Indian Journal of Traditional Knowledge
Vol 18(3), July 2019, pp 458-467

A comparative study on nutritional, fatty acids, carotenoids, aroma and antioxidative characteristics of *Microcarpum DC* and *Vulgare alef* varieties of coriander foliage

Siddharth Priyadarshi[1,2] & Madeneni Madhava Naidu*[,1,2,+]

[1]Academy of Scientific and Innovative Research (AcSIR), CSIR-CFTRI Campus, Mysuru, Karnataka, India
[2]Department of Spices & Flavour Sciences, CSIR-CFTRI, Mysuru, Karnataka, India

E-mail: [+]mmnaidu@cftri.res.in

Received 29 November 2018; revised 15 February 2019

Fresh coriander foliage (*Vulgare alef* and *Microcarpum DC* varieties) were analysed for studying their nutritional, dietary fibre, fatty acids, carotenoids and antioxidant properties. *Microcarpum DC* foliage had higher amount of fat, protein, minerals, soluble and insoluble dietary fibre contents than *Vulgare alef*. Calcium (158.76±2.37 mg/100 g) and potassium (98.93±1.63 mg/100 g) were the most abundant minerals in *Microcarpum DC*. α-Linolenic and cis-Linoleic acids were the two primary fatty acids present in both foliages. β-Carotene content in *Microcarpum DC* (10.35±0.16 mg/100 g) was six times higher than in *Vulgare alef* (1.54±0.10 mg/100 g). Most common compounds identified by GC-MS in both the varieties were decanal, 2-decenal (Z), undecanal, dodecanal, 2-dodecenal (E), 2-tridecenal (E), tetradecanal, E-9-tetradecenal, 7-hexadecenal (Z) and n-hexadecanoic acid. Total phenolic content in *Vulgare alef* (44.00±0.85 g GAE/100 g) and *Microcrpum DC* (44.93±0.64 g GAE/100 g) were nearly equal. Extracts from *Microcarpum DC* showed higher antioxidant capacities compared to *Vulgare alef*. *Microcarpum DC* foliage has higher protein, dietary fibre, minerals, fatty acids, β-Carotene, flavonoids and total phenolics along with higher antioxidant potential. The outcome confirms the significant compositional differences in both the varieties studied. *Microcarpum DC* is having higher nutritional, nutraceutical and antioxidant capacity than *Vulgare alef*.

Keywords: Aroma profile, Carotenoids, Dietary fibres, Fatty acids, GC-MS, HPLC
IPC Code: Int. Cl.[19]: A23L 5/44, A01M 29/12, A23L 33/21, A23L 33/12, C07D 471/04, C07K 1/16

Coriandrum sativum L. belongs to *Apiaceae* family; occupies a prominent position among flavouring substances and is known for its distinctive flavour, colour and therapeutic properties. Coriander originated around the Mediterranean region. There are two distinct morphological types of *Coriandrum sativum* L.; *Vulgare alef* and *Microcarpum DC*. They are used for their flavouring and organoleptic properties in cosmetics, food products and perfumes[1]. The extracts and essential oil from coriander possesses antibacterial, anticancerous, antidiabetic, antimutagenic, antioxidant and various other properties[2].

Green leafy vegetables (GLV) occupy a prominent position in Indian culinary. GLV are rich sources of ascorbic acid, carotenoid, folic acid, riboflavin, vitamins and minerals[3]. They are also known for their distinctive flavour, colour and therapeutic properties. Fruits and vegetables contribute around 95% of total β-carotene available from all sources in India of which 52% is provided by GLV[4]. Increasing the daily dietary intake of *β*-carotene, dietary fibre, as well as micronutrients through GLV help in attaining nutritional security, improve micronutrient deficiency status and prevent degenerative diseases. GLV are comparatively economical and readily available in the market and are rich in iron and *β*-carotene which are vital for human health. The dietary way to deal with micronutrient malnutrition lies in expanding the availability and utilization of micronutrient-rich foods[4].

Coriander is one of the commonly consumed GLV, and it exists as *Vulgare alef* and *Microcarpum DC* varieties. Although limited data on volatile and non-volatile seed and leaves extracts of coriander exist[5], no studies have been reported on proximate composition, mineral content, fatty acid profile and carotenoids content of these two varieties of coriander foliage. The present study represents the proximate composition, fatty acids, individual carotenoid and antioxidant capacities of *Vulgare alef* and *Microcarpum DC* variety of fresh coriander foliage.

*Corresponding author

Methodology

Fresh *Vulgare alef* and *Microcarpum DC* varieties of coriander foliage were procured from regular grower and local seller in Mysuru market (Karnataka, India). Briefly, 3000 g of each variety of coriander foliage were collected; roots were separated by cutting; washed with fresh water to remove any dust as well as other adhering particles and excess surface moisture was removed using filter paper. The cleaned foliage of two varieties were stored in separate airtight polyethene bags at 4 ºC for further analysis. Only analytical grade chemicals and solvents were used for analyses (Merck, Mumbai, India). Standards violaxanthin, lutein, chlorophyll b, chlorophyll a and β-carotene were purchased from Sigma (St. Louis, MO, USA).

Moisture content

Fresh *Vulgare alef* and *Microcarpum DC* varieties of coriander foliages were weighed (~1 g) in separate aluminium dishes, and moisture content determined following AOAC oven method[6].

Crude fat

Crude fat was obtained by extracting the samples with hexane for 16 h in a Soxhlet apparatus. The solvent was removed under reduced pressure (40 millibars) at 50±2 ºC in a rotary evaporator, and the fat content was determined as mentioned in AOAC method[6].

Total ash

Coriander samples (5 g) were weighed into a crucible and charred in hot plate till fuming stopped. Transferred the crucible into the muffle furnace and kept at 550ºC for overnight. The completion of ashing was indicated by turning into white. Crucibles were cooled and transferred to desiccators and weighed as explained by AOAC method[6]. The total ash content was calculated as,

$$\text{Ash content } \left(\frac{\text{g}}{100\ \text{g}}\right) = \frac{\text{weight of ash} \times 100}{\text{weight of sample}}$$

Total proteins

Kjeldahl method was utilised to estimate the nitrogen content in coriander samples[6] and nitrogen content was multiplied by 6.25 to get total protein. Total protein content was calculated using the equation,

$$\text{Protein } \left({}^{\text{g}}/_{100\ \text{g}}\right) = \frac{(\text{c} - \text{b}) \times 14\text{d} \times 6.25 \times 100}{\text{a} \times 1000}$$

where, 'a' is the amount of sample taken (g); 'b' is blank titre value; 'c' is sample titre value and 'd' is normality of alkali required for back-titration and to neutralise 25 mL of 0.1 mol equi/L boric acid.

Dietary fibre

Total dietary fibre (TDF) content included both total soluble and insoluble dietary fibres and was determined according to following method[7]. In brief, defatted sample (1 g) was weighed accurately (W) and transferred to an Erlenmeyer flask. Added 25 mL of sodium phosphate buffer (0.1 mol/L, pH 6.0) and mixed the contents thoroughly followed by Termamyl (100 mL) addition. The flask with the aluminium film was covered and incubated in a boiling water bath for 15 min (with occasional mixing). The contents were allowed to cool, and 20 mL of distilled water was added. The pH was adjusted to 1.5 with HCl. A Hundred milligrams of pepsin was added, the flask was covered and incubated in the water bath maintained at 40±1ºC with agitation for 60 min. Add 20 mL of distilled water to it and adjust the pH with NaOH to 6.8. Pancreatin (100 mg) was added; the flask was covered and incubated in the water bath (40±1ºC) for further 60 min. Adjusted the pH to 1.5 with HCl. The precipitate formed was filtered through a dry and weighed crucible (porosity 2) containing 0.5 g of dry celite (exact weight known) as the filter aid and washed twice with distilled water (10 mL).

***The residue (insoluble fibre)*:** Residue was washed twice with 95% ethanol (10 mL) and two times with acetone (10 mL). The residue was dried at 105±1ºC to obtain a constant weight. Cool the residue in the desiccator and weigh (D_1), then it was incinerated for five h at 550±3 ºC and finally cooled in the desiccator and weighed (I_1).

***The filtrate (soluble fibre)*:** Volume of the combined filtrate and washings were made up to 100 mL with distilled water. Added 400 mL of warm (60±1ºC) 95% ethanol and allowed to precipitate for one hour. The content was filtered through a dried and weighed crucible (porosity 2) containing 0.5 g of celite. The residue was washed twice with 78% ethanol (10 mL), followed by 96% ethanol (2 × 10 mL), and two times with acetone (10 mL). The precipitate was dried to constant weight at 105±1ºC, cooled in a desiccator and weighed (D_2). It was incinerated for five h, at 550±3ºC, cooled in a desiccator and then weighed (I_2).

Blank: Insoluble and soluble blank values were obtained by running the procedure without sample (B_1 and B_2).

Calculations:

$$\text{Insoluble dietary fibre (IDF)} = \frac{(D_1 - I_1 - B_1)}{W} X\ 100$$

$$\text{Soluble dietary fibre (SDF)} = \frac{(D_2 - I_2 - B_2)}{W} X\ 100$$

where, 'W' is the weight of the sample (g); 'D' is the weight after drying (g); 'I' is the weight of incineration (g) and 'B' is the weight of ash-free blank (g).

Mineral content

The mineral content was determined for coriander foliage by atomic absorption spectrophotometer (AAS) method[8].

Determination of fatty acids

In brief, 20 mg of lipids extracted from coriander foliage were dissolved in 5 mL hexane followed by the addition of 0.2 mL of 2 M methanolic KOH and resulting mixture was vortexed for 5 min. Fatty acid methyl esters (FAME) obtained in the hexane layer was collected in a tube containing anhydrous Na_2SO_4 and analyzed by gas chromatography–mass spectrometry (GC-MS)[9]. The GC-MS analysis of FAME was carried out using a Perkin-Elmer Turbomass Gold GC (Massachusetts, USA). The GC-MS equipped with a quadrupole mass spectrometer with the help of TR-FAME column (30 m, 0.32 mm id., film thickness 0.25 µm) coated with 70% cyanopropyl (Equiv) polysilphenylene-siloxane (Thermo Scientific, USA). Helium was utilised as the carrier gas at a stream rate of 1 mL/min. Quadrupole mass spectroscopy scanning was performed over 40–400 m/z range. The oven temperature (60ºC) was increased immediately to 120ºC at 5 ºC/min and then held for zero min. Again it was increased to 160ºC at 10ºC/min and maintained for zero min then the final temperature was achieved at 220 ºC at 5ºC/min and held for 2 min at final temperature. The injection temperature was 220ºC, the ionisation voltage was 70 eV, and the ion source temperature was 180ºC. FAME (100 mL) sample was diluted tenfold with hexane, and one µL was injected under a 1:20 split ratio mode. Identification of fatty acid was carried out by comparing the fragmentation pattern and computer matching of the mass spectral fragmentation pattern of compounds.

Determination of major carotenoids by high-performance liquid chromatography (HPLC)

Fresh coriander samples (50 g) were ground using a mortar and pestle with 5 g of sodium sulphate and two mM α-tocopherol in methanol (100 μL/g). Carotenoids were extracted using ice-cold acetone, and extraction process repeated till no residual colour was observed (total volume 250 mL). The extract (50 mL) was then mixed with petroleum ether (100 mL) in a separating funnel, and upper layer decanted. The extraction was repeated three times (total volume 250 mL), the pooled ether extract was dried over anhydrous sodium sulphate and filtered through Whatman no. 1 filter paper. Residual solvent was removed using a rotary evaporator (Heidolph, Germany) at 50ºC under reduced pressure (40 millibars) and redissolved in known volume of hexane (5 mL). An aliquot (100 μL) of the extract was taken and dried under the stream of nitrogen. The remaining residue was redissolved in 1 mL of acetonitrile/methanol/dichloromethane (60:20: 20 v/v/v) containing 0.1% ammonium acetate and finally analyzed by HPLC[10].

HPLC separated the carotenoids on a LiChrospher® 100 RP-18 (5 µm) Hibar® RT 250-4, 6 column, 25 cm×4.6 mm i.d., 5 μm, 120 A^0 (Merck Millipore., India). A Mobile phase [acetonitrile/methanol/ dichloromethane (60:20:20 v/v/v)] with 0.1% ammonium acetate was used for separation of carotenoids. The samples (20 µL) were injected under isocratic condition (flow rate 1 mL/min) for 25 min total run time, at 450 nm with UV-visible detector (Shimadzu, Japan). The peaks were identified, and their λ_{max} values were confirmed by the retention time of respective standards, recorded with a Shimadzu model LC-10AT series equipped with the SPD-M10AVP detector. The individual peak was quantified from the respective reference standard.

Extraction of volatile oil and identification of volatile aroma compounds

Freshly ground coriander samples were homogenized with distilled water. The volatiles were extracted by Clevenger distillation for 4-6 h[11].

GC-MS analysis of volatile oils was carried out using a Perkin-Elmer Turbomass Gold GC (Massachusetts, USA) having a quadrupole mass spectrometer using SPB-1 fused silica column (30 m, 0.32 mm id., film thickness 0.25 mm) coated with polydimethylsiloxane. The flow rate of Helium (carrier gas) was kept at 1 mL/min. Quadrupole mass

spectroscopy scanning was performed over 40–400 m/z range. The oven temperature was programmed at 50ºC for one minute and increased to 250ºC at 4ºC/min and then held for 10 min at the final temperature. The injection and ion source temperatures were 250 ºC while the ionization voltage was 70 eV. Volatile oil (100 µL) was diluted tenfold with acetone, and one µL was injected under 1:20 split ratio mode. Standard n-alkanes ranging from n-hexane (C_6) to n-heptacosane (C_{27}) were analyzed under the above conditions. Retention indices were calculated for each compound against the n-alkane standard (C_6-C_{27}) using the equation according to the Kovats method[12]. Fragmentation pattern was used to identify the volatile components, and computer matching of the mass spectral fragmentation pattern of compounds was carried out[13]. These were compared with the published mass spectra[14].

Extract preparation and total polyphenol content

Fresh coriander foliage of both the varieties (25 g) was ground and loaded into a separate glass column and extracted with ethanol: water (1:1 ratio) at a material solvent ratio of 1:10. The sample was steeped in the solvent for two hours and eluted dropwise. Desolventization was carried out using a rotary evaporator and stored at 4ºC. The extracts were analysed for total extract yield, total polyphenol content (TPC), total flavonoid content (TFC) and antioxidant capacities.

Total polyphenol content of coriander extracts was determined following the Folin-Ciocalteu method[15]. The concentration of polyphenol was calculated using gallic acid as standard, and the results are expressed on the dry weight basis as gallic acid equivalents per gram (mg GAE/ g) of extract.

Determination of total flavonoids

Total flavonoid contents in extracts of two varieties of coriander foliage were measured by colourimetric assay[16]. In brief, 0.1 mL of various extracts (1 mg/mL) were added separately to 10 mL test tubes followed by addition of 0.3 mL $NaNO_2$ (5%). After 5 min, 0.3 mL $AlCl_3$ (10%) was added. At 6 min, 2 mL NaOH (1 M) were added to the mixture. The final volume of the reaction mixture was made up to 10 mL with double distilled water and mixed thoroughly. The optical density of the final solution was measured at 510 nm versus blank. Total flavonoids contents of the samples were expressed on dry weight basis as mg/100 g catechin equivalents (mg CE/100 g).

Determination of antioxidant capacities

The antioxidant capacities were determined by the scavenging activity of stable 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical, ferric reducing antioxidant power (FRAP), β- carotene bleaching test, and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) assay.

DPPH* radical scavenging activity

Antioxidant activity of different extracts prepared from two varieties was measured by 2, 2-diphenyl-1-picrylhydrazil (DPPH) method[17]. The free radical scavenging activity on dry weight basis is expressed as the inhibition percentage and calculated using the following formula-

$$\text{Radical scavenging activity (\%)} = \frac{(A_{control} - A_{sample})}{A_{control}} \times 100$$

where, A_{sample} and $A_{control}$ are the equilibrium absorbances of the test sample and the control, respectively.

Ferric reducing antioxidant power assay

Antioxidant activity of coriander extracts prepared from ethanol (50%) was measured by ferric reducing antioxidant power (FRAP)[5].

β-carotene bleaching assay

The β-carotene bleaching assay was conducted to measure the total antioxidant activity (AA)[18] and was calculated according to the following equation,

$$\text{Antioxidant Activity (\%)} = \left[1 - \frac{(A_0 - A_t)}{(A_0^0 - A_t^0)}\right] \times 100$$

where 'A_0' is absorbance of the sample at zero min; 'A_t' is absorbance of the sample at 180 min; 'A_0^0' is absorbance of control at zero min and 'A_t^0' is absorbance of control at 180 min.

ABTS$^+$ radical scavenging activity

The 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) radical scavenging activities of fresh coriander foliage extracts in 50% methanol were determined[19]. The scavenging capability of extracts was determined using the equation-

$$\text{ABTS scavenging activity (\%)} = \frac{(A_{control} - A_{sample})}{A_{control}} \times 100$$

where, A_{sample} and $A_{control}$ are the equilibrium absorbance of the test sample and the control, respectively.

Statistical analyses

All analyses were carried out in triplicate. Data are expressed as means ± standard deviation. Duncan's Multiple Range Test was used to differentiate the means of different test samples at $p \leq 0.05$[20].

Results and discussion

Proximate composition of coriander foliage

From Table 1 it is clear that the moisture content of fresh *Microcarpum DC* leaves is lower (86.00±1.19%), than *Vulgare alef* (91.00±1.23%). *Microcarpum DC* has comparatively higher protein content of 3.58±0.22% and crude fat of 0.73±0.05% as compared to *Vulgare alef*, which has crude protein of 3.17±0.18% and crude fat of 0.43±0.02%. Total ash content is also higher in *Microcarpum DC* (2.57±0.44%) whereas in *Vulgare alef* it is lower (1.47±0.23%). *Vulgare alef* has lower insoluble dietary fibre (3.30±0.42%) and soluble dietary fibre (0.29±0.01%) contents than *Microcarpum DC* insoluble dietary fibre (5.44±0.71%) and soluble dietary fibre (0.63±0.02%). Previous report indicated that coriander leaves contain 0.95±0.01 (g/100 g) of crude fat, 4.05±0.21 (g/100 g) of crude protein, 5.24±0.23 (g/100 g) of crude fibre and 1.9±0.05 (g/100 g) of ash[5].

Mineral content

Mineral contens in two varieties of coriander foliage (Table 1) shows that coriander foliages are excellent sources of calcium (Ca), potassium (K) and magnesium (Mg). Calcium is the most abundant mineral while copper is lowest in both varieties of coriander foliage. *Microcarpum DC* has higher contents of Ca (158.76±2.37 mg/100 g), K (98.93±1.63 mg/100 g) and Mg (21.71±1.23 mg/100 g) than *Vulgare alef* which contains 64.62±1.92 mg/100 g of Ca, 57.80±1.58 mg/100 g of K and 9.99±1.12 mg/100 g of Mg. Children, lactating and pregnant women require more calcium for teeth and bone development. High potassium content in the body increases iron utilisation and is beneficial to those taking diuretics to control hypertension and to those suffering from excess excretion of potassium through body fluid[21]. The recommended daily allowances for potassium is 2000 mg for adults, 350 mg magnesium for adult male and calcium for both adults and children is 800 mg per day[22]. Hence 100 g of *Microcarpum DC* foliage will provide about 20% of calcium, 5% of potassium and 6% of magnesium of the recommended daily dose. Our results show the variation in mineral content as compared to earlier report[23] where coriander herb was reported to contain 509.8±17 mg/100 g of potassium which is the most abundant mineral followed by phosphorous (146.8±5.5 mg/100 g). Changes in agronomic practices, genetics and soil and weather conditions may influence the variation in the results[24,25].

Table 1 — Nutritional and mineral composition of *Vulgare alef* and *Microcarpum DC* variety of coriander foliage

Parameter		*Vulgare alef*	*Microcarpum DC*
Moisture (%)		91.00±1.23[b]	86.00±1.19[a]
Total ash (%)		1.47±0.23[a]	2.57±0.44[b]
Crude Fat (%)		0.43±0.02[a]	0.73±0.05[b]
Total Sugars (%)		0.34±0.01[a]	1.05±0.11[b]
Crude protein (%)		3.17±0.18[a]	3.58±0.22[a]
Insoluble dietary fibre (%)		3.30±0.42[a]	5.44±0.71[b]
Soluble dietary fibre (%)		0.29±0.01[a]	0.63±0.02[b]
Minerals (mg/100 g)	Iron	1.01±0.11[a]	4.40±0.24[b]
	Zinc	0.27±0.01[a]	0.31±0.01[b]
	Magnesium	9.99±1.12[a]	21.71±1.23[b]
	Calcium	64.62±1.92[a]	158.76±2.37[b]
	Manganese	0.62±0.01[a]	1.24±0.03[b]
	Potassium	57.80±1.58[a]	98.93±1.63[b]
	Copper	0.03±0.001[a]	0.08±0.001[a]

*Means followed by the same superscripts in a row are not significantly different at p≤0.05 (n=3)

Fatty acid composition

GC–MS analysis of the lipid extract of *Vulgare alef* and *Microcarpum DC* foliages revealed that there are seven fatty acids (FA) accounted for 89.66% and 88.98% respectively, for the total extract composition. *Vulgare alef* contains cis-linoleic acid as the most abundant FA (31.41±0.45) followed by α-linolenic acid (29.90±0.37); whereas α-linolenic acid is the most abundant FA (32.16±0.98) followed by linoleic acid (27.85±0.29) in *Microcarpum DC* (Table 2). Other FA present in both the varieties are palmitic,

Table 2 — Fatty acid composition of *Vulgare alef* and *Microcarpum DC* variety of coriander foliage

Compounds Identified	RT (min)	Relative conc. (%)	
		Vulgare alef	*Microcarpum DC*
Palmitic acid	16.87	14.94±0.24[a]	13.93±0.34[a]
Palmitoleic acid	17.23	1.12±0.01[a]	1.25±0.04[a]
Roughanic acid	18.46	9.07±0.35[a]	11.50±0.25[b]
Petroselenic acid	19.21	1.39±0.05[a]	1.44±0.29[a]
cis-Linoleic acid	19.84	31.41±0.45[b]	27.85±0.29[a]
α-Linolenic acid	20.64	29.90±0.37[a]	32.16±0.98[b]
Trans-phytol	21.71	1.83±0.24[b]	0.85±0.01[a]

*Means followed by the same superscripts in a row are not significantly different at p≤0.05 (n=3)

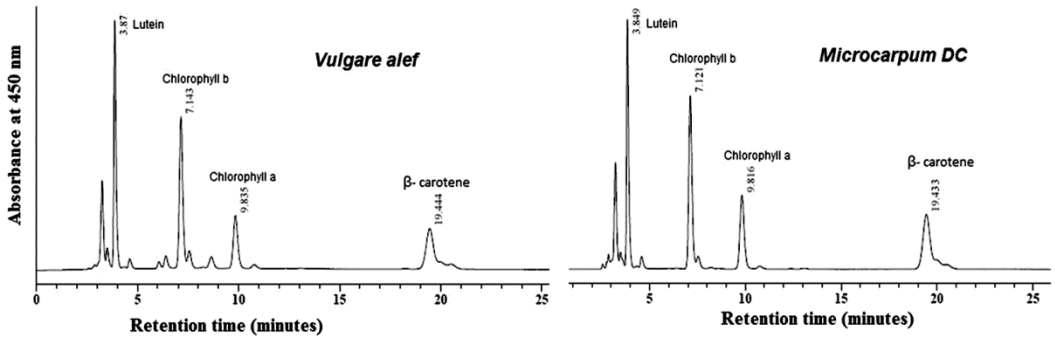

Fig. 1 — HPLC profile of carotenoids in *Vulgare alef* and *Microcarpum DC* variety of coriander foliage

palmitoleic, roughanic, petroselenic and trans-phytol. Both α-linolenic acid and linoleic acid are the essential fatty acids (EFA) present in *Vulgare alef* and *Microcarpum DC* in high amounts to the extent of 61.3% and 60.01% of the total amount of FA, respectively. Our results indicate that the coriander foliage contains higher (1.6 times) amounts of EFAs than in leaves of *Vernonia amygdalina*[26]. Our finding suggests that these two varieties of coriander foliages can form as excellent supplements to human diet. α-Linolenic acid (an omega-3 fatty acid), is a precursor in the biosynthesis of docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). Linoleic acid is an omega-6 FA which acts as a metabolic precursor for the group of biologically essential lipids called eicosanoids. Eicosanoids include leukotrienes, lipoxins prostaglandins, and thromboxanes which play a significant role in blood clotting, immunity and inflammation[27].

Carotenoid composition of coriander foliage

Qualitative HPLC profiles of the major carotenoids in *Vulgare alef* and *Microcarpum DC* foliages were found to be almost similar (Fig. 1). The concentrations of lutein, chlorophyll b, chlorophyll a and β-carotene in both coriander varieties are shown in Table 3. The major differences were in the concentration of individual carotenoids. It can be seen that lutein content in *Microcarpum DC* (10.35±0.13 mg/100 g) is higher compared to *Vulgare alef* (10.52±0.11 mg/100 g) foliage. The foliage of *Vulgare alef* and *Microcarpum DC* contained chlorophyll b (0.41±0.01 and 0.47±0.01 mg/100 g), chlorophyll a (0.41±0.01 and 0.57±0.01 mg/100 g) and β-carotene (1.54±0.10 and 10.35±0.16 mg/100 g). Various environmental factors and species variations may be responsible for these differences. Factors such as level of maturity, species, plant part, cultivation method and post harvest handling influence carotenoid levels[28]. Similar levels of lutein (9.92 mg/100 g) and β-carotene (67.50 mg/100 g) contents are reported in coriander leaves[29]. Carotenoids like β-Carotene act as a precursor to vitamin A which plays a vital role in the vision process; whereas lutein and zeaxanthin are nutritionally important as antioxidants and help in the prevention of age-related macular degeneration (AMD) and atherosclerosis[30]. The concentration of carotenoid related lutein and zeaxanthin in human serum is chiefly dependent on extent of consumption of carotenoid-rich sources like fruits and vegetables which may contribute to the prevention of AMD and protect the eye.

Table 3 — Major carotenoids identified in *Vulgare alef* and *Microcarpum DC* variety of coriander foliage

Sample	Lutein (mg/100g)	Chlorophyll b (mg/100g)	Chlorophyll a (mg/100g)	β-Carotene (mg/100g)
Vulgare alef	10.52±0.11[a]	0.41±0.01[a]	0.41±0.01[a]	1.54±0.10[a]
Microcarpum DC	10.35±0.13[a]	0.47±0.01[a]	0.57±0.01[a]	10.35±0.16[b]

*Means followed by the same superscripts in a column are not significantly different at p≤0.05 (n=3)

Identification of aroma compounds

The relative concentrations of individual aroma components and their calculated Kovats indices are summarized in Table 4. GC-MS profiles of *Vulgare alef* and *Microcarpum DC* varieties were shown to be almost similar, but major differences were found in the concentration of individual aroma component in the two varieties.

Table 4 shows the most common compounds identified in two varieties were decanal, 2-decenal (Z), undecanal, dodecanal, 2-dodecenal (E), 2-tridecenal (E), tetradecanal, E-9-tetradecenal, 7-hexadecenal (Z) and n-hexadecanoic acid. However, the concentrations of these individual compounds varied depending on the variety of coriander foliage. There are some compounds such as 4-hexen-1-ol, 3-hexen-1-ol, acetate,

(Z), octane, 3,5-dimethyl, benzeneacetaldehyde, Z-10-tetradecen-1-ol acetate and 2-decen-1-ol are present in *Vulgare alef* but are absent in *Microcarpum DC* variety. Thus, quantitative and qualitative variations were observed in the aroma profile of the two varieties.

Vulgare alef is more concentrated with 4-hexen-1-ol (3.06%), benzeneacetaldehyde (6.92%), decanal (4.73%), dodecanal (7.66%), Z-10-tetradecen-1-ol acetate (5.85%), 2-dodecenal, (E) (3.49%), E-9-tetradecenal (7.19%), trans-2-undecen-1-ol (13.68%), 2-decen-1-ol (7.64%) and 7-hexadecenal, (Z) (3.72%) while *Microcarpum DC* is dominant in decanal (15.13%), 2-decenal, (Z) (13.34%), dodecanal (6.19%), 2-dodecenal, (E) (9.31%) and E-9-tetradecenal (9.53%). Similar data were observed in previous studies where coriander leaves were reported to contain decanal, undecanal, (E)-2-undecenal, dodecanal,1-dodecanol, 2-dodecenal, 2E-dodecenal, 2-decen-1-ol, (E)-2-tridecenal, tetradecanal and (E)-2-tetradecenal[5, 31, 32]. Our findings suggest that these variations in aroma profile are due to the variety of coriander foliage.

Table 4 — Major aroma compounds identified in *Vulgare alef* and *Microcarpum DC* variety of coriander foliage

Compounds Identified	RT (min)	KI	Relative conc. (%)	
			Vulgare alef	*Microcarpum DC*
4-Hexen-1-ol	6.03	926	3.06	n.i.
Octanal	7.57	981	1.78	1.57
3-Hexen-1-ol, acetate, (Z)-	7.80	988	1.55	n.i.
Octane, 3,5-dimethyl-	8.07	996	1.42	n.i.
Benzeneacetaldehyde	8.42	1008	6.92	n.i.
Decanal	14.23	1184	4.73	15.13
2-Decenal, (Z)-	15.99	1234	1.81	13.34
Undecanal	17.61	1282	0.35	2.65
2-Decen-1-ol, (Z)-	20.56	1372	2.36	0.52
Dodecanal	20.89	1381	7.66	6.19
Z-10-Tetradecen-1-ol acetate	21.10	1387	5.85	n.i.
2-Dodecenal, (E)-	22.59	1436	3.49	9.31
2-Tridecenal, (E)-	25.60	1535	0.79	1.03
Tetradecanal	26.96	1581	1.17	1.91
E-9-Tetradecenal	28.55	1637	7.19	9.53
Sedanolide	29.28	1663	n.i.	1.11
trans-2-Undecen-1-ol	30.74	1715	13.68	1.70
2-Decen-1-ol	30.86	1720	7.64	n.i.
7-Hexadecenal, (Z)-	31.26	1735	3.72	0.97
E-2-Tetradecen-1-ol	31.58	1747	1.91	0.89
trans-2-Undecen-1-al	32.06	1765	1.36	1.70
n-Hexadecanoic acid	36.26	1930	1.05	2.61
trans-13-Octadecenoic acid	40.13	2094	1.17	0.50
Total			80.66	70.66

Total polyphenolics and flavonoid content

Results regarding total polyphenol content (TPC), total flavonoid content (TFC), free radical scavenging activity (RSA) and β-Carotene bleaching assay (AA) for *Vulgare alef* and *Microcarpum DC* foliages are presented in Fig. 2. The ethanol: water (1:1) extracts of *Vulgare alef* (44.00±0.85 g GAE/100 g) and *Microcarpum DC* (44.93±0.64 g GAE/100 g) are rich in total polyphenol content. The present values are higher compared to earlier reported values which were 26.75±1.85 mg/g and 30.00±2.64 mg/g of total polyphenol for *Vulgare alef* and *Microcarpum DC*, respectively[33]. Polyphenol biosynthesis is influenced by various factors like biotic and abiotic, cultivar, intraspecific chemo-diversity, ontogenetic stage, plant breeding, post-harvest handling and solvent used for extraction[33, 34].

Total flavonoid content in *Microcarpum DC* is higher than *Vulgare alef* (Fig. 2). Flavonoids when present in plant-rich diet exhibit higher antioxidant activities[35]. Flavonoids and other phenolic compounds provide potential health benefits including anticarcinogenic, antioxidant, cardioprotective and also guard against other nontransmissible chronic diseases[36, 37].

Antioxidant capacity of *Vulgare alef* and *Microcarpum DC* foliage

Non-volatiles from *Vulgare alef* and *Microcarpum DC* foliage were extracted through solvent extraction using ethanol: water (1:1) as the solvent. Different levels (50, 100 and 200 ppm) of extracts were prepared by dissolving the extracts in ethanol (50%). Fig. 2 shows the radical scavenging activity of

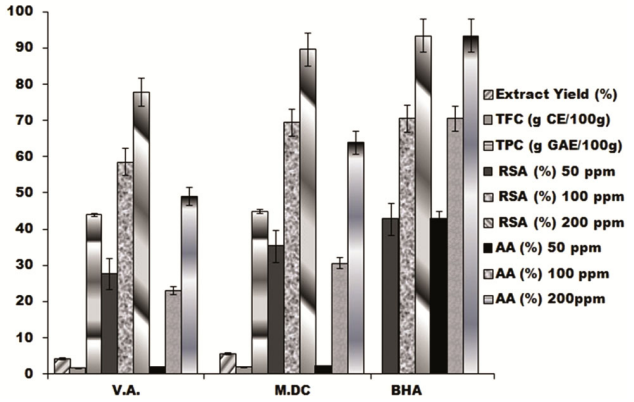

Fig. 2 — Extract yield, total flavonoid, polyphenols content, radical scavenging and β-Carotene bleaching antioxidant activity of *Vulgare alef* and *Microcarpum DC* variety of coriander foliage. TFC: total flavonoid content; TPC: total polyphenol content; RSA: radical scavenging activity; AA: β-Carotene bleaching antioxidant activity; BHA: butylated hydroxyanisole

extracts of both varieties at various concentrations. Both varieties exhibited dose-response activity which means the radical scavenging activity increased with increase in the concentration of extracts and reached maximum at 200 ppm. The increasing activity is attributed to higher polyphenol content at increasing levels. Thus a direct correlation is observed between the polyphenol content and radical scavenging activity[38]. *Microcarpum DC* extract showed higher radical scavenging activity (89.68±1.6%) as compared to *Vulgare alef* extract (77.85±1.42%) at 200 ppm level. But the radical scavenging activity of ethanol (50%) extract at various concentrations was slightly lower than the synthetic antioxidant butylated hydroxyanisole (BHA). Our results bear a close relationship with the earlier report indicating *Microcarpum DC* has high total phenolic content and also high antioxidant activity at 200 ppm[33].

β-Carotene bleaching assays were conducted for antioxidant activity. *β*-Carotene undergoes fast discolouration in the absence of an antioxidant. The methylene group present in linoleic acid loses a hydrogen atom thus forming its free radical. *β*-Carotene loses the double bonds when attacked by these free radicals thus, in turn, loses its characteristic orange colour. Ethanolic: aqueous (1:1) extracts from both varieties exhibited powerful antioxidant activity at all concentrations (50, 100 and 200 ppm) studied. Our results indicate a direct relationship between antioxidant activity and extract concentration. *Microcarpum DC* extract showed maximum antioxidant activity (64.02±2.1%) in comparison with *Vulgare alef* extract (49.10±1.63%) at 200 ppm level (Fig. 2). But the antioxidant activity of ethanol (50%) extracts from two varieties at various concentrations was lower than the synthetic antioxidant BHA.

Reducing ability of ethanolic: aqueous (1:1) extracts from both varieties were also determined using the FRAP method at different concentrations (0.1, 0.2, 0.3 and 0.4 mg/mL). Table 5 indicates that there is an apparent increase in antioxidant activity with the increase in extract concentration. *Microcarpum DC* extract exhibited higher antioxidant activity than *Vulgare alef* extract confirming similar trends observed in DPPH and β-Carotene bleaching antioxidant assays. These results are found to be higher than the earlier published data[33] confirming that ethanolic: aqueous (1:1) is a better solvent than other solvents. Both the varieties showed a significant reduction in the ferric ion content. The maximum value for *Microcarpum DC* extract is 0.41±0.01 while the highest value for *Vulgare alef* extract is 0.26±0.01 at 0.4 mg/mL concentration (Table 5).

Table 5 — Antioxidant capacity of *Vulgare alef* and *Microcarpum DC* variety of coriander foliage

Parameter	Concentration (mg/mL)	*Vulgare alef*	*Microcarpum DC*
FRAP (absorbance)	0.1	0.11±0.01[a]	0.13±0.01[a]
	0.2	0.14±0.01[a]	0.18±0.01[b]
	0.3	0.19±0.01[a]	0.27±0.01[b]
	0.4	0.26±0.01[a]	0.41±0.02[b]
ABTS (μM TE/g)	0.1	39.7±1.63[a]	44.10±1.81[b]
	0.5	133.02±2.69[a]	190.68±2.36[b]
	1.0	213.13±2.93[a]	379.96±3.13[b]
	2.0	482.52±6.21[a]	597.85±5.97[b]

*Means followed by the same superscripts in rows are not significantly different at p≤0.05 (n=3). FRAP: ferric reducing antioxidant power; ABTS: 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid radical scavenging activity

The discolouration of $ABTS^+$ radical which has a characteristic colour showing maxima at 734 nm was performed using TEAC assay. These tests are based on the interaction between $ABTS^+$ radical and antioxidant. $ABTS^+$ radical scavenging ability of ethanolic: aqueous (1:1) extracts from both varieties was also determined at concentrations of 0.1, 0.2, 0.3 and 04. mg/mL. It is evident from Table 5 that both the samples exhibited dose-dependent activity indicating an increase in $ABTS^+$ radical scavenging activity with increasing concentration of extracts and reached maximum at 2 mg/mL concentration. *Microcarpum DC* extract showed higher $ABTS^+$ radical scavenging activity (597.85±5.97 μM TE/g) as compared to *Vulgare alef* extract (482.52±6.21 μM TE/g) at 2 mg/mL concentration.

Conclusions

GLV are rich sources of antioxidants, carotenoids, essential fatty acids, fibres, minerals, phenolic compounds and vitamins. In this study, *Microcarpum DC* and *Vulgare alef* varieties of coriander foliage were studied, and the findings indicated that *Microcarpum DC* contained higher levels of calcium, cis-linoleic acid, α-linolenic acid, β-Carotene, flavonoids and total phenolics as compared to *Vulgare alef*. Direct correlation was observed between TPC and antioxidant capacity when measured by DPPH, FRAP, β-carotene bleaching assay, and ABTS assay. The results also revealed a higher content of nutritional, nutraceutical and antioxidant activity in *Microcarpum DC* foliage. Thus *Microcarpum DC*

foliage may help in attaining nutritional security and can assist in eradicating micronutrient deficiency.

Acknowledgement

The authors acknowledge the Director, CSIR-CFTRI, Mysuru for the facilities provided to carry out this research work. This investigation was monetarily upheld under 12th plan project (Agropathy, BSC-0105).

References

1 Kaur P, Kumar A & Arora S, Quality of dried coriander leaves as affected by pretreatments and method of drying, *Eur Food Res Technol*, 223 (2006) 189–194.

2 Priyadarshi S, Harohally NV, Roopavathi C & Naidu MM, Isolation, identification, structural elucidation and bioactivity of Heneicos-1-ene from *Coriandrum sativum* L. foliage, *Sci Rep*, 8 (2018) 1-6.

3 Prakash D & Pal M, Nutritional and antinutritional comparison of vegetable and grain Amaranthus leaves, *J Sci Food Agric*, 57 (1991) 573–585.

4 Singh G, Kawatra A & Sehgal S, Nutritional composition of selected green leafy vegetables, herbs and carrots, *Plant Foods Hum Nutr*, 56 (2001) 359-364.

5 Shahwar MK, El-Ghorab AH, Anjum FM, Butt MS, Hussain S, *et al*., Characterization of coriander (*Coriandrum sativum* L.) seeds and leaves: volatile and non volatile extracts, *Int J Food Prop*, 15 (2012) 736–747.

6 AOAC, Official methods of analysis (17th ed.), Gaithersburg, MD, USA: Association of Official Analytical Chemists, (2000).

7 Asp NG, Johnos CG, Hollmer H & Slijestrom M, Rapid enzymatic assay of dietary fiber, *J Agric Food Chem*, 31 (1983) 476-482.

8 Ranganna S, Hand book of Analysis and quality control for fruits and vegetable products, 2nd edition, Tata McGraw-Hill Publishing Company Limited, New Delhi, (2001).

9 Ichihara K, Shibahara A, Yamamoto K & Nakayama T, An improved method for rapid analysis of the fatty acids of glycerolipids, *Lipids*, 31 (1996) 535-539.

10 Lakshminarayana R, Raju M, Krishnakantha TP & Baskaran V, Determination of major carotenoids in a few Indian leafy vegetables by high-performance liquid chromatography, *J Agric Food Chem*, 53 (2005) 2838–2842.

11 Schilcher H, Zur wertbestimmung von Flores Chamomillaeim Apothekenund Industrie laboratorium, *Deutsche apotheker-zeitung*, 104 (1964) 1019-1023.

12 Jennings W & Shibamoto T, Qualitative analysis of flavour and fragrance volatiles by glass capillary gas chromatography, Academic Press: New York, (1980).

13 NIST, NIST/EPA/NIH Mass Spectral Database (NIST11), Standard Reference Database 1A, 2011, Standard Reference Data Program, National Institute of Standards and Technology, Gaithersburg, MD (2011).

14 Stenhagen E, Abrahamson S & McLafferty FW, Registry of mass spectral data; John Wiley & Sons: New York (1974).

15 Singleton VL & Rossi J, Calorimetry of total phenolic with hosphomolybdic-phosphotungstic acid agents, *Am J Enol Vitic*, 16 (1965) 144-158.

16 Kim DO, Jeong SW & Lee CY, Antioxidant capacity of phenolic phytochemicals from various cultivars of plums, *Food Chem*, 81 (2003) 321-326.

17 Oktay M, Culcin I & Kufrevioglu OI, Determination of *in vitro* antioxidant activity of fennel (*Foeniculum vulgare*) seed extracts, *LWT-Food Sci Technol*, 36 (2003) 263-271.

18 Osman H, Rahim AA, Isa NM & Bakhir NM, Antioxidant activity and phenolic content of *Paederia foetida* and *Syzygium aqueum*, *Molecules*, 14 (2009) 970-978.

19 Kriengsak T, Unaroj B, Kevin C, Luis CZ & David HB, Comparison of ABTS, DPPH, FRAP and ORAC assays for estimating antioxidant activity from guava friut extracts, *J Food Compost Anal*, 19 (2006) 669-675.

20 Duncan DB, Multiple range and multiple F tests, *Biometrices*, 11 (1955) 1- 42.

21 Sodamode A, Bolaji O & Adeboye O, Proximate analysis, mineral contents and functional properties of *Moringa oleifera* leaf protein concentrate, *IOSR J Applied Chem*, 4 (2013) 47–51.

22 NRC, Recommended dietary allowances (10th ed.).Washington, DC: The National Academies Press, (1989).

23 Santos J, Herrero M, Mendiola JA, Oliva-Teles MT, Ibanez E, *et al*., Fresh-cut aromatic herbs: Nutritional quality stability during shelf-life, *LWT-Food Sci Technol*, 59 (2014) 101-107.

24 Khader V & Rama S, Effect of maturity on macromineral content of selected leafy vegetables, *Asia Pac J Clin Nutr*, 12 (2003) 45-49.

25 Sanchez-Castillo CP, Dewey PJS, Aguirre A, Lara JJ, Vaca R, *et al*., The Mineral content of mexican fruits and vegetables, *J Food Compost Anal*, 11 (1998) 340-356.

26 Erasto P, Grierson DS & Afolayan AJ, Evaluation of antioxidant activity and the fatty acid profile of the leaves of *Vernonia amygdalina* growing in South Africa, *Food Chem*, 104 (2007) 636–642.

27 Bourre JM, Bonneil M, Clement M, Dumont O, Durand G, *et al*., Function of dietary polyunsaturated fatty acids in the nervous system, *Prostaglandins Leukot Essent Fatty Acids*, 48 (1993) 5–15.

28 Chen BH & Chen YY, Determination of carotenoids and chlorophylls in water convolvulus (*Ipomea aquatica*) by liquid chromatography, *Food Chem*, 45 (1992) 129–134.

29 Marisiddaiah R, Sadineni V, Rangaswamy L, Thirumalai PK & Vallikannan B, Carotenoid composition and vitamin A activity of medicinally important green leafy vegetables, *Food Chem*, 101 (2007) 1598–1605.

30 Humphries JM & Khachik F, Distribution of Lutein, Zeaxanthin, and Related Geometrical Isomers in Fruit, Vegetables, Wheat, and Pasta Products, *J Agric Food Chem*, 51 (2003) 1322-1327.

31 Chung IM, Ahmad A, Kim SJ, Naik PM & Nagella P, Composition of the essential oil constituents from leaves and stems of Korean *Coriandrum sativum* and their immunotoxicity activity on the *Aedes aegypti* L, *Immunopharmacol Immunotoxicol*, 34 (2012) 152-156.

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

33 Priyadarshi S, Khanum H, Ravi R, Borse BB & Naidu MM, Flavour characterisation and free radical scavenging activity of coriander (*Coriandrum sativum* L.) foliage, *J Food Sci Technol*, 53 (2016) 1670-1678.

34 Goyeneche R, Roura S, Ponce A, Vega-Galvez A, Quispe-Fuentes I, *et al*., Chemical characterization and antioxidant

capacity of red radish (*Raphanus sativus* L.) leaves and roots, *J Funct Foods*, 16 (2015) 256–264.

35 Kim JS, Kang OJ & Gweon OC, Comparison of phenolic acids and flavonoids in black garlic at different thermal processing steps, *J Funct Foods*, 5 (2013) 80– 86.

36 Celli GB, Pereira-Netto AB & Beta T, Comparative analysis of total phenolic content, antioxidant activity, and flavonoids profile of fruits from two varieties of Brazilian cherry (*Eugenia uniflora* L.) throughout the fruit developmental stages, *Food Res Int*, 44 (2011) 2442–2451.

37 Grassi D, Desideri G & Ferri C, Flavonoids: Antioxidants against atherosclerosis, *Nutrients*, 2 (2010) 889–902.

38 Kahkonen MP, Hopia AI, Vuorela HJ, Rauha JP, Pihlaja K, *et al*., Antioxidant activity of plant extracts containing phenolic compounds, *J Agric Food Chem*, 47 (1999) 3954–3962.