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Aroma characterization of coriander (*Coriandrum sativum* L.) oil samples

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Abstract Coriander (*Coriandrum sativum* L.) seeds from eight regions of India, labelled as S1 to S8 were examined for their volatile constitutents by gas chromatography–mass spectroscopy (GC–MS). GC–olfactometry (GC–O) was carried out for major compounds and odour profiling was done by trained panelists. Essential oil content of coriander samples ranged from 0.18 to 0.39%. The GC–MS analysis revealed presence of 30 compounds in coriander oil and around 98% of the compounds were identified in all the samples. Linalool which has floral and pleasant odour notes was the major compound (56.71–75.14%) in the essential oil, but the variation in the linalool content did not significantly affect the pleasantness of samples as perceived by the panelists. Higher α-pinene content of S7 and S8 could be related to the higher turpentine note. Sweet and rose-like odour notes of S1 could be due to occurrence of higher levels of geranyl acetate and lemonol. The odour profiling depicted the overall odour perceived, while the GC–O represented the odour notes of specific volatile compounds of coriander. Principal component analysis showed that samples S7 and S8 loaded with α-pinene, myrcene and undecanal. The results of GCO, sensory and PCA indicated possible association of major compounds with the intensity of characteristic odour notes perceived by the trained panel. Electronic nose pattern matching further complimented sensory and GC–MS results by showing segregation of samples. The study provides description of a few aroma notes in the coriander essential oil and the possibility of discriminating the aroma by sensory and instrumental methods.

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Introduction

Coriander (*Coriandrum sativum* L.) is a culinary and medicinal plant from Umbelliferae family, extensively cultivated in India and also in Russia, Central Europe, Asia and Morocco. India is the world's largest producer of coriander and a potential exporter to the countries like USA, EU, Middle East and South East Asia. The dried fruits are extensively employed as a condiment, especially for flavouring of sauces, meat products and bakery and confectionery items. It is also a standard ingredient in many of the Indian curry powders. The aroma and flavour of coriander are due to essential oil present in oil glands in the mericarp. Essential oil of coriander has many medicinal values [1]. It is employed in medicine as a flavouring agent to mask the bitter taste. In USA and Europe, coriander is also used for flavouring liquors. The commercial value of coriander essential oil depends on its physical properties, chemical composition and aroma quality. The international standard for oil or coriander prescribes a minimum linalool content of 70% [2]. An unusual sample of coriander oil from Mysore, India, having a strong sweet, floral odour which was attributed to the high content of geranyl acetate was reported [3]. Variation in the seed yields and essential oil content of cultivars of coriander grown at several locations in western Canada is also reported [4]. Reports are available on isolation of the coriander oil by steam distillation and supercritical carbon dioxide extraction and identification of more than 40 compounds by GC–MS [5]. Researchers have concluded that GC–IRMS finger print can be used to assess the authenticity of essential oils with 10

authentic coriander oils of different origin [6]. Researchers have identified 35 compounds in the Cuban coriander oil by GC–MS and reported that linalool was the major compound (54.57%) followed by geranial (6.97%) [7]. Workers have compared volatile compounds and odour characteristics of coriander oils extracted by supercritical and liquid CO_2 extraction methods and concluded that the odour attributes of liquid CO_2 extracted samples were less intense than those of freshly ground coriander samples [8]. It is evident that many workers have reported the volatile constituents of coriander oil; however, a more comprehensive assessment of quality is possible by adopting a combined approach consisting of instrumental and sensory analysis. Researchers have reported a comparative study of odour and GC-olfactometric profile of selected essential oils. They have concluded that there was a good correlation of compounds and intensity perception by GC–O [9]. The different odour notes perceived in the oils described by both sensory and GC–O methods gave a clear picture of the characteristic notes in the particular oil [9]. Reports are available on the use of gas chromatography–mass spectrometry (GC–MS) and gas chromatography–olfactometry (GC–O) combined with sensory aroma recombination studies to identify small subset of aroma compounds that can mimic the aroma of varietal wines [10].

Electronic nose pattern matching was carried out for studying the aroma of coriander samples. E-Nose, like human nose makes a global analysis of vapours emitted from a sample, and performs a classification process by comparing the samples with a database. It performs a quick assessment of aroma quality and is being used by food industry to carry out quality control and product development. Electronic nose testing has been used for analysing coffee aroma and instant coffee powders of different origins [11], and quality control of tea [12]. Researchers have used electronic nose to determine origin of spices and compare formulae components of the system [13].

The objective of the present study was to make a comparative study of odour and the chemical compounds of coriander grown in different regions by sensory and instrumental analysis. Also the precision of electronic nose in discriminating between headspace volatiles of coriander oil samples has been evaluated.

Materials and methods

Coriander seeds were collected from eight different locations in India and were labelled as S1, S2, S3, S4, S5, S6, S7 and S8 of India. Essential oil from freshly ground coriander powder were recovered by Clevenger's distillation method [14] by taking the ground material (50 g) in a 500 ml round bottom

Table 1 Descriptors and reference compounds used for sensory profiling of essential oil of *Coriandrum sativum* L.

S. no.	Descriptor	Reference compound
1	Turpentine	α-Pinene
2	Pleasant	Cinnamyl alcohol, Myrcene
3	Floral	Phenyl ethyl alcohol
4	Green	1-Hexanal
5	Herbal	*iso*-Propyl quinoline
6	Cooling	Menthol, Spearmint
7	Earthy	*iso*-Propyl quinoline
8	Spicy	Coriander powder
9	Sweet	Terpineol
10	Rose like	Lemonol

flask containing 250 ml distilled water to which two drops of antifoam were added. The contents were subjected to distillation for 8 h. The collected essential oil was dried over anhydrous Na_2SO_4 and stored at 4 °C in vials with Teflon sealed screw cap.

Odour analysis of coriander essential oil

Quantitative descriptive analysis (QDA) method was used for odour profiling of coriander essential oil [15]. Panelists were asked to describe the coriander oil samples with as many descriptor terms as they found applicable. Following this, an open discussion was held to finalize the descriptors by following the guidelines of earlier workers [16–18]. The common descriptors, selected by at least one third of the panel were utilized for the development of scorecard. Descriptors and standards used for flavour profiling of coriander oil to train the panelists are given in Table 1.

Odour analysis of coriander oil was done by the sniff testing method [19]. Coriander oil samples (20 μl) were trapped in 50 ml glass bottle and plugged with cotton and the bottles were coded with 3 digit numbers. The panelists were presented with samples one by one in a random order and were asked to mark the perceived intensity of odour attributes on a QDA scale. The scorecard consisted of a 15 cm scale in which 1.25 cm was anchored as low (recognition threshold) and 13.75 cm as high (saturation threshold). Testing was performed in a sensory laboratory with individual booths under fluorescent lighting equal to daylight and at a temperature of 20 ± 2 °C with good ventilation. The data were analysed and used to generate the profilogram by plotting sample mean scores over attributes (Fig. 1 a and b).

Gas chromatography

GC analysis of coriander oil volatiles was carried out by using a Shimadzu GC-9A chromatograph with a capillary
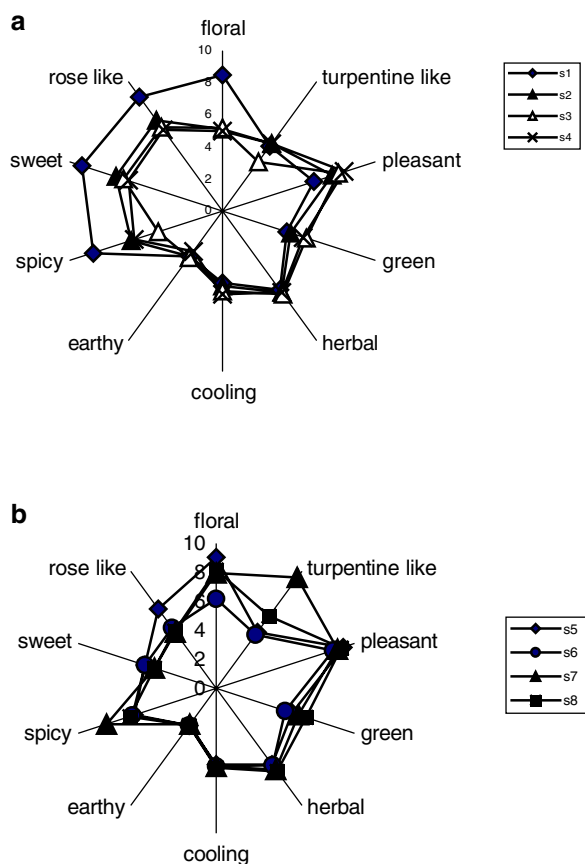
Fig. 1 **a**, **b** Sensory odour profilogram of coriander oil

column SPB-1 (30 m × 0.25 mm and 0.25 μm thickness). Carrier gas was nitrogen and detector was flame ionization detector (FID). Analysis was done with 0.2 μl of sample dissolved in HPLC grade acetone (1:40 times dilution), under the following temperature programme: Column temperature was 60 °C (hold 2 min) to 25 °C at the rate of 2 °C/min with a hold time of 1 min. FID temperature and the injector temperature was 250 °C.

Gas chromatography–olfactometry (GC–sniff port analysis)

The volatiles emerging at the exit port of GC were sniffed by ten panelists, trained in odour evaluation. The panelists were asked to sniff the volatiles at the exit port corresponding to the retention time of major compounds of coriander. Conditions of analysis were same as mentioned under GC analysis section except the detector temperature, which was kept at 30 °C. The panelists were asked to describe the odour quality of the column effluents at specific retention times. The descriptors for the specific retention times were compiled and are depicted in the aromagram along with the major compounds.

GC–MS analysis

Shimadzu GC-17A with a QP5000 MS was used for the analysis of volatiles. Two microlitres of volatile oil of coriander was injected to a SPB-1 column (Supelco, USA, 30 m × 0.32 mm film thickness 0.25 μm). The analysis was carried out under the following conditions: oven temperature was programmed at 60 °C for 2 min followed by raising at 2 °C/min to 250 °C; injection port temperature 250 °C; detector temperature 250 °C; carrier gas: helium; flow rate 1 ml/min. Retention indices of all the constituents were determined by Kovat method using *n*-alkanes as standards [20, 21]. The volatile constituents were identified by a comparison of their kovats indices and their identification was confirmed by computer matching of their mass spectral fragmentation patterns of compounds in the NIST-MS library and published mass spectra [22].

Electronic nose analysis

Electronic nose (Alpha Fox 3000) with metal oxide semiconducting sensors was used. Experiments conditions employed for analyses were: acquisition time (s): 120, acquisition period (s): 0.5, delay (s): 100, start injection (s): 0, injection time (s): 60, headspace generation time (s): 120 and zero air flow (ml/min): 150.

Ground coriander sample (0.1 g) was taken in sample vial provided by the manufacturers. Headspace volatiles accumulated in the vial was carried through zero air to the sensor chambers. The resistance of the sensor offered decreases in the presence of an odour, with size of response depending on the nature of molecule and type of metal oxide. Thus, the response depends on the reaction kinetics, the headspace, the volume of measured headspace and the flow rate of the carrier gas.

Statistical analysis

Duncan's multiple-range test was used to find the significant differences in sensory odour attributes of coriander samples [23]. Sensory odour profiling and GC–MS data were subjected to principal component analysis using statistical software [24].

Results and discussion

Essential oil content

Essential oil yield was found to be in the range of 0.18–0.39% for the eight samples of coriander analysed. Variation in yield

Table 2 Mean scores for sensory odour descriptors of essential oil of *Coriandrum sativum* L.

Samples	Floral	Turpentine	Pleasant	Green	Herbal	Cooling	Earthy	Spicy	Sweet	Rose-like
S1	8.48 b	5.11 a	7.12 a	4.18 a	6.09 a	4.42 a	3.02 a	8.41 c	9.28 d	8.80 b
S2	5.02 a	5.21 a	7.17 a	4.48 a	6.33 a	4.72 a	3.14 a	6.02 b	6.97 c	7.08 ab
S3	5.25 a	6.08 a	7.54 a	5.54 ab	6.34 a	4.98 a	3.21 a	4.22 a	6.56 bc	6.5 ab
S4	5.00 a	5.17 a	7.80 a	5.36 ab	6.48 a	5.16 a	3.25 a	5.87 b	6.13 bc	6.26 a
S5	9.10 b	4.94 a	8.00 a	5.53 ab	6.50 a	5.28 a	3.27 a	6.00 b	5.23 ab	6.75 ab
S6	6.21 a	4.62 a	8.02 a	4.94 ab	6.51 a	5.41 a	3.50 a	5.97 b	5.16 ab	5.21 a
S7	8.05 b	8.55 b	8.35 a	5.90 ab	6.98 a	5.51 a	3.55 a	8.00 c	4.50 a	4.85 a
S8	8.21 b	9.25 b	9.17 a	6.47 b	7.08 a	5.54 a	3.66 a	6.35 a	4.48 a	4.85 a
SD	1.58	2.02	1.88	1.25	2.11	1.25	1.62	1.42	1.63	1.85

Means in the same column with different letters differ significantly ($p < 0.05$) by DMRT.

can be attributed to factors like conditions of cultivation especially the extent of use of fertilizers and irrigation [4].

Sensory odour analysis

Sensory odour descriptors of coriander essential oil and the corresponding reference compounds are given in Table 1. The term 'cooling' is included as an odour descriptor because the sensation of cooling is also associated certain odour sensation, cooling sensation is one of the trigeminal perception and menthol is known for the cooling sensation. Mean scores for odour attributes given in Table 2 showed that all the samples had cooling effect as given by scores ranging from 4.42 to 5.54. Sample 1 had the highest scores for 'spicy', 'rose-like' and 'sweet' odour attributes and it had the second highest score for 'floral' note. This sample contained highest level (24.51%) of geranyl acetate and had second highest (2.35%) lemonol content. These compounds are known to have rose like and floral notes. Level of cuminal which is an odour impact compound associated with spicy note [25] was found to be present in low (0.13–0.54%). Sample S1 having the highest spicy note (8.4) was found to contain the highest (0.54%) level of cuminal. But, spicy odour is not solely dependent on cuminal content as can be seen from the sensory scores for S4 and S6. Cuminal contents were low (0.13 and 0.15%, respectively) for both the samples but sensory scores for spiciness were 5.87 and 5.97, respectively which were significantly ($p \leq 0.05$) higher than that of S3 having 0.22% cuminal. Linalool which was the major (57.52–75.14%) compound in the essential oils generally contributed to the floral and pleasant notes [25]. In addition to linalool, several other compounds like terpene hydrocarbons, mono and poly unsaturated fatty aldehydes also contribute to the characteristic aroma of coriander fruits [26]. No significant ($p \leq 0.05$) differences were found in pleasantness scores. Highest (75.14%) linalool content and highest (9.17) pleasant score were observed in S5. Samples S7 and S8 were different from other samples in having higher scores for turpentine odour. It has been reported that α-pinene has

characteristic turpentine odour [25]. Possibly the higher contents (23.23 and 8.95%, respectively) of α-pinene in S7 and S8 imparted higher intensities of turpentine odour. Slightly lower scores for sweet and rose like odour were obtained but these were not significantly ($p \leq 0.05$) different. On the other hand, floral notes were significantly higher (8.05 and 8.21, respectively) and were comparable with that of S1. Sensory analysis has shown that floral and pleasant notes were comparatively higher in most of the samples, but characteristic aroma of coriander was contributed by spicy and turpentine like attributes along with herbal note.

GC–olfactometry

GC–olfactometry was used in our studies for the detection of aroma of a few compounds. An aromagram was generated by superimposing sensory aroma descriptors of GC effluent emerging at different intervals depending on their retention time on the GC fingerprint. Odour characterization was validated with the standard (Sigma, USA) individual compounds. Concentration of major volatile compounds along with the corresponding aroma descriptors are given in Table 3. Odour description of a few compounds of coriander essential oil and their odour descriptors obtained from GC–O is presented in the aromagram. Linalool, the highest constituent of the essential oil was described by the panelists as having floral, fresh and pleasant notes while the second ma-

Table 3 Major volatile compounds of essential oil of *Coriandrum sativum* L. and their GC–O odour description

Compound	Concentration range (%)	Odour descriptors
α-Pinene	2.36–23.23	Woody, spicy, oily
Linalool	57.52–75.14	Floral, grassy, pleasant, citrussy
Terpineol	0.08–5.37	Sweet, lilac odour
Cuminal	0.13–0.54	Spicy, harsh
Citronellol	0.65–1.67	Strong floral, rose, sweet like
Geraniol	0.45–2.35	Fresh, sweet, rose like
Geranyl acetate	8.95–24.51	Pleasant, floral rose, herbal

Fig. 2 Aromagram of
coriander oil
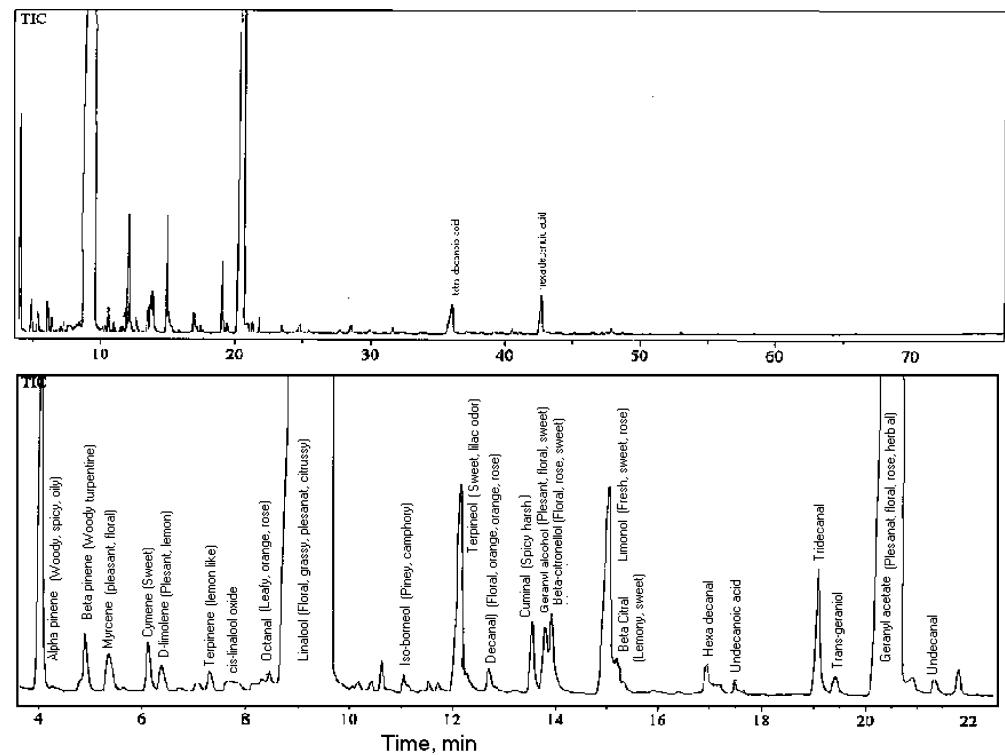
jor compound geranyl acetate was characterized by pleasant, floral, rose and lavender like notes (Fig. 2). Linalool, geranyl acetate, α-pinene, terpineol, cuminal, citronellol and lemonol were found to have dominant odours and together they constituted 70–98% of the essential oil of coriander.

Composition of essential oil

More than 30 compounds were detected in the essential oil out of which 26 were identified. The composition of volatile constituents of the samples is given in Table 4 which shows that percentage of compounds 97.05–99.06% of the compounds present in essential oils were identified (Table 4). Linalool was the main constituent in all the samples, the content of which varied from 56.7 to 75.1%, followed by geranyl acetate (8.95–24.51%) and α-pinene (2.36–23.23%). The samples S7 and S8, which were procured from northern India relatively had higher α-pinene content of 23.23 and 8.95%, respectively; while other samples from southern India were high in geranyl acetate content (24.5 − 5.39%).

Electronic nose analysis

The PCA pattern of E-nose data for coriander samples is as shown in (Fig. 4). PC1 accounted for major differences (89.55%) in variance. PC2 accounted for minor differences (10.45%). As expected, the coriander samples S7 and S8, which had intense pleasant, cooling, floral and green at-

tributes were grouped together in the same quadrant. Sample S6 has separated out singly with earthy and spicy as dominant attributes. Coriander samples S1–S5 were in another quadrant with spicy and herbal notes.

Principal component analysis of volatile compounds

To explore the relationship among the samples from various regions and their relation to specific volatile compounds, the GC–MS data was subjected to principal component analysis. The first three PCs explained the variance by 37.93, 18.90 and 14.05%, respectively, and they accounted for 71% of the total data variance (Fig. 3a). Sample S1 was distinguished with high loadings for geranyl acetate, tridecanal, cymene, limonene, beta citronellol and iso-borneol (Fig. 3b) while S3 was high with tetra and hexa decanoic acid and cuminal. Sample S2 was high with β-pinene, decanal, octanol and myrcene. Samples S7 and S8 (northern India) were loaded with α-pinene, myrcene and undecanal while S5 was high with linalool and terpinene. S4 and S6 (southern India) formed a group with trans-geraniol and limonene (Fig. 3b).

Conclusion

GC–olfactometry and sensory odour analysis of coriander oil identified the aroma of major compounds and defined their characteristic odour notes with descriptors. Floral, turpentine

Table 4 Chemical composition (%) essential oil of *Coriandrum sativum* L.

| Peak no.	Compounds	Coriander samples								SD
		S1	S2	S3	S4	S5	S6	S7	S8	
1	A-pinene (AL-PI)	2.81	4.94	6.40	5.10	2.36	6.19	23.23	8.95	6.69
2	B-pinene (B-PI)	0.48	0.52	0.68	0.50	0.31	0.50	1.11	0.74	0.24
3	Myrcene (MYR)	0.37	0.52	0.47	0.53	0.44	0.36	0.64	0.52	0.09
4	Cymene (CYM)	0.42	–	0.47	0.27	0.22	0.49	0.17	0.16	0.17
5	d-Limolene (LIM)	0.22	0.10	0.81	0.31	0.09	0.26	0.10	0.12	0.08
6	Camphene (CAM)	0.08	0.01	0.01	0.16	0.10	0.01	0.30	0.01	0.11
7	Terpinene (TER)	0.15	0.32	0.01	0.13	0.92	0.01	0.01	0.31	0.31
8	Cis linallol oxide (CIS-LI)	0.22	0.27	0.63	0.31	0.01	0.76	–	2.63	0.86
11	Octanol (OCT)	0.16	2.00	0.81	0.19	0.01	0.83	1.78	–	0.79
12	Linalool (LIN)	57.52	69.11	56.71	59.41	75.14	60.99	59.15	66.93	6.56
15	Iso borneol (ISO-B)	0.14	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05
18	Terpineol (TER-ol)	2.02	0.08	0.95	5.37	0.08	3.31	0.09	–	1.97
20	Decanal (DEC)	0.20	0.63	0.30	0.16	0.17	–	0.40	0.55	0.21
21	Cuminal (CUM)	0.54	0.26	0.25	0.13	0.22	0.15	0.17	0.22	0.13
23	Beta citronellol (B-CIT)	0.65	0.01	1.67	0.52	0.01	0.63	–	–	0.58
24	Geraniol (CIS)	2.35	0.61	0.33	3.87	0.01	2.30	0.45	0.94	1.34
25	B-citral (M-CIT)	0.24	0.10	0.01	0.01	0.01	0.38	0.10	0.08	0.13
27	Hexadecanal (HEX)	0.35	0.85	0.38	0.30	0.10	0.10	0.10	0.50	0.26
28	Undecanoic acid (UND)	0.07	0.01	0.01	0.1	0.01	0.13	0.33	–	0.12
31	Tridecanal (TRI)	1.03	0.47	0.97	0.83	0.48	0.76	0.22	0.33	0.30
32	Trans-geraniol (TRANS)	0.15	0.08	0.01	0.11	0.09	0.16	–	–	0.06
33	Geranyl acetate (GER-ACE)	24.51	14.34	24.01	19.76	18.32	19.94	8.95	13.25	5.39
35	Undecanal (UNDEC)	0.13	0.45	–	–	–	–	0.29	0.37	0.19
44	Tetradecanoic acid (TET)	0.92	1.44	1.02	–	0.08	0.16	0.09	0.26	0.52
49	Hexadecanoic acid (HEX)	1.80	0.54	0.91	–	0.14	0.70	0.41	1.54	0.64
		97.53	97.62	97.14	98.21	99.26	99.10	98.08	98.40	–

a

b
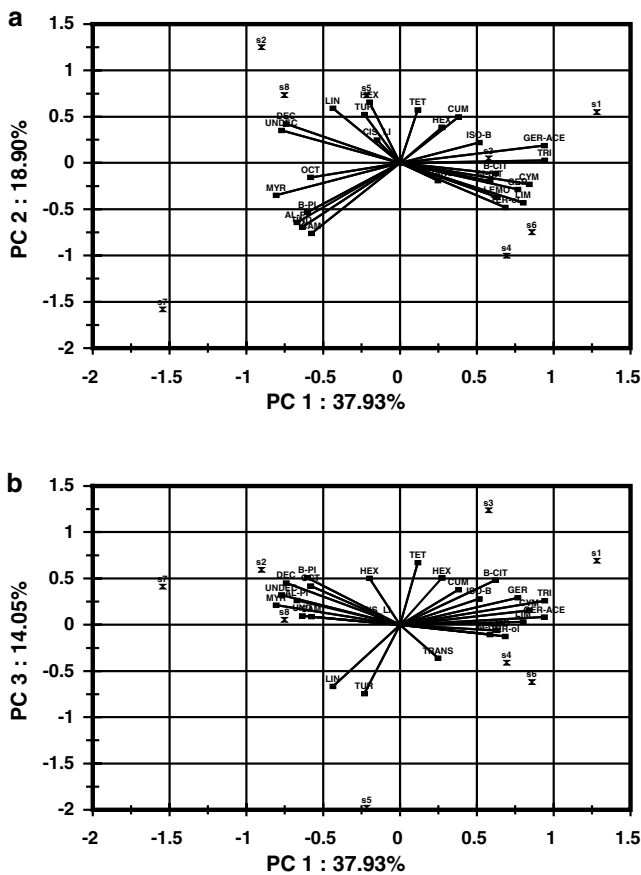
Fig. 3 **a** PCA plot of coriander oil–volatile compounds (PC1 vs. PC2). Please refer Table 3 for attributes. **b** PCA plot of coriander oil–volatile compounds (PC1 vs. PC3). Please refer Table 3 for attributes
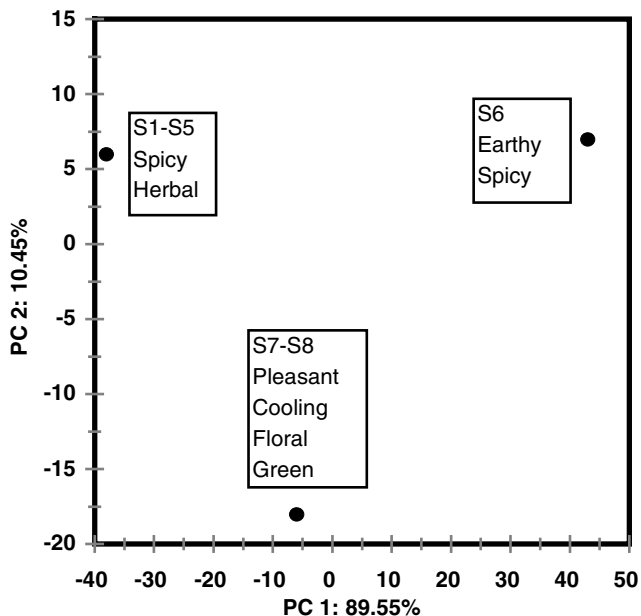

Fig. 4 Electronic nose pattern matching of coriander samples

like, pleasant, green, herbal, cooling, earthy, spicy, sweet and rose-like were the major descriptors of coriander aroma. Major volatile compounds were identified by GC–MS and kovats retention index. Linalool was the dominant compound in all the samples, the content of which ranged from 56 to 75% followed by geranyl acetate from 9 to 24% and α-pinene from 2.36 to 23.23%. Variation in the composition of essential oil had a significant impact in sensory odour characteristics. The electronic nose analysis of coriander samples further complimented sensory and GC–MS results, thus showing the discrimination in odour profile of coriander samples of different regions. The PCA mapping clearly distinguished the samples in accordance with their dominant volatile compounds. It can be concluded that flavour impact is a combined effect of large number of volatiles, results of this work indicated the possible association of major compounds with the intensity of characteristic odour notes perceived by the trained panel. The study gives an insight into the different odour notes present in the coriander oil and the information thus generated can be used in selecting right type of coriander for use in a product to provide required flavour notes.

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