Flavour characterisation and free radical scavenging activity of coriander (*Coriandrum sativum* L.) foliage

Siddharth Priyadarshi^{1,2} · Hafeeza Khanum² · Ramasamy Ravi³ · Babasaheb Baskarrao Borse² · Madeneni Madhava Naidu²

Revised: 28 September 2015 / Accepted: 22 October 2015 / Published online: 6 November 2015
© Association of Food Scientists & Technologists (India) 2015

Abstract The primary objective was to characterize Indian *Coriandrum sativum* L. foliage (*Vulgare alef* and *Microcarpum DC* varieties) and its radical scavenging activity. Foliage of *Vulgare alef* and *Microcarpum DC* contained ascorbic acid (1.16 ± 0.35 and 1.22 ± 0.54 mg/g), total carotenoids (1.49 ± 0.38 and 3.08 ± 1.2 mg/g), chlorophyll ‘a’ (8.23 ± 2.4 and 12.18 ± 2.9 mg/g), chlorophyll ‘b’ (2.74 ± 0.8 and 4.39 ± 1.3 mg/g) and total chlorophyll (10.97 ± 2.6 and 16.57 ± 3.2 mg/g). The polyphenol content was 26.75 ± 1.85 and 30.00 ± 2.64 mg/g in *Vulgare alef* and *Microcarpum DC*, respectively. Ethanol extracts (200 ppm) of *alef* and *Microcarpum DC* showed higher radical scavenging activity of 42.05 ± 2.42 % and 62.79 ± 1.36 % when compared with 95 % butylated hydroxyanisole. The principal component analysis results indicated that e-nose can distinguish the volatiles effectively. Quantitative descriptive sensory analysis showed that *Microcarpum DC* variety is superior to *Vulgare alef* variety. Nearly 90 % of the flavour compounds present were identified by GC-MS in both varieties. The principal component identified in both the varieties were decanal (7.645 and 7.74 %), decanol < n- > (25.12 and 39.35 %), undecanal (1.20 and 1.75 %), dodecanal (7.07 and 2.61 %), tridecen-1-al < 2E > (6.67 and 1.21 %), dodecen-1-ol < 2E- > (16.68 and 8.05 %), 13-tetradecenal (9.53 and

8.60 %), tetradecanal (5.61 and 4.35 %) and 1-octadecanol (1.25 and 3.67 %).

Keywords Coriander foliage · *Microcarpum DC* and *Vulgare alef* varieties · Volatile flavour compounds · Radical scavenging activity · E-Nose · Descriptive sensory analysis

Introduction

Coriandrum sativum L. the spice belongs to the family *Apiaceae*. It was originated in the Mediterranean region and commercially grown in the tropical areas of Ukraine, Russia, Romania, Morocco, Mexico, India, and Argentina. India, being the largest coriander growing country in the world (Priyadarshi and Borse 2014). Coriander is a small herb and contains several branches and sub-branches. The recently produced leaves are oval, but aerial leaves are elongated. The fresh leaves and dried seeds are used in cooking although all parts of the plant are edible. The mature leaves and fruits have a pleasant and fresh flavour (Sharma and Sharma 1999). The genus *Coriandrum sativum* L. has two species and exists in two categories (Rajeshwari and Andallu 2011) at commercial level; large fruited *C. sativum* L. var. *vulgare alef* (locally called as *Farm*) and small-fruited *C. sativum* L. var. *microcarpum DC* (locally called as *Nati*). The major compounds present in coriander are Aliphatic - hydrocarbons, aldehydes and alcohols; Monoterpene - oxides, hydrocarbons, esters and alcohols; Carbonyls, Phenols, Sesquiterpenes and a few miscellaneous compounds like acetic acid and α -pdimethyl styrene (Parthasarathy et al. 2008). The content and composition of essential oil varies with various climatic conditions. The different phytonutrients present in coriander provide various health benefits including aflatoxin protective, antibacterial, antimutagenic, antispasmodic, carminative,

✉ Madeneni Madhava Naidu
mmnaidu@cftri.res.in

¹ Academy of Scientific and Innovative Research (AcSIR), New Delhi, India

² Department of Spice & Flavour Science, CSIR-CFTRI, Mysore, Karnataka 570020, India

³ Department of Traditional Food & Sensory Science, CSIR-CFTRI, Mysore, Karnataka, India

cytotoxic, fungicidal, hypoglycemic, hypolipidemic, insecticidal, lipolytic, stimulant, and stomachic (Rajeshwari and Andallu 2011). The coriander oil acts as a crucial ingredient in curry mixes and as ground or volatile isolate used in flavouring beverages, bakery products, sweets and tobacco goods.

Several studies have been done on the composition of coriander essential oil. Singh et al. (2006) reported that coriander seed oil contains more than 52 compounds out of which α -pinene (4.09 %), geranyl acetate (8.12 %) and linalool (75.30 %) are the major ones. The 20 compounds identified in the essential oil of coriander seed by Bandoni et al. (1998) covered 96.6–99.7 % of total oil content. The major compounds identified included α -pinene, camphor, geraniol, geranyl acetate, linalool and γ -terpinene.

The free radicals after oxidation by metabolic process cause significant damage to cells. The antioxidants prevent the damage and thus help to maintain healthy condition of the cells. The secondary metabolites like polyphenols present in spices prove advantageous physiologically by their antioxidant action (Martinez et al. 2000). These polyphenols exhibit various health-promoting activities such as antioxidant, antihepatotoxic, antimicrobial, anti-inflammatory and antitumor. Several experiments have been carried out to ascertain the antioxidant potential of coriander. Melo (2002) demonstrated that 2.7 mg of total phenolics present in the aqueous extract of coriander showed substantial antioxidant activity. Shalini and Mohanty (2013) showed that the aqueous extract of selected coriander leaves acts as a natural reducing agent with antioxidant activity. Thus, coriander can serve as a natural source of food preservative and protect human health.

Although, several studies were reported on the medicinal properties of coriander seeds, very limited ones are available on the physicochemical characteristics and antioxidant potential with respect to *Vulgare alef* (V.A.) and *Microcarpum DC* (M.DC) particularly about the foliage. Hence, the primary objective of this study was to characterize *Vulgare alef* and *Microcarpum DC* varieties of coriander foliage with respect to various physicochemical parameters and assess their antioxidant potential.

Materials and methods

Plant material

The two varieties (V.A. and M.DC) of the fresh coriander foliage (*Coriandrum sativum* L.) were procured from the local market (Mysore, Karnataka, India). The green foliage was handpicked, roots were separated by cutting and plants were cleaned with fresh tap water. The cleaned leaves were placed in airtight polyethylene bags and stored at 4 °C for further experiments.

Chemicals and reagents

All chemicals and solvents used for analysis were of analytical grade and procured from Merck, Mumbai, India. N-alkane standards (C6–C27) were procured from Sigma (St. Louis, MO, USA).

Moisture

The moisture content of V.A. and M.DC varieties was determined in the fresh coriander foliage (5 g) by toluene co-distillation method using Dean and Stark apparatus as described by Ranganna (2001). The distillation was carried out for 4 h.

Colour measurement

The varietal colour difference was measured by the method described by Smith and Guild (1931). The surface colour was measured following the CIE colour components (L^* , a^* and b^*), by Hunter Colorimeter (Hunter Associates Laboratory, Labscan, XE, USA), where " L^* " represents the lightness index, " a^* " represents red-green, while " b^* " represents yellow-blue colour components. The instrument was calibrated using a standard white ($L^* = 90.70$, $a^* = 1.08$, $b^* = 0.65$) and blank reference tile under illuminated conditions such as illuminate D65 and view angle 10°. Chroma indicates the purity of the colour or hue as measured along an axis. Hue angle visualizes how an average person sees the colour. Hue angles 0, 90, 180, and 270 indicate red, yellow, green, and blue colours, respectively.

Chlorophyll content

The chlorophyll content was estimated spectrophotometrically by the method of Sadasivan and Manicham (1991). Coriander foliages (1 g), both V.A. and M.DC varieties were macerated separately with the addition of 20 ml of 80 % acetone to a fine pulp in a mortar and pestle. The paste was centrifuged for 5 min at 5000 rpm. The supernatant was decanted, and the left residue was then ground with 20 ml of 80 % acetone, centrifuged for 5 min at 5000 rpm, and the supernatant was again decanted. The extraction was repeated 4–5 times until the residue was colourless. The extracts were collected in a beaker, filtered and made up to 100 ml with 80 % acetone in a volumetric flask. This was repeated for both V.A. and M.DC varieties of coriander foliage separately. The absorbances of the extracted solutions were recorded (Shimadzu UV-1800, Kyoto, Japan) at 645 nm and 663 nm against the solvent (80 % acetone) blank. The amount of chlorophyll present in extract i.e. mg of chlorophyll per gram of tissue on dry weight basis was calculated using the following equations,

- (a). Chlorophyll 'a' (mg/g of tissue) = $[12.7 \times X - 2.69 \times Y] \times \frac{V}{(1000 \times W)}$
- (b). Chlorophyll 'b' (mg/g of tissue) = $[22.9 \times Y - 4.68 \times X] \times \frac{V}{(1000 \times W)}$
- (c). 'Total chlorophyll' (mg/g of tissue) = $[20.2 \times Y + 8.02 \times X] \times \frac{V}{(1000 \times W)}$

Where, X = absorbance at 663 nm

Y = absorbance at 645 nm

W = weight of fresh tissue extracted (1 g)

V = final volume of extract in 80 % acetone (100 ml)

Extraction of volatile flavour compounds (VFCs)

The fresh coriander foliage (V.A. and M.DC varieties) samples were coarsely ground separately to 1–2 mm dia using a domestic mixer grinder (400 g each) and homogenized with distilled water (1500 ml). The slurry was subjected to Clevenger hydro distillation for volatile extraction using the apparatus modified according to Schilcher (1964). Distillation was carried out for 4–5 h to get maximum quantity of oil. The volatile oil yield was determined on a dry weight basis. The oil samples collected were dried over anhydrous sodium sulphate and stored at 4 °C for further analysis.

Extraction of total carotenoids

Fresh coriander foliages of V.A. and M.DC were used for the extraction of carotenoids. Carotenoids were extracted according to the procedure of Raju et al. (2007). In brief the coriander foliage (2 g) samples were ground along with 2 mM α -tocopherol and 2 g of anhydrous sodium sulphate and pigments were extracted using ice-cold acetone. The extraction was repeated until the residue became colourless. The solvent was removed at 40 °C under reduced pressure (40 m bar) in a rotavapor. The concentrated extract samples were then dissolved in methanol (50 ml) and diluted suitably, and absorbance was recorded at 450 nm. The carotenoid concentration on dry weight basis was estimated as,

Carotenoids(mg/100g)

$$= \frac{\text{O.D. of sample at 450 nm}}{\text{Extinction co-efficient of solvent in sample}} \times \text{Dilution factor}$$

Estimation of ascorbic acid (Vitamin C)

Ascorbic acid was determined using 2, 6-dichlorophenol- indophenol visual titration method (Ranganna 2001).

Standardization of dye Standard ascorbic acid (100 mg of L-ascorbic acid made up to 100 ml with 3 % H_3PO_4 ; 10 ml diluted to 100 ml with 3 % H_3PO_4 , (5 ml), was transferred to Erlenmeyer flasks containing 5 ml of metaphosphoric acid (3 %). A micro burette was filled with the dye. Ascorbic acid solution was titrated against the standard indophenol solution. Appearance of rose pink colour is the end point, which persisted for 15 s. The dye factor was estimated as mg of ascorbic acid per ml of the dye, by the formula:

Dye factor = 0.5/titre value

Preparation of sample Fresh coriander foliage (2 g) was ground with aqueous metaphosphoric acid (3 %) in a pestle and mortar. The solution was filtered and made up to 50 ml with 3 % H_3PO_4 . A 10 ml of aliquot was taken and titrated against the standard dye to an end point of pink colour, which persisted for 15 s. Ascorbic acid content on dry weight basis was calculated as,

Ascorbic acid(mg per 100 g)

$$= \frac{A \times B \times V \times 100}{W \times \text{Aliquot of the extract taken}}$$

Where, A = volume (ml) of standard dye used for titration

B = weight (mg) of ascorbic acid equivalent to 1 mL of the indophenol solution, i.e. dye factor

V = volume made up

W = weight (g) of sample

Foliage extract

The fresh coriander herb of both varieties (25 g) were ground and packed into the column and solvents (acetone, ethanol and ethyl acetate) were allowed to stand for 2 h and eluted with material solvent ratio of 1:20. Desolventization was done in a rotary evaporator (Heidolph, Germany) at 50 °C and the extract obtained was stored in refrigerator until use.

Determination of total polyphenols

The samples were analyzed for total polyphenol content by using Folin-Ciocalteu method as described by Singleton and Rossi (1965). A known volume of the coriander extract (10 mg) prepared in different solvents (acetone, ethanol and ethyl acetate) was dissolved separately in 10 ml of respective solvents. A 0.1 ml aliquot of the resulting respective solution was added to Folin-Ciocalteu reagent (0.5 ml), and 20 % saturated solution of Na_2CO_3 (1.5 ml) was also added. This was made up to 10 ml with distilled water and incubated at 27 °C for 2 h. The optical density of the resulting solution was measured at 765 nm using spectrophotometer. The

concentration was calculated using gallic acid as a standard, and the results are expressed on dry weight basis as gallic acid equivalents/100 g extract.

Determination of free radical scavenging activity by DPPH

Free radical scavenging activity of coriander extract prepared in acetone, ethanol and ethyl acetate was measured by 1, 1-diphenyl-2-picrylhydrazil (DPPH) method as described by Oktay et al. (2003). Extracts with 50, 100, and 200 ppm concentrations were taken in different test tubes. The volume was made up to 1 ml by adding respective solvents. Then 4 ml of a 0.1 mM methanol solution of DPPH were added to each test tube and well shaken. The tubes were subsequently incubated in dark at room temperature for 20 min. A control sample was prepared as above without extract, and methanol was used for the baseline correction. The variation in absorbance of the samples was measured at 517 nm. Butylated hydroxyanisole (BHA) (95 %) was used as a standard antioxidant. All analyses were done in triplicate, and the mean values were taken. The free radical scavenging activity on dry weight basis was expressed as percent inhibition and was calculated using the formula,

Radical scavenging activity(%)

$$= \frac{\text{Control OD} - \text{Sample OD}}{\text{Control OD}} \times 100$$

GC-MS analysis

Prior to GC–mass spectroscopy (MS) analysis, the preliminary gas chromatography (GC) analysis of the volatile oil samples was done with SPB-1 column to standardize the resolution parameters helpful for GC-MS analysis. Consequently, the volatile oil samples were analyzed using GC (GC-17A, Shimadzu, Singapore). The GC-MS analysis of essential oil samples was carried out using a Perkin-Elmer Turbomass Gold GC (Massachusetts, USA) equipped with a quadrupole mass spectrometer with the help of SPB-1 fused silica column (30 m, 0.32 mm id., film thickness 0.25 mm) coated with polydimethylsiloxane. Helium gas was used as the carrier with a flow rate 1 ml/min. Quadrupole mass spectroscopy scanning was performed over 40–400 m/z range. The oven temperature was programmed at 50 °C for 1 min and increased to 250 °C at 4 °C/min and then held for 10 min at the final temperature. The injection temperature was 250 °C, the ionization voltage was 70 eV, and the ion source temperature was 250 °C. The volatile oil (100 µl) sample was diluted tenfold with acetone, and 1 µl was injected under 1:20 split ratio mode. Standard n-alkanes ranging from n-hexane (C6) to n-heptacosane (C27) were analyzed under the above conditions. Retention indices

were calculated for each compound against n-alkane standard (C6–C27) using the equation according to the Kovats method as explained by Jennings and Shibamoto (1980).

The volatile oil constituents were identified by the fragmentation pattern and computer matching of the mass spectral fragmentation pattern of compounds (NIST 1998) and compared with the published mass spectra (Stenhagen et al. 1974; Adams 1989).

E-Nose analysis

An electronic nose (Alpha Fox 4000, Alpha MOS, Toulouse, France) with metal oxide semiconducting sensors was used. The conditions were as follows: acquisition time (sec): 120; acquisition period (sec): 0.5; delay (sec): 100; start injection (sec): 0; injection time (sec): 60; headspace generation time (sec): 120; and zero air flow: 150 ml/min. One g of sample was taken in each sample vial provided by the manufacturer. Headspace volatiles generated by the sample vials for 20 min were carried through zero air to the sensor array. The changes in resistance of the sensors in the presence of the volatile compounds were recorded, and the response depended on the nature of volatile molecule and type of sensors used. Many factors can influence the results including the reaction kinetics, the headspace, volume of measured headspace, and the flow rate of the carrier gas. Data analysis was done based on the values of maximum change in resistance (ΔR)/ R_0 of the sensors by subjecting to multivariate analysis, i.e., principal component analysis (PCA) using the inbuilt software supplied by the manufacturer. The results are shown in the 2D representation of PCA with respect to first two axes (PC1 and PC2).

Descriptive sensory analysis

Sensory analysis of fresh coriander samples was carried out by using quantitative descriptive analysis as per the standard method developed by Stone et al. (1974). Training of panellist was conducted in two sessions using a 15 cm unstructured linear line scale anchored as “Low” (1.25 cm) and “High”(13.75 cm), representing the detection threshold and saturation threshold, respectively. Samples were served in a stoppered conical flask coded with three-digit random numbers. The order, of serving the samples was randomized so that bias due to “order or sequence of sample presentation” was minimized. The panellists were asked to mark the perceived intensity of each attribute listed on the score card by drawing the vertical line on the line scale and writing the code number. The scores for each attribute for the given sample were tabulated, representing the individual judgment of panellists. At the end of the evaluation, scorecards were decoded, and mean values were taken for each attribute, represented graphically either as sunburst graph or in spider web forms.

Statistical analysis

The extraction and other properties were performed in triplicates and expressed as mean $\pm$ SD. The significant of differences between treatment means were calculated by DMRT (Duncans New Multiple Range Test) (SYSTAT, San Jose, CA 95110, USA, version 5.0) at $p \leq 0.05$.

Results and discussion

Moisture content and volatile oil yield

The moisture content of fresh V.A. coriander foliage was about 86 %, whereas that of fresh M.DC variety was 90 %. These results are comparable with earlier reports, where the moisture content of leaves was reported as 87.9 % (Diederichsen 1996). The volatile oil samples extracted from fresh V.A. and M.DC foliage which was estimated by cleveger hydro distillation method are presented in Table 1. The fresh V.A. and M.DC varieties gave 0.025 % and 0.1 % essential oil, respectively, and the volatile oil content is higher in M.DC variety. This is corroborating with the report of Rao et al. (2004), where the essential oil yield content ranged from 0.04 to 0.12 ml per 100 g of coriander foliage.

Ascorbic acid, chlorophyll content and carotenoids

The ascorbic acid, carotenoid and chlorophyll contents in V.A. and M.DC varieties are presented in Table 1.

It can be observed that fresh V.A. variety contains 1.16 ± 0.35 (mg/g) of ascorbic acid, which is comparatively lower than M.DC variety (1.22 ± 0.54 mg/g), which means a reduction of 4.9 % of ascorbic acid content in the former. Our results are in agreement with Khanum et al. (2013), where they reported ascorbic acid content of fresh coriander leaves as 1.10 mg/g.

Table 1 Physico-chemical characteristics of V.A. and M.DC varieties of coriander

Parameters	Coriander varieties	
	V.A.	M.DC
Moisture (%)	$86.00^a \pm 0.2$	$90.00^b \pm 0.3$
Oil yield (%)	$0.025^a \pm 0.01$	$0.1^b \pm 0.001$
Ascorbic acid (mg/g)	$1.16^a \pm 0.35$	$1.22^b \pm 0.54$
Carotenoids (mg/g)	$1.49^a \pm 0.38$	$3.08^b \pm 1.2$
Chlorophyll a (mg/g)	$8.23^a \pm 2.4$	$12.18^b \pm 2.9$
Chlorophyll b (mg/g)	$2.74^a \pm 0.9$	$4.39^b \pm 1.3$
Total chlorophyll (mg/g)	$10.97^a \pm 2.6$	$16.57^b \pm 3.2$

(*Coriandrum sativum* L.) foliage

Means $\pm$ SD in the same row with different superscripts differ significantly at $p < 0.05$ by DMRT

The chlorophyll content of fresh coriander leaf samples was estimated by spectrophotometric method. The chlorophyll a, b and total chlorophyll contents are presented in Table 1. The results indicate that chlorophyll a, b and total chlorophyll contents in M.DC variety are higher as compared to V.A. variety. The M.DC variety contained 12.18 ± 2.9 mg/g of chlorophyll a, 4.39 ± 1.3 mg/g of chlorophyll b and 16.57 ± 3.2 mg/g of total chlorophyll whereas V.A. variety contained 8.23 ± 2.4 mg/g of chlorophyll a, 2.74 ± 0.8 mg/g of chlorophyll b and 10.97 ± 2.6 mg/g of total chlorophyll.

The total carotenoid in M.DC variety is 3.08 ± 1.2 mg/g which is significantly higher than V.A. variety (1.49 ± 0.38 mg/g). The carotenoid content in fresh variety is comparable with the values obtained by Peethambaran et al. (2012); where they reported that fresh coriander leaves contained 2.175 ± 0.0557 mg/g of total carotenoid.

Colour measurement

The V.A. variety showed more intense surface green colour as compared to M.DC variety. Lightness (L^* value), greenness ($-a$ value) and yellowness ($+b$ value) of fresh V.A. coriander foliage are 49.44 ± 1.4 , -6.48 ± 0.3 and 24.98 ± 0.8 and for M.DC variety the corresponding values are 37.52 ± 1.1 , -5.63 ± 0.3 and 24.57 ± 0.9 (Table 2). The results are in agreement with Khanum et al. (2013) where the values for the colour components reported were $L = 35.9 \pm 0.02$, $a = -10.6 \pm 0.02$ and $b = 22.4 \pm 0.007$.

Total polyphenolic content

The total polyphenolic content of the ethanol, ethyl acetate and acetone extracts of the fresh coriander foliage of both V.A. and M.DC varieties were measured using Folin's reagent.

The results are presented in Fig. 1, from which it is clear that the ethanol extract of both the varieties are rich in total

Table 2 CIE colour components of V.A. and M.DC coriander varieties

CIE colour components	Coriander varieties	
	V.A.	M.DC
L^*	$49.44^b \pm 1.75$	$37.52^a \pm 3.89$
a^*	$-6.48^b \pm 0.11$	$-5.63^a \pm 0.49$
b^*	$24.98^a \pm 0.34$	$24.57^a \pm 1.43$
dE^{*ab}	$54.79^a \pm 1.42$	$65.22^b \pm 3.00$
Chroma	$25.80^a \pm 0.36$	$25.20^a \pm 1.50$
Hue angle	$75.45^a \pm 0.12$	$77.09^b \pm 0.37$

Mean $\pm$ SD in the same row with different superscripts differ significantly at $p < 0.05$ by DMRT

Fig. 1 Essential oil yield, total polyphenol content and DPPH scavenging activity of ethanol, ethyl acetate and acetone extracts of V.A. and M.DC varieties of coriander

polyphenols as compared to ethyl acetate or acetone extracts. The ethanol extract of V.A. contained 26.75 ± 1.85 mg/g, while ethyl acetate and acetone extracts contained 23.75 ± 1.62 and 20.87 ± 1.68 mg/g of total polyphenol, respectively. The ethanol extract of M.DC has 30.00 ± 2.64 mg/g polyphenolic content, while ethyl acetate and acetone extracts contain 28.50 ± 2.65 and 22.37 ± 1.43 mg/g, respectively. Shahwar et al. (2012) showed that the total phenolic content of methanol extract of coriander contains 30.25 ± 3.42 mg/g.

Radical scavenging activity

The non-volatiles from both varieties of coriander foliage were extracted using ethanol, ethyl acetate and acetone as solvents. Different concentrations (50, 100 and 200 ppm) of extracts were made by dissolving the dry extracts in these solvents. Figure 1 shows the radical scavenging activities of ethanol, ethyl acetate and acetone extracts of V.A. and M.DC varieties at various concentrations. It can be observed that the radical scavenging activity increased with increasing concentration of extracts and reached maximum at 200 ppm. Ethanol extracts of both V.A. and M.DC varieties showed higher radical scavenging activity at 200 ppm, while ethyl acetate and acetone extracts showed lower radical scavenging activity, as evident from Fig. 1.

The autoxidation of unsaturated lipids in food is caused by free radicals (El-Ghorab et al. 2006). Kahkonen et al. (1999) showed a direct correlation between total phenolic content and antioxidant activity indicating that samples that are higher in total phenolic content will have higher antioxidant activity. Our results have also revealed that the ethanol extract of M.DC has high total phenolic content and also high antioxidant activity at 200 ppm.

Identification of volatile constituents

The chemical constituents in the volatile oil samples were identified by GC-MS analysis, fragmentation pattern as well as by computing the Kovats indices and comparison of the mass spectra with the NIST (1998). The calculated values of Kovats indices and relative peak area percentages are presented in Table 3.

The essential oil from fresh V.A. foliage according to GC-MS analysis showed 48 compounds out of which 12 were the

Table 3 Major volatile constituents of V.A. and M.DC varieties of coriander (*Coriandrum sativum* L.) foliage

Compounds identified	RT (min)	Kovats index	Relative conc. (%)	
			V.A.	M.DC
Decanal	13.998	1176	7.645	7.744
Decenal < 4E->	15.798	1228	nil	3.714
Decanol < n->	16.619	1253	25.122	nil
Decanol < 3->	16.724	1256	nil	39.349
Undecanal	17.354	1273	1.204	2.613
Undecenal	19.105	1327	nil	1.746
E-2-Tetradecen-1-ol	19.58	1341	0.469	8.602
Dodecanal	20.535	1371	7.068	3.667
2-Dodecenal	22.301	1426	nil	3.678
Tridecen-1-al < 2E->	22.396	1429	6.669	nil
Dodecen-1-ol < 2E->	22.831	1444	16.677	8.048
1,9-Nonanediol	22.901	1446	1.251	nil
7- Tetradecenal	28.183	1623	nil	4.350
13-Tetradecenal	28.318	1628	9.528	0.063
Tetradecanal	28.388	1631	5.609	1.534
Tridecanal	28.418	1632	0.144	1.208
1-Octadecanol	30.844	1719	1.252	nil
Total			82.638	86.316

Fig. 2 PCA plot of electronic nose profile of fresh coriander leaf samples

major compounds whereas 49 compounds were identified in M.DC variety of which 13 were major ones. In both varieties, a total of 73 volatile components were identified, of which 17 were major ones which formed 90 % of the total volatile compounds.

The major compounds identified in V.A. variety are decanal (7.645 %), decanol < n- > (25.122 %), undecanal (1.204 %), dodecanal (7.068 %), tridecen-1-al < 2E > (6.669 %), dodecen-1-ol < 2E- > (16.677 %), 1,9-nonanediol (1.251 %), 13-tetradecenal (9.528 %), tetradecanal

(5.609 %), 1-octadecanol (1.252 %); whereas the major volatiles in M.DC variety were decanal (7.744 %), decanal < 4E- > (3.714 %), decanol < 3- > (39.349), undecanal (2.613 %), undecenal (1.746 %), E-2-tetradecen-1-ol (8.602 %), dodecanal (3.667 %), 2-dodecenal (3.678 %), dodecen-1-ol < 2E- > (8.048 %), 7-tetradecenal (4.350 %), tetradecanal (1.534 %), tridecanal (1.208 %). Our results are similar to Rao et al. (2004) who identified following major compounds in leaf sample: decanol, (E)-2-decen-1-ol, decanal, (E)-2-undecen-1-ol, (E)-2-dodecenol and (E)-2-

Fig. 3 Sensory profilogram of fresh coriander leaf samples: Quantitative descriptive analysis (QDA)

tetradecenal. However the concentration of the volatiles can vary depending upon the variety as well as geographical location, and seasonal conditions.

E-Nose analysis

PCA plots of V.A. and M.DC coriander samples were fingerprinted using an electronic nose and data were analysed using PCA, and the results are depicted in Fig. 2. The PCA results indicated that 93 % of the variance could be explained by PC1 axis followed by 3.0 % by PC2 indicating the segregation is complete and the e-nose can distinguish the volatiles successfully. The clusters formed for each variety is unique and can be used for authentication of varieties (Ramasamy et al. 2007).

Descriptive sensory analysis

Descriptive sensory profiles of coriander are depicted in Fig. 3. From the figure, it is clear that the major descriptors like floral, herbal, spicy, earthy fresh, pleasant, lingering coriander were the key flavour descriptors that can distinguish the coriander profile between V.A. and M.DC varieties. It is clear that there is no significant difference between the varieties normally, but it is the volatile quality at ppm levels that determines the slight variations. Flavour release is a critical factor for the specific aroma which again depends on the temperature conditions also (Prakash et al. 2007).

Conclusions

Coriander varieties VA and M.DC were analysed for their physicochemical and sensory properties. Among the parameters studied, variety M.DC was found to have higher essential oil, ascorbic acid, carotenoids and chlorophyll contents. The polyphenol content ranged from 26.75 to 30.00 mg/g in the varieties. Ethanol extracts of both varieties showed higher radical scavenging activity when compared with corresponding values of 95 % of BHA. Nearly 90 % of the flavour compounds were identified by GC-MS in both varieties. The principal component analysis indicated that e-nose can distinguish the volatiles effectively, and descriptive sensory analysis revealed the important key sensory descriptors of V.A. and M.DC varieties.

Acknowledgments The authors acknowledge Director CSIR-CFTRI, Mysore for the facilities provided and a keen interest in our research work and Academy of Scientific and Innovative Research (AcSIR), New Delhi, India. This work was carried under the funding provided by project no. BSC-0105. First author Siddharth Priyadarshi would like to thank University Grants Commission (UGC), New Delhi, India for awarding Rajiv Gandhi National Fellowship (RGNF) 2012-13.

References

- Adams RP (1989) Identification of essential oils by ion trap mass spectroscopy. Academic Press, New York
- Bandoni AL, Mizrahi I, Juarez MA (1998) Composition and quality of the essential oil of coriander (*Coriandrum sativum* L.) from Argentina. J Essent Oil Res 10(5):581–584
- Diederichsen A (1996) Coriander promoting the conservation and use of underutilized and neglected crops. 3. In: Spices, Vol. 2; Purseglove JW, Brown, EG, Green CL, Robbins SRJ, Eds, Longman: New York 736–788
- El-Ghorab A, Mahgoub MH, Bekheta M (2006) Effect of some bio-regulators on the chemical composition of essential oil and its antioxidant activity of Egyptian carnation (*dianthus caryophyllus* L.). J Essent Oil Bear Plants 9:214–222
- Jennings W, Shibamoto T (1980) Qualitative analysis of flavour and fragrance volatiles by glass capillary gas chromatography. Academic Press, New York
- Kahkonen MP, Hopia AI, Vuorela HJ, Rauha JP, Pihlaja K, Kujala TS (1999) Antioxidant activity of plant extracts containing phenolic compounds. J Agric Food Chem 47:3954–3962
- Khanum H, Sulochanamma G, Borse BB (2013) Impact of drying coriander herb on antioxidant activity and mineral content. Journal of Biological and Scientific Opinion 1(2):50–55
- Martinez VI, Periago MJ, Ros G (2000) Significado nutricional de los compuestos fen! Olicos de la dieta. Arch Latinoam de Nutr 50:5–18
- Melo EA (2002) Caracterizaao dos principais compostos antioxidantes presentes no coentro (*Coriandrum sativum* L.). Ph.D. thesis, Universidade Federal de Pernambuco (UFPE). Recife, Brasil
- NIST (1998) NIST/EPA/NIHs mass spectral database, standard reference database 1, 1992; NIST 98, standard reference database 1, 1998. Standard Reference Data Program, National Institute of Standards and Technology, Gaithersburg, MD
- Oktay M, Culcin I, Kufrevioglu OI (2003) Determination of *in vitro* antioxidant activity of fennel (*foeniculum vulgare*) seed extracts. Lebensm-WissTechnol 36:263–271
- Parthasarathy VA, Chempakam B, Zachariah TJ (2008) Coriander in chemistry of spices. CAB International UK:190–206
- Peethambaran D, Bijesh P, Bhagyalakshmi N (2012) Carotenoid content, its stability during drying and the antioxidant activity of commercial coriander (*Coriandrum sativum* L.) varieties. Food Res Int 45:342–350
- Prakash M, Dattatreya A, Bhat KK (2007) Sensory flavor profiling and mapping of regional varieties of coriander (*Coriandrum sativum* L.). J Sens Stud 18(5):409–422
- Priyadarshi S, Borse BB (2014) Effect of the environment on content and composition of essential oil in coriander. International Journal of Scientific & Engineering Research 5(2):57–65
- Rajeshwari U, Andallu B (2011) Medicinal benefits of coriander (*Coriandrum sativum* L.). Spatula DD 1(1):51–58
- Raju M, Varakumar S, Lakshminarayana R, Krishnakranth TP, Baskaran V (2007) Carotenoid composition and vitamin a activity of medicinally important green leafy vegetables. Food Chem 101:1598–1605
- Ramasamy R, Maya P, Bhat KK (2007) Aroma characterization of coriander (*Coriandrum sativum* L.) oil samples. Eur Food Res Technol 225(3–4):367–374
- Ranganna S (2001) Hand book of analysis and quality control for fruits and vegetable products, 2nd edn. Tata McGraw-Hill Publishing Company Limited, New Delhi
- Rao VK, Rao TK, Shivashankara KS, Varalakshmi B (2004) A comparative study of whole herb and leaf essential oils of coriander. J Essent Oil Bear Plants 7(1):49–55
- Sadasivan S, Manicham A (1991) Biochemical Methods; Wiley Eastern Limited: New Delhi.

- Schilcher H (1964) Zur wertbestimmung von Flores chamomillaeim apothekenund industrie laboratorium. Dtsch Apoth Ztg 104(30): 1019–1023
- Shahwar MK, El-Ghorab AH, Anjum FM, Butt MS, Hussain S, Nadeem M (2012) Characterization of coriander (*Coriandrum sativum* L.) seeds and leaves: volatile and non volatile extracts. Int J Food Prop 15:736–747
- Shalini P, Mohanty S (2013) Screening of antioxidant activity of *Coriandrum sativum*. Indian Journal of Research 3(4):284–285
- Sharma MM, Sharma RK (1999) Coriander handbook of herbs and spices. Woodhead publishing limited, Sawston, pp. 1–6
- Singh G, Maurya S, de Lampasona MP, Catalan CAN (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 Fragrance J 21:472–479
- Singleton VL, Rossi J (1965) Calorimetry of total phenolic with hosphomolybdic-phosphotungstic acid agents. Am J Environ Vitic 16:144–158
- Smith T, Guild J (1931) The C.I.E. colorimetric standards and their use. Transactions of the Optical Society 33 3:73–134
- Stenhagen E, Abrahamson S, McLafferty FW (1974) Registry of mass spectral data; John Wiley & Sons: New York
- Stone H, Sidel J, Oliver S, Woolsey A, Singleton RC (1974) Sensory evaluation by quantitative descriptive analysis. Food Technol 28(11):24–34