativum: vulgare Alef. and microcarpum DC. These varieties differ in the fruit size and oil yield: vulgare has fruits of 3–5 mm diameter and yields 0.1–0.35% essential oil, while microcarpum fruits are 1.5–3 mm and yield 0.8–1.8% essential oil (60,9). The Coriander essential oil is generally obtained by steam distillation of the dried fully ripe fruits (seeds) and oil has a characteristic odor of linalool and a mild, sweet, warm, aromatic flavor(9). At one time, It was among the world's leading essential oil plants (33,19). Coriander has a long history of use. Coriander was used in traditional Greek medicine by Hippocrates (ca. 460–377 B.C.). The seeds of coriander were found in the ancient Egyptian tomb of Ramses the Second. It was used for cooking and for children's digestive upset and diarrhea. The Greeks and Romans also used coriander to flavor wine and as a medicine(23) and the oil has been used as a food and fragrance ingredient since the 1900s (9).

Common Applications and Uses

Coriander is recognized as one of the most important spices in the world and is of great significance in international trade (60). Today, the herb is cultivated world widely for fruit, as a spice or production of essential oil and fatty acid, the stem leaves and fruits by having a pungent aromatic odor, commonly used as a condiment or spice in the Mediterranean area (9,62). This spice blend has not been replaced by a liquid essential oil mixture. In the US the leaves, are extensively used in Eastern cooking, Indian foods and in certain Mexican dishes. The roots are often used in Thai cooking. The seeds are used to prepare an infusion (3%), tincture and fluid extract. Additionally, a brownish-yellow liquid oleoresin (a naturally occurring mixture of a resin and an essential oil) is produced from selected quality seeds, the plant when young are used in preparing chutneys and sauces. The fruits and seeds are grounded and used in producing curry powder, pickling spices, sausages and seasonings. This plant is of economic importance as it has a pleasant odor, due to the particular composition of the essential oil (up to 1%), that monoterpenoid and

linalool is main components, which are mainly used as flavoring agent in food products like liquor, cocoa, pastry, pickles, cookies, buns and chocolates. The fruits are also used in the preparation of fish and meat, seasoning but also for baking (9,43). The average use levels range from 0.1 to 100 ppm. In perfumery, the warm and sweet notes of coriander oil blend well with bergamot and sage colognes, with floral notes in jasmine, lilac, honeysuckle and apple-blossom. In perfumes of an 'Oriental type', coriander oil produces interesting effects with Ceylon cinnamon, and olibanum is also known as frankincense, an aromatic resin obtained from trees of the genus Boswellia, particularly Boswellia sacra. Coriander oil is also used in consumer products such as soap creams, lotions, perfumes and cosmetics. It has the advantage of being more stable and of retaining its agreeable odor longer than any other oil of its class (16). Recently, Coriander oil has been reported to possess many medicinal properties, including antimicrobial properties against selected pathogenic,(41,57,45) antioxidant,(19) antidiabetic,(59)anticancer and antimutagenic activities (62) The seeds have medical uses and traditionally applied for curing digesting disorder's pain in joints and rheumatism. Stomachic, spasmolytic, carminative, diarrhoea and dyspepsia of various origin's coriander are also used in aromatherapy (38,17,48,59,43,62). The fruits and oil of coriander are used to cover the taste or correct the nauseating or griping qualities of other medicines. The oil is mainly used as a flavoring agent in pharmaceutical preparations(9). Coriander has been reported to possess strong lipolytic activity, and as a member of carrot family, its use has been suggested with caution, because of potential allergic reactions from furanocoumarins (9). Coriander oil may have future use as a free radical scavenger, preventing oxidative deterioration in foods. In a report by Ramadan and Moersel (2006),(53) coriander oil was shown to have greater activity against the radical generating activity of 1,1-diphenyl-2- picrylhydrazyl in several oils. The order of effectiveness among various oils in inhibiting free radicals was coriander> blackcumin> cottonseed> peanut> sunflower> walnut> hemp seed> linseed> olive> niger seed. 1.1.5.2. Non-food uses (9). Emamghoreishi et al. 2005 (18) Evaluated the anxiolytic effect of the herb and found that powdered fruits or dry extract, tea, tincture, decoction or infusion can be used for dyspeptic complaints, loss of appetite, convulsion, insomnia and anxiety. In 2005 G. Singth et al (59) analyzed the essential oil and oleoresin from for antifungal, antioxidant and sprout suppressant activities and reported that the inhibition effect of the oleoresin on oxidation was the main component, possesses potent antifungal activity, and can be used as natural sprout suppressant, while the oleoresin, rich in oleic acid and linoleic acid, may be used as an alternative source of natural antioxidant (14). Moreover, it has been verified by many other researchers that the essential oils and various extracts from coriander possess antibacterial, antioxidant, antidiabetic, anticancerous and antimutagenic activities (43).

According to the described results by J, Sriti et al. who analyzed Tunisian coriander fruit**,** different parts of C. sativum fruits can be proposed for several uses, The high linalool and the petroselinic acid content, in the seed oil, suggests the exploitation of (16) as a low-cost renewable source of bioactive compounds for industrial processing in the fields of cosmetics, perfumes and

nutraceuticals. However, fruit pericarp provides low yields of essential oil, but is a rich source of essential fatty acids and sterols (62).

Profile of Chemical Composition

Coriander oil, essential or volatile, is obtained by steam distillation of the dried, fully ripe fruits (seeds) of C. sativum. The volatile oil yield ranges between 0.3% and 1.1%. The seeds contain on average 18% oil (fatty acids/triglycerides); however, the essential oil content of seeds is approximately 0.84%. The essential oil (steam distilled) is produced mainly in Eastern Europe, with Russia as one of the leading producers (20,9). Typical compositional analysis of coriander oil is as follows: alcohols: linalool (60–80%), geraniol (1.2–4.6%), terpinen- 4-ol (trace-3%), a-terpineol (<0.5%); hydrocarbons: c-terpinene terpinene (1–8%), r-cymene (trace-3.5%), limonene (0.5–4%), a-pinene (0.2–8.5%), camphene (trace-1.4%), myrcene (0.2–2%); Ketones (7–9%): camphor (0.9–4.9%); esters: geranyl acetate (0.1–4.7%), linalyl acetate (0–2.7%); coumarins/furanocoumarins: umbelliferone, bergapten (9). The main component of coriander oil is linalool, which forms approximately two-thirds of the oil (56,32,24). Coriander oil was reported to contain approximately 30% terpene hydrocarbons and 70% oxygenated compounds. The BACIS (1999)(2) reports the presence of 122 constituents in coriander leaf, although the final number may be >200. The 18 main components constitute approximately 97% of the total oil. When reconstituted in the concentrations found in the natural sample, the reconstituted oil did not give the odor impression of coriander oil (61). Hence, a major sensory effect of the oil apparently comes from the remaining trace constituents that occur, on average, in concentrations of about 0.01% or less. Mono- and polyunsaturated fatty aldehydes, although minor components, contribute to the characteristic aroma of the oil because of their powerful odor. In contrast to the seed oil, coriander leaf oil contains these aldehydes as main constituents, e.g. 2-decenal and 2-dodecenal (7,9). Coriander oil is no longer important as a raw material for the production of linalool and its derivatives. However, it is still used extensively in seasoning mixtures and in perfume compositions (65). Ishikawa et al. (2003) (29) reported identification of 33 compounds from the water-soluble portion of the methanol extract of coriander fruit. Gil et al. (2002) (22) compared the essential oil composition of coriander fruits from plants growing in Argentina and Europe and reported that, The variation in the oil composition was related to the relative proportion of the constituents and not to the presence or absence of a particular component. Geographic location, fertilization and weed competition also affected the chemical profile. The European samples showed more stable concentration of the major components compared to samples from Argentina. Hirvi et al. (27) investigated the oil content of coriander fruit cultivated at two different localities in Finland during 1983 and 1984. They found the oil content vary from 0.34 to 1.49 ml/100 g in the samples of the two consecutive years. The considerable variation was explained by the annual variation of climatic conditions during the growth season (31). Carruba et al. (12) reported that the Essential oil composition of Italian coriander fruits was greatly influenced by the age and origins, also. The effect of maturity stage on the essential oil composition was mentioned by (67,42), furthermore, variations of composition of the essential oil in many different fruits, depending on

genetic and environmental factors as well as ontogeny and analytical methods (34,19,43). The composition of coriander fruits was shown to change according to the degree of maturity (42), Coriander fruits were gathered from northeastern Tunisia over a two month period, at initial maturity (full green fruits), for middle stage maturity (green–brown fruits) and brown fruits representing the final stage of maturity. During the initial stage, the quantitatively predominant substance was geranyl acetate, but which represented less than 1.0% of the total constituents at the mature stage. Linalool, the second most quantitatively predominant substance (10.96 of 66.29%), became the most predominant substance in the mature fruit, representing 87.54% of a 95.39% of volume identified (9). Many phytochemical studies so far investigated the chemical composition of the essential oil from coriander fruits from different origins (4,5,62). Coriander oil is an almost colorless to pale yellow liquid with a characteristic odor, The most common applied method for extraction of essential oils has been hydrodistillation and various parts of coriander plant like seeds leaf and fruit were subjected to this method by different researchers (59,16,43,62).Nitz et al. (1992)(44) reported no obvious sensory differences in flavors of coriander extracts prepared by distillation or by supercritical carbon dioxide extraction. The organoleptic characteristics of the distilled oil tend to deteriorate during prolonged storage, especially if left exposed to light and air. However, storage of the oil for one year in the dark, did not affect the organoleptic characteristics of the oil (40,9). Hydrodistillation, subcritical water extraction and Soxhlet extraction were compared for the extraction of essential oil from Coriandrum sativum L.by M.H. Eikani et al.(16) and it was reported that Hydro distillation and Soxhlet extraction has higher extraction efficiencies, but the subcritical water extraction resulted to the essential oils more concentrated in valuable oxygenated components. They also reported that the main component of C. sativum is linalool. The concentration of linalool was between 78% and 83%. In 1995 Kallio and Takeoka applied liquid carbon dioxide and hydrodistillation to the extract essential oil of coriander fruits; No significant difference was found in the total yield of isolated extract between hydrodistillation and CO2 extraction. Which is in agreement with the results of Takeoka et al., but it was demonstrated that CO2 extracts contain more components (66,31). According to the literature, the amounts of oil in coriander fruits varies between 0.15 and 1.7 ml/ 100 g (31), they also reported that the total amount of monoterpene hydrocarbons was significantly lower in CO2 extracts (about 13.5 %) than either in hydrodistillate (20 %) or solvent extracts (24.5%). α-Pinene, D-limonene and 7- terpinene were the major monoterpenes in all extracts. In the hydrodistillate α-pinene was the most abundant monoterpene, whereas in other extracts 7-terpinene was most prominent(31).

The literature demonstrates that the composition of C. sativum essential oil is primarily made up of aldehydes (>80%). Of these, E-2-alkenals, with E- 2-decenal being the most abundant component (26.0%) followed by 1-decanol (19.6%) Other important compounds were E-2-tetradecenal (7.0%), decanal (6.6%), and E-2-dodecenal (5.4%).but only contributed 0.39% of the total odor activity and reported in the majority of the literature. E-2-decenal would be expected to be the most potent odorant, with a "very powerful, waxy, orange like, aldehydic odor". This has important implications for the production of commercial coriander herb oil where it may be desirable to limit

enzyme action in order to produce oil with a greater E-2-decenal content and subsequently stronger aroma(49,19).

PERSICARIA ODORATA L

Persicaria odorata (Polygonum odoratum Lour. family Polygonaceae.) is a culinary herb which is indigenous to Tropical south Asia and is known by different names in different countries, English name includes Vietnamese coriander, Cambodian mint, hot mint, Vietnamese mint and Vietnamese cilantro. In Vietnamese called, Rau Rdm, Often pronounced "zow-zam," In Malaysia known as kesum or daun kesom and widely used as a flavoring material in food preparation and in Singapore, is known as laksa plant (also laksa herb or laksa leaves); These names reflect the usage of Vietnamese coriander for the famous Chinese-Malaysian noodle curry laksa and The Hindi term is lakh. This herb is widely sold in the U.S. under the name "Vietnamese coriander." (1,50)**.**

Laksa plant is a tender perennial herb 30-35 cm height with pointed leaves 6-15 cm with distinctive dark purple marking in the centre of the leaves which are green, lanceolate and red stems, closely resembling the European water-pepper (64,30,63). Vietnamese coriander is native to peninsular Southeast Asia (Indochina), where it grows in wet environments with a rich, moist soil in semi-shade, although full sun is tolerated if abundant moisture is provided(50)and Propagation of the herb is usually by cuttings, and roots are produced easily from the nodes.

Common Application and Uses

Polygonum odoratum is used in Southeast Asian cooking to season meat dishes, and widely used for production of Kesom oil, a potential source of natural aliphatic aldehydes (8).This plant is believed to have a range of medicinal and other beneficial properties such as dabble the feverish, restrain thirst, for the correlation of lung and stomach injuries, feverish coughs, oppressed feeling thirsty and heat diabetes and is sometimes employed as an anaphrodisiac, and many other beneficial properties, include antimicrobial property, anti-inflammatory activity, antitumor-promoting activity, antioxidative property and insect antifeedant activity (46,30). Due to this, the plant has been extensively studied for its chemical compositions related to such properties.

Profile of Chemical Composition

In addition to the various properties mentioned above, the leaves of P. odorata have a very strong coriander odour. Regarding to the aroma constituent of the herb, it has been reported differently by researchers, depending on the place of cultivation, harvest and used analytical method. Starkenmann et al. (63), have studied the volatile constituent of this herb oil extracted by hydrodistillation and reported that the aldehyde such as dodecanal, decanal, (Z)-3-hexanal, (E)-2-hexanal and (Z)-3-hexen-1-ol are the main ones. Dung et al. (15) by using steam distillation identified 28 volatile compounds of which B-caryophyllene (36.5%), dodecanal(11.4%) and caryophyllene oxide (8.2%) were main ones. Hunter et al. (28) also applied steam distillation and

isolate the Australian persicaria odorata essential oil and identified 17 components with dodecanal (44.1%) and decanal (27.7%) as the major compounds and Sesquiterpenes (α-humulene, β-caryophyllene) account for about 15% of the essential oil. In 2003 also an author (J.jiang)(30) reported results correspond to volatile composition of P.odorata, by means of following isolation techniques, dynamic headspace sampling, simultaneous distillation and extraction and liquid-liquid extraction with dichloromethane and identified a total of 46 compounds, it was reported that dynamic headspace sampling and simultaneous distillation and extraction, extracted more volatile compounds than liquid-liquid extraction. The major compounds include dodecanal (3–40%), (E)-2-hexenal (20–35%), decanal (4–22%), (Z)-3-hexen-1-ol(4–31%, hexanal (1.7–5.1%) and B-caryophyllene (1.7–2.3%). In 2005 Cadwallader et al. (10) applied a cold direct solvent extraction method and reported that dodecanal and decanal by 27.5% and 23.2% respectively, were in highest abundance. In another study carried out recently by C.T. To Quynh et al. (52) three methods of analyzing namely solvent extraction, water extraction and hot water extraction was used, aliphatic aldehydes were the most abundant compounds when solvent extraction and hot water extraction was applied, where dodecanal(57.55%) and decanal(27%) was reported as the major ones. They also reported that, solvent extraction is the most effective method for the isolation of dodecanal while decanal showed the highest yield of isolation when water extraction employed. Based on documented studies Decanal and dodecanal are the most abundant compounds in the herb, followed by undecanal and (Z)-3-hexenal. In addition, sesquiterpenes such as b-caryophyllene and a-humulene are at considerable levels. (8,63)and as Carbonyls (aldehydes/ketones) and alcohols are the predominant classes of volatile compounds, accounting for almost 90% (or above) of the total volatiles extracted from the laksa plant. Significantly, high levels of both (E)-2-hexenal and (Z)-3-hexen-l-ol may make the weed plant become a potential source of ‘green note’ aroma compounds (30)**,** a summary of identified compounds is shown in Table 3. The oil odor has very rich C10 & C12 aldehydes and to a lesser extent C10 & C12 alcohols, and is such an intense green clear lemony, fresh coriander foliage and pungent-aldehydic that is often associated with other plants belong to cilantro mimic group. Its odor (green, pungent, cut-leaf) is related to decanal, undecanal, and dodecanal at lower odor potency (8,39).

CONCLUSION

Essential oils have the potential for both the flavour/fragrance markets, and also as active constituents of commercial products, In summary, the above-described studies show that herbs, including Eryngium foetidum L. Coriandrum satvuim and Persicaria odorata Lour, by having unusually high content of aliphatic aldehydes are excellent source for production of natural aliphatic aldehydes, As synthetics are currently used are highly expensive, and have limited availability in the production of flavour and fragrance ingredients.

Table-1. Compounds identified in E. foetidum essential oil

Name of compounds	References	Name of compounds	References
Nonane	(19)	Eucalyptol	(19,13)
Undecane	(19,6)	γ-Terpinene	(37,19)
Tridecane	(19,6)	E-linlool oxide	(19)
1-hexanol	(19)	1-Undecene	(19)
1-Dodecanol	(47,26,19)	Z-Linalooloxide (furanoid)	(19)
(E)-2-Dodecen-1-ol	(19)	Linalool	(19)
(E)-2-Tetradecen-1-ol	(19)	α-Pinene oxide	(19,13)
Z-3-Hexen-1-ol	(19)	Camphenone,6	(19)
1-Octen-3-ol	(19)	Limonene oxide	(19,13)
Nonanal	(19,13)	2-Undecanone	(19)
Decanal	(19)	α -Copaene	(19)
Undecanal	(19,6)	α -E-Bergamotene	(19)
Dodecanal	(19,6)	β-Ionone	(19)
Tetradecanal	(19,13,6)	Germacrene A	(19)
E-2-Decenal	(26,19,6)	E-Nerolidol	(19)
E-2-Undecenal	(26,19,13)	β -Caryophyllene oxide	(19)
E-2-Dodecenal	(35,69,11,19,13,6,45)	α-Copaene	(6)
E-2-Tridecenal	(11,19,13,45)	1- Tetradecenal	(6)
E-2Tetradecenal	(11,19,6)	Thujopsene	(6)
E-2Hexadecenal	(19)	β- Chamigrene	(6)
2.09Z-2-Dodecenal	(19,6)	A- Muurolene	(6)
Z-2Tetradecenal	(19,6)	δ- Cadinene	(6)
Z-4Tetradecenal	(19)	(E.E)-2.4-dodecadienal	(6)
Benzaldehyde, 2,4,6-trimethyl	(19)	Apofarnesol	(6)
Benzaldehyde, 2,4,5-trimethyl	(69,47,11,19,13,45)	hexadecane	(6)
E,E-2,4-Dodecadienal	(19)	16. (E)-4-Decenal	(45)
.14 a-Pinene	(60,11,19,13)	19. 7-Octadecanal	(11)
Sabinene	(19,13)	22.4-Hydroxy-3,5 dimethylacetophenone	(37)
β -Pinene	(19,13)	23. Duraldehyde	(45)
β -Myrcene	(19,13)	24. 5-Undecanone	(37)
Benzene, 1,2,3-trimethyl-	(19)	25. Carotol	(35,69,47,11,13)
p-Cymene	(19)	Limonene	(19,13)
26. Hexadecanoic acid	(47)	2,3,4-Trimethylbenzaldehyde	(45)
27. (E)-2-Dodecenoic acid	(35,11)	3-dodecenal	(35,69,47,11,13,45)

Table-2. Compounds identified in C.sativum oil

Name of compounds	References	Name of compounds	References
Heptanal	(43,62)	cis-Dihydrocarvone	(31)
α -Thujene	(31,19,59,16,43,62)	Nerol	(43,62)
α -Pinene	(59,16,43,62)	Citronellol	(59,16,43,62)
Sabinene	(59,16,43,62)	Neral	(43,62)
β -Pinene	(31,19,59,16,43,62)	Carvone	(43,62)
d3-Carene	(43,62)	Geraniol	(31,58,59,16,43,62)
α -Terpinene	(19,59,43,62)	Geranial	(43,62)
p-Cymene	(31,19,59,16,43,62)	Anethol	(43,62)
Limonene	(31,19,59,16,43,62)	Thymol	(43,62)
1,8-Cineole	(59,43,62)	Carvacrol	(43,62)

β -Ocimene	(59,16,43)	d-Elemene	(43)
g-Terpinene	(31,19,59,16,43,62)	Eugenol	(43,62)
cis-Linalool oxide	(43)	Neryle acetate	(59,43,62)
Terpinolene	(31,19,59,16,43,62)	Geranyl acetate	(31,58,59,16,43,62)
Linalool oxide	(31,19,59,43,62)	b-Caryophyllene	(59,43,62)
decanal	(58,19,16,62)	α -Humulene	(59,43,62)
Linalool	(31,58,59,16,43,62)	Germacrene-D	(43,62)
Camphor	(31,58,59,16,43,62)	Eugenyl acetate	(43)
Borneol	(31,59,43,62)	Camphene	(31,59,62)
Menthol	(43,62)	β -Thujene	(31)
Terpinene-4-ol	(31,19,59,16,43,62)	β -myrcene	(31,19,59,16,62)
p-Cymen-8-ol	(43)	β -phellandrene	(31)
cis–Hex-3-enyl butyrate	(43)	α -phellandrene	(59)
Terpineol	(31,19,59,43,62)	2-decenal	(31,19)
1-dodecanol	(31,19)	Sesquiphellandrene	(59)

Table-2. continue

2-undecenal	(31,19,59)	Elemol	(59)
Tetradecanoic acid, 1-methylethyl ester	(31)	Caryophyllene oxide	(59)
Octanoic acid	(31)	ar-Curcumene	(59)
cis-3-Hexenyl butanoate	(31)	Nonane	(19)
Carvacrol			
Hexadecanoic acid, methyl ester	(31)	Decane	(19)
Decanoic acid 6-Methyldocosane	(31)	Undecane	(19)
6-Octadecenoic acid, methyl ester	(31)	Tridecane	(19)
Verbenene	(59)	1-Hexanol	(19)
6-Methyl-5-hepten-2-one	(59)	1-Nonanol	(19)
3-Carene	(19,59)	1-Decanol	(19)
1-Octanol	(19,59,62)	1-Undecanol	(19)
-Campholene aldehyde	(59)	E-2-Hexen-1-ol	(19)
trans-Pinocarveol	(59)	E-2-Nonen-1-ol	(19)
Citronellal	(59)	E-2-Decen-1-ol	(19)
Verbenone	(59)	E-2-Undecen-1-ol	(19)
Cuminal	(59)	E-2-Dodecen-1-ol	(19)
Citronellyl acetate	(59)	E-2-Tridecen-1-ol	(19)
-Ylangene	(59)	E-2-Tetradecen-1-ol	(19)
ar-Turmerone	(59)	E-3-Hexen-1-ol	(19)
Z-2-Hexen-1-ol	(19)	Z-3-Hexen-1-ol	(19)
1-Octen-3-ol	(19)	Z-4-Decenal	(19)

Table-3. Compounds identified in P. odorata essential oil

Name of compounds	References	Name of compounds	References
Nonane	(30)	3-Methylbutanal	(15,30)
-Pinene	(30)	1-Penten-3-one	(30)
Limonene	(30)	3-Pentanone	(30)
-Ocimene	(30)	(E)-2-Pentenal	(30)
Undecane	(30)	2-Methyl-4-pentenal	(30)
Tridecane	(30)	Hexanal	(15,30)
-Caryophyllene	(30)	(E)-2-Hexenal	(15,30)
(Z)--Farnesene	(30)	2,4-Hexadienal	(30)
-Caryophyllene	(15)	Isophorone	(30)
-Bergamotene	(30)	Phenylacetaldehyde	(30)
Total hydrocarbons	(30)	Decanal	(15,30)
1,2-Propanediol	(30)	Undecanal	(15,30)
(Z)-2-Penten-1-ol	(15)	Dodecanal	(15,30)
(Z)-3-Hexen-1-ol	(15)	Octadecanal	(30)
(E)-2-Hexen-1-ol	(15)	Total carbonyls	(30)
2-Butoxyethanol	(30)	(E)-3-Hexenoic acid	(30)
7-Octen-4-ol	(30)	tert-Butyl propanoate	(30)
6-Methyl-5-hepten-2-ol	(15)	Methyl methoxyacetate	(30)
Phenylmethanol	(30)	Hexyl formate	(30)
2-Ethyl-1-hexanol	(15)	(Z)-3-Hexenyl acetate	(30)
2-Phenylethanol	(30)	2-Ethylfura	(30)
Nonanol	(15)	5-Ethyl-2(5H)-furanone	(30)
1-Decanol	(15)	Pyridine	(30)
Total alcohols	(30)	1-Dodecanol	(15)
1-penten-3-ol	(15)	(Z)-Nerolidol	(15)

Table-3. Continue

1-octen-3-ol	(15)	Carbitol	(15)
2-octanol	(15)	Nerol	(15)
Hexanol	(15)	Geraniol	(15)
Octanol	(15)	(E)-nerolidol	(15)
Undecanol	(15)	Undecane	(15)
tetradecanol	(15)	6-methyl-5-hepten-2-one	(15)
Tetradecanal	(15)	4-hexanolide	(15)
(Z)-3-hexenal	(15)	Benzyl alcohol	(15)
(Z)-2-hexenoic acid	(15)	2-phenylethyl alcohol	(15)
Hexanoic acid	(15)	Caryophyllene oxide	(15)
Octanoic acid	(15)	4-decanolide	(15)
Decanoic acid	(15)	Eugenol	(15)
Undecanoic acid	(15)	Chavicol	(15)
Dodecanoic acid	(15)	4-vinylphenol	(15)
Ethyl acetate	(15)	indole	(15)
Methyl butanoate	(15)	vanillin	(15)
Methyl	(15)	Methyl dodecanoate	(15)
2- Methyl butanoate	(15)	Methyl hexadecanoate	(15)
Methyl hexanoate	(15)	Methyl benzoate	(15)
Methyl	(15)	Methyl cinnamte	(15)
Methyl octanoate	(15)	β -caryophyllene	(15)
Methyl decanoate	(15)	α-humulene	(15)
β -bisabolene	(15)	y-elemene	(15)

REFERENCES

Gernot Katzer's spice pages on http://www.uni-graz.at/~katzer/engl/index.html.

Coriander seed (1999) Database of Volatile Compounds in Food, TNO Nutrition and Food Research, Boelens Aroma Chemical Information Service, The Netherlands (CD-ROM). BACIS.

Aly AA (2010) ".Biosynthesis of phenolic compounds and water soluble vitamins in cilantro (Eryngium foetidum L.) plantlets as affected by low doses of gamma irradiation". Fascicula Biologie Vol. 2, pp.356-361.

Anitescu G, Doneanu C & Radulescu V (1997) "Isolation of Coriander Oil: Comparison Between Steam Distillation and Supercritical CO2 Extraction". Flavour and Fragrance Journal Vol. 12, No.3, pp.173-176.

Bandoni AL, Mizrahi I & Juárez MA (1998) "Composition and Quality of the Essential Oil of Coriander (Coriandrum sativum L.) from Argentina". Journal of Essential Oil Research Vol. 10, No.5, 581-584.

Banout JAN, Havlik J, Kulik M et al. (2010) "Effect of Solar Drying on the Composition of Essential oil of Sacha Culantro (Eryngium Foetidum L.) Grown in The Peruvian Amazon". Journal of Food Process Engineering Vol. 33, No.1, pp.83-103.

Bauer K, Garbe D & Surburg H (1997) "Coriander oil, Common Fragrance and Flavor Materials: Preparation, Properties and Uses". Weinheim: Wiley-VCH Verlag GmbH.

Benitez DE, Cadwallader KR & Suriyaphan O (2001) Aroma-active components of Vietnamese Coriander (Polygonum odoratum). In IFT Annual Meeting. Louisiana, New Orlands.

Burdock GA & Carabin IG (2009) "Safety assessment of coriander (Coriandrum sativum L.) essential oil as a food ingredient". Food and Chemical Toxicology Vol. 47, No.1, pp.22-34.

Cadwallader Keith R, Benitez D, Pojjanapimol S et al. (2005) "Characteristic Aroma Components of the Cilantro Mimics". In Natural Flavors and Fragrances, pp. 117-128: American Chemical Society.

Cardozo E, Rubio M, Rojas LB et al. (2004) "Composition of the Essential Oil from the Leaves of Eryngium foetidum L. from the Venezuelan Andes". Journal of Essential Oil Research Vol. 16, No.1, pp.33-34.

Carrubba A, la Torre R, Prima AD et al. (2002) "Statistical Analyses on the Essential Oil of Italian Coriander (Coriandrum sativum L.) Fruits of Different Ages and Origins". Journal of Essential Oil Research Vol. 14, No.6, pp.389-396.

Chowdhury JU, Nandi NC & Yusuf M (2007) "Chemical constituents of essential oil of the leaves of Erygium foetidum from Bangladesh". Bangladesh J Sci Ind Res Vol. 42, pp.347-352.

D.L.J O (1973) "Monographs on Fragrance Raw Materials". Food and Cosmetics Toxicology Vol. 11, No.4, pp.855-876.

Dũng NX, Van Hac L & Leclercq PA (1995) "Volatile Constituents of the Aerial Parts of Vietnamese Polygonum odoratum L". Journal of Essential Oil Research Vol. 7, No.3, pp.339-340.

Eikani MH, Golmohammad F & Rowshanzamir S (2007) "Subcritical water extraction of essential oils from coriander seeds (Coriandrum sativum L.)". Journal of Food Engineering Vol. 80, No.2, pp.735-740.

Elgayyar M, Draughon FA, Golden DA et al. (2001) "Antimicrobial activity of essential oils from plants against selected pathogenic and saprophytic microorganisms". Jornal of Food Protection Vol. 64, No.7, pp.1019-1024.

Emamghoreishi M, Khasaki M & Azam MF (2005) "Coriandrum sativum: Evaluation of its anxiolytic effect in the elevated plusmaze". Journal of Ethnopharmacology Vol. 96, pp.365-370.

Eyres G, Dufour J-P, Hallifax G et al. (2006) "Identification of character impact odorants in coriander and wild coriander leaves using GC-olfactometry and GC x GC-TOFMS". In Developments in Food Science, pp. 197-200 [LPB Wender and P Mikael Agerlin, editors]: Elsevier.

Floreno A (1997) "Russian essential oil market may see good times ahead". Chemical Marketing Reporter Vol. 18, pp.252.

García MD, Sáenz MT, Gómez MA et al. (1999) "Topical antiinflammatory activity of phytosterols isolated from Eryngium foetidum on chronic and acute inflammation models". Phytotherapy Research Vol. 13, No.1, pp.78-80.

Gil A, de la Fuente EB, Lenardis AE et al. (2002) "Coriander Essential Oil Composition from Two Genotypes Grown in Different Environmental Conditions". Journal of Agricultural and Food Chemistry Vol. 50, No.10, pp.2870-2877.

Grieve M (1971) "Coriander. A Modern Herbal: The Medicinal, Culinary, Cosmetic and Economic Properties, Cultivation and Folk-Lore". New York: Dover Publications.

Grosso C, Ferraro V, Figueiredo AC et al. (2008) "Supercritical carbon dioxide extraction of volatile oil from Italian coriander seeds". Food Chemistry Vol. 111, No.1, pp.197-203.

Gupta MP (1995) "270 Plantas Medicinales Iberoamericanas". Colombia: Santaf´e de Bogot´.

Hill J & Raner GM (2004) Inhibition of human cytochrome P450 2E1 by eryngial and related alkanals and (2E)-alkenals. In 56th Southeast Regional Meeting. USA.

Hirvi T, Salovaara I, Oksanen H et al. (1985) Progress in Essential Oil Research
Proceedings of the International Symposium on Essential Oils, pp.111-116.

Hunter M (1996) "Australian kesom oil- a new essential oil for the flavour and fragrance industry". Agro-Food-Industry Hi-Tech Vol. 7, pp.26-28.

Ishikawa T, Kondo K & Kitajima J (2003) "Water-Soluble Constituents of Coriander". Chemical & Pharmaceutical Bulletin Vol. 51, No.1 pp.32-39.

Jiang J (2005) "Volatile composition of the laksa plant (Polygonum hydropiper L.), a potential source of green note aroma compounds". Flavour and Fragrance Journal Vol. 20, No.5, pp.455-459.

Kallio H & Kerrola K (1992) "Application of liquid carbon dioxide to the extraction of essential oil of coriander (<i>Coriandrum sativum</i> L.) fruits". Zeitschrift für Lebensmitteluntersuchung und -Forschung A Vol. 195, No.6, pp.545-549.

Lawrence BM (1980b) " Progress in essential oils". Perfumer and Flavorist Vol. 5, pp.55-58.

Lawrence BM (1993) " A planning scheme to evaluate new aromatic plants for the flavor and fragrance industries In New Crops". New York: Wiley.

Lawrence BM (editor) (2002) "From the sensation to the synthesis". Cambridge: Royal Society of Chemistry.

Leclercq PA, Duñg NX, Lô VN et al. (1992) "Composition of the Essential Oil of Eryngium foetidum L. from Vietnam". Journal of Essential Oil Research Vol. 4, No.4, pp.423-424.

Lo VN, An NT, Toanh NV et al. (1991) "Study of essential oil of Eryngium foetidum L". Tap Chi Duoc Vol. 6, pp.19-20.

Martins AP, Salgueiro LR, da Cunha AP et al. (2003) "Essential Oil Composition of Eryngium foetidum from S. Tomé e Príncipe". Journal of Essential Oil Research Vol. 15, No.2, pp.93-95.

Meena M & Sethi V (1994) "Antimicrobial activity of essential oils from spices". Journal of food science and technology Vol. 31, No. 1, pp.68-70.

Michael D (2002) New Pharmaceutical,Nutraceutical & Industrial Products.

Misharina TA (2001) "Effect of conditions and duration of storage on composition of essential oil from coriander seeds ". Prikladnaia Biokhimiia i Mikrobiologiia Vol. 37, pp.726-732.

Morean F (1988) Shado benni: A popular Caribbean seasoning herb and folk medicine. In Trinidad Guardian. Port-of-Spain, Trinidad.

Msaada K, Hosni K, Ben Taarit M et al. (2007) "Variations in the essential oil composition from different parts of Coriandrum sativum L. cultivated in Tunisia ". Italian Journal Biochemistry Vol. 56, pp.47-52.

Msaada K, Hosni K, Taarit MB et al. (2009) "Variations in essential oil composition during maturation of coriander (coriandrum sativum l.)". Journal of Food Biochemistry Vol. 33, No.5, pp.603-612.

Nitz S, Kollmannsberger H & Punkert M (1992) " Supercritical fluid extraction of spices". Chemie, Mikrobiologie, Technologie der Lebensmittel Vol. 14, pp.108-116.

Paul JHA, Seaforth CE & Tikasingh T (2011) "Eryngium foetidum L.: A review". Fitoterapia Vol. 82, No.3, pp.302-308.

Perry LM (1980) "Medicinal plants of East and Southeast Asia". Cambridge MIT Press.

Pino JA, Rosado A & Fuentes V (1997) "Chemical Composition of the Seed Oil of Eryngium foetidum L. from Cuba". Journal of Essential Oil Research Vol. 9, No.1, pp.123-124.

Platel K & Srinivasan K (2004) "Digestive stimulant actions of spices: a myth or reality?". Indian Journal of Medicinal Research Vol. 119, pp.167-179.

Potter TL (1996) "Essential Oil Composition of Cilantro". Journal of Agricultural and Food Chemistry Vol. 44, No.7, pp.1824-1826.

Potter TL & Fagerson IS (1990) "Composition of coriander leaf volatiles". Journal of Agricultural and Food Chemistry Vol. 38, No.11, pp.2054-2056.

Pourmortazavi SM & Hajimirsadeghi SS (2007) "Supercritical fluid extraction in plant essential and volatile oil analysis". Journal of Chromatography A Vol. 1163, No.1–2, pp.2-24.

Quynh CT, Iijima Y, Morimitsu Y et al. (2009) "Aliphatic Aldehyde Reductase Activity Related to The Formation of Volatile Alcohols in Vietnamese Coriander Leaves ". Biosci, Biotechnol, Biochem Vol. 73, pp.641-647.

Ramadan MF & Moersel J-T (2006) "Screening of the antiradical action of vegetable oils". Journal of Food Composition and Analysis Vol. 19, No.8, pp.838-842.

Ramcharan C (editor) (1999) "Culantro: a much utilized, little-understood herb". Alexandria, VA, USA: ASHS Press.

Sáenz MT, Fernández MA & García MD (1997) "Antiinflammatory and analgesic properties from leaves of Eryngium foetidum L. (Apiaceae)". Phytotherapy Research Vol. 11, No.5, pp.380-383.

Salzer UJ & Furia TE (1977) "The analysis of essential oils and extracts (oleoresins) from seasonings - A critical review". C R C Critical Reviews in Food Science and Nutrition Vol. 9, No.4, pp.345-373.

Seaforth CE (1988) Eryngium foetidum—fitweed (Umbelliferae). In Natural products in Caribbean folk Medicine. Trinidad Univ.

Seidmann J (2005) "world spice plant": Springer-Verlag.

Singh G, Maurya S, de Lampasona MP et al. (2006) "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 Vol. 21, No.3, pp.472-479.

Small E (1997) "Coriander. Culinary Herbs". Ottawa: NRC Research Press.

Smallfield B (2003) Coriander–Coriandrum sativum. The New Zealand Institute for Crop and Food Research Limited. .<http://www.crop.cri.nz/psp/broadshe/ coriand.htm/>.

Sriti J, Talou T, Wannes WA et al. (2009) "Essential oil, fatty acid and sterol composition of Tunisian coriander fruit different parts". Journal of the Science of Food and Agriculture Vol. 89, No.10, pp.1659-1664.

Starkenmann C, Luca L, Niclass Y et al. (2006) "Comparison of Volatile Constituents of Persicaria odorata (Lour.) Soják (Polygonum odoratum Lour.) and Persicaria hydropiper L. Spach (Polygonum hydropiper L.)". Journal of Agricultural and Food Chemistry Vol. 54, No.8, pp.3067-3071.

Steward AR (1930) "The Polygoneae of eastern Asia". Contr. Gray Herb Vol. 88, pp.129.

Surburg H & Panten J (2006) "Common Fragrance and Flavor Materials": WILEY-VCH Verlag GmbH.

Takeoka G, Ebeler S & Jennings W (1985) "Capillary Gas Chromatographic Analysis of Volatile Flavor Compounds". In Characterization and Measurement of Flavor Compounds, pp. 95-108: American Chemical Society.

Visai C & Vanoli M (1997) "Volatile compound production during growth and ripening of peaches and nectarines". Scientia Horticulturae Vol. 70, No.1, pp.15-24.

Willis JC (1960) "A dictionary of the flowering plants and ferns". Cambridge: Cambridge Univ Press.

Wong KC, Feng MC, Sam TW et al. (1994) "Composition of the Leaf and Root Oils of Eryngium foetidum L". Journal of Essential Oil Research Vol. 6, No.4, pp.369-374.