

Analysis of volatile components of *Curcuma sichuanensis* X. X. Chen by gas chromatography–mass spectrometry

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Abstract

Volatile components of *Curcuma sichuanensis* X. X. Chen growing in Sichuan, China, were extracted by steam distillation and analyzed by using gas chromatography and gas chromatography–mass spectrometry. A total of 44 volatile essential oil components were identified in the extract of *C. sichuanensis* X. X. Chen, representing 87.1% of the total integrated chromatographic peaks. The major compounds were found to be *epi*-curzerenone (26.9%), germacrone (12.4%), isocurcumenol (9.7%), β -elemene (6.4%) and curzerene (6.2%). The results of semi-quantitative analysis indicated that levels of total sesquiterpene fraction (85.4%) were more than 55 times higher than those of monoterpene components (1.5%). © 2006 Elsevier B.V. All rights reserved.

Keywords: *Curcuma sichuanensis* X. X. Chen; Essential oils; *epi*-Curzerenone; GC–MS

1. Introduction

The plants of the genus of *Curcuma* represent some of the most popular medicinal herbs. *Curcuma* genus belongs to the Zingiberaceae family. Their active constituents are divided into the fractions of curcumin and essential oils [1,2]. Five *Curcuma* sp. such as *Curcuma longa* L. (*C. domestica* Val.), *Curcuma wenyujin* Y. H. Chen et C. Ling, *Curcuma sichuanensis* X. X. Chen, *Curcuma phaeocaulis* Val. and *Curcuma kwangsinensis* S. G. Lee et C. F. Lian have been widely used in traditional Chinese medicines. Therapeutic activities of anti-tumor, anti-bacteria, anti-oxidation, against early pregnancy and liver protection have been reported for the applications of the *Curcuma* sp. in Chinese medicines [1–3].

It has been reported that the curcumin and the volatile oil extracts from *C. longa* exhibited anti-inflammatory activity [3]. The essential oil of *C. longa* showed good effectiveness of antioxidants and antiradicals [4]. Three curcuminoids generated from the fractionation of ethyl acetate extract from rhizomes of *C. longa* Linn have been demonstrated for topoisomerase I

an II enzyme inhibition activity [5]. By studying the molecule mechanism of curcuma aramatica oil on inhibiting hepatoma in mice, Shi et al. found that the curcuma aramatica oil inhibited the expression of cyclin D₁ and PCNA, as a results it inhibited the growth of hepatic carcinoma [6].

The essential oils from rhizomes of *Curcuma* genus are important for pharmaceutical industries. The chemical constituents of several species of the genus have also been reported [7–14]. Studies on different species of *Curcuma* indicated that terpenes, sesquiterpene and sesquiterpene lactones were the major chemical constituents of essential oils [7–14]. It was reported that the oil of *C. wenyujin* Y. H. Chen et C. Ling collected in Zhejiang, China from 1998 to 2000 contained β -elemene (3.36–10.0%), curcumol (6.24–16.2%) and curzerone (3.55–8.83%) [7]. By using GC–FTIR and GC–MS, curzerene (4.2–15.3%), elemene (0.2–22.5%), germacrone (6.7–15.8%) and zingibere (1.8–14.2%) were identified in volatile oils of *C. longa* L., *Curcuma* sp., *Curcuma kwangsiensis* and *C. wenyujin* [8]. Curzerone (13.1%) and curdione (34.67%) were characterized as the major volatile components in *C. phaeocaulis* Val. by using supercritical fluid extraction and column chromatography with silica gel [9]. We identified the major volatile oil components of 1,8-cineole (0.8–5.3%), camphor (0.7–10.11%), β -elemene (2.9–6.1%), curcumol (3.0–6.6%), germacrone

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(6.1–9.1%), curzerene (3.5–24.9%), curdione (1.1–17.1%) and neocurdione (2.6–2.9%) as in *C. wenyujin* Y. H. Chen et C. Ling and *C. phaeocaulis* Val. [10]. Recently, the chemical composition of the essential oil from leaves of *Curcuma* sp. have been reported [11,12]. α -Terpinyl acetate (8.4%), isoborneol (7%), dehydrocurdione (9%) and selina-4(15),7(11)-dien-5-one (9.4%) were determined as the major constituents of the essential oil in *Curcuma zedoaria* (Zingiberaceae) leaves [11]. The leaf oils of *Curcuma caesia* Roxb. and two cultivars of *C. longa* L. were analyzed by using GC. The leaf oils were characterized with the following major constituents—*C. longa* ‘Roma’: terpinolene (87.8%); *C. longa* ‘Kasturi’: myrcene (48.8%) and terpinolene (10.1%); *C. caesia*: 1,8-cineole (27%) and camphor (16.8%) [12]. Recently, a method with GC–MS and pressurized liquid extraction (PLE) was developed for the identification and determination/estimation of 11 sesquiterpenes including germactene D, curzerene in Ezhu which are derived from three species of *Curcuma*, namely *C. phaeocaulis*, *C. wenyujing* and *C. kwangsiensis* [13]. A solid-phase microextraction coupled with GC–MS for the analysis of volatile compounds in *C. wenyujing* Y. H. Chen et C. Ling is reported [14]. The results were comparable with those obtained from steam distillation followed by GC–MS analysis. In the present work, we report the chemical compositions in the essential oil extracted from *C. sichuanensis* X. X. Chen that grows in the Sichuan, China.

2. Experimental

2.1. Chemicals and plant materials

The anhydrous magnesium sulphate (analytical grade) was purchased from Shanghai Chemical Reagent CO., Ltd. (Shanghai, China). HPLC grade ethyl acetate was obtained from Tedia Company Inc. (USA). Sample solutions of the essential oils were prepared by dissolving the essential oil in ethyl acetate at a concentration of 1 mg/ml.

The roots of *C. sichuanensis* X. X. Chen were collected on 8 March 2002 at Shuangliu city of Sichuan province, China. A voucher specimen Ezhu-020308 is now planted at the key

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2.2. Extraction procedure

Plant material was ground and steam-distilled in a Clevenger-type apparatus for 8 h, according to the method recommended by the China Pharmacopoeia [15]. The essential oil was dried over anhydrous magnesium sulphate and stored at 4 °C in the dark. The yield was 1.9% based on the dried weight.

2.3. Analysis of the essential oils

The essential oil extract was analyzed by using gas chromatography with flame ionization detection (GC–FID) and gas chromatography–mass spectrometry (GC–MS). The GC or GC–MS conditions were optimized on the basis of the property of the essential oil extract. The GC–FID analysis was performed on a Hewlett Packard (Palo Alto, CA, USA) model 6890 gas chromatograph equipped with an FID detector. A fused silica capillary Hewlett Packard HP-5 (5% phenyl methyl siloxane) column (30 m \times 0.25 mm i.d., 0.25 μ m film thickness) was used for the separation. Helium was used as carrier gas with a flow rate of 1.0 ml/min and the injector was set at 250 °C and split mode with the split ratio of 1:100. The FID detection was performed at 250 °C. The following GC temperature programs were tested: (1) from 60 to 100 °C at 10 °C/min, and to 185 °C at 5 °C/min, then to 300 °C at 20 °C/min [9]; (2) from 60 to 100 °C at 10 °C/min, and to 200 °C at 4 °C/min, then to 300 °C at 20 °C/min [10]; (3) from 60 to 230 °C at 3 °C/min; (4) from 70 to 230 °C at 5 °C/min; (5) from 70 to 230 °C at 7 °C/min. The results showed that the peaks was broaden with program (3), and some peaks could not be separated by programs (1), (2) and (5). Good resolution and peak shape were obtained by using program (4). A 1 μ l of the sample extract was injected. The identification of the essential oil components was based on the comparison of their retention indices (RI) that were obtained from calculated values relative to C₉–C₁₈ *n*-alkanes. The intensity of each peak was integrated. The samples were analyzed three times. The average peak areas of all GC sig-

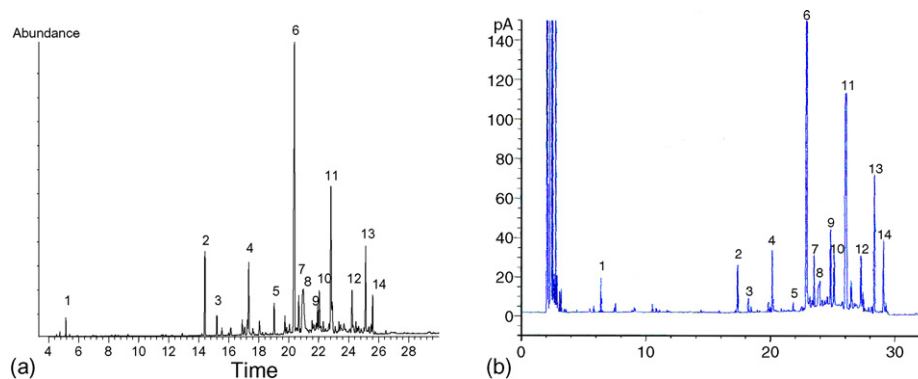


Fig. 1. (a) GC–MS total ion chromatogram of *Ccurma sichuanensis* X. X. Chen; (b) GC chromatogram of *Ccurma sichuanensis* X. X. Chen. The detected major components were—1: β -pinene; 2: β -elemene; 3: *Trans*-caryophyllene; 4: curzerene; 5: germacrene; 6: *epi*-curzerenone; 7: curzerenone; 8: *iso*-curcumenol; 9: *ar*-tumerone; 10: β -tumerone; 11: germacrene; 12: unknown 1; 13: unknown 2; 14: unknown 3.

nals were added together and the percentage of each component peak was calculated by comparing its average area to the total areas.

The GC–MS analysis was carried out in a Hewlett Packard model 6890 gas chromatograph coupled with a Hewlett Packard model 5973 mass detector. A Hewlett Packard HP-5 (5% phenyl methyl siloxane) fused silica capillary column (30 m × 0.25 mm i.d., 0.25 μm film thickness) and a Hewlett Packard ULTRA 1 (cross-linked methyl siloxane) fused silica capillary column (25 m × 0.2 mm i.d., 0.33 μm film thickness) were used for the separation. The oven temperature was programmed from 70 to 230 °C at 5 °C/min. Helium was used as carrier gas (1.0 ml/min). A 1 μl of the sample extract was injected using the split mode split ratio 1:60. The first GC column was used for obtaining the retention indices for identification, while the second column and MS detection was used the confirmation. Mass spectra were recorded in full-scan mode at 70 eV with a mass range of 15–500 Da.

3. Results and discussion

The sample extract of *C. sichuanensis* X. X. Chen was analyzed by using GC–FID and GC–MS analyses. A total ion chromatogram obtained from the GC–MS analysis is presented in Fig. 1, and GC chromatogram is also showed in Fig. 1. Retention indices of the detected components were calculated according to method described in the literature [15,16] and listed in Table 1 in the order of their elution on the Hewlett Packard HP-5 column. The constituents of the essential oil from *C. sichuanensis* were identified by comparing their retention indices. Most essential oil components extracted from *C. sichuanensis* X. X. Chen were identified by comparing the obtained mass spectra of the analytes with those of authentic standards from the NIST (National Institute of Standards and Technology), Wiley libraries and with the mass spectra published previously [16–19]. The obtained MS data of the identified compounds are presented in Table 2. The relative level of each component was calculated by comparing its GC peak area to the total areas that were summed from all detected peaks. The obtained semi-quantitative results of peak area percentage are listed in Table 1.

The major components of the essential oil identified in the sample extract from *C. sichuanensis* X. X. Chen were *epi*-curzerenone (26.9%), germacrone (12.4%), isocurcumenol (9.7%), *cis*-β-elemene (6.4%), curzerene (6.2%), curzerenone (4.6%), ar-turmenone (2.7%), β-elemenone (2.4%), β-turmenone (2.3%) and germacrene B (2.1%). Other compounds identified in the sample extract are listed in Table 1. The results showed that the percentages of *epi*-curzerenone (26.9%) and isocurcumenol (9.7%) were higher than those reported in other *Curcuma* sp. [10,14]. *epi*-Curzerenone was reported in the essential oil of *C. phaeocaulis* Val. collected from two different products with 17.88 and 6.65%, respectively [10]. Compared to the existing GC methods [8–10], good resolution and sharp peak shape were obtained by using the developed simple and linear GC temperature program. Three unknown components detected at higher retention time could not be identified due to the lack of

Table 1

Retention time and percentage composition of essential oil components identified in *Curcuma sichuanensis* X. X. Chen

Compound	Retention index	Relative level (%)	R.S.D. (%)
α-Pinene	0943	0.1	0.9
Camphene	0954	0.2	1.0
β-Pinene	0976	0.9	1.3
<i>p</i> -Cymene	1010	<0.1	
Limonene	1021	<0.1	
α-Terpinolene	1076	<0.1	
Pinocarveol	1126	<0.1	
Camphor	1136	<0.1	
Isoborneol	1148	0.1	1.1
Endo-borneol	1154	<0.1	
<i>p</i> -Cymen-8-ol	1162	<0.1	
α-Terpineol	1173	<0.1	
Myrtenol	1181	<0.1	
Borneyl acetate	1272	0.2	1.2
2-Undecanone	1278	<0.1	
4-Vinyl-2-methoxy-phenol	1285	<0.1	
2-Undecanol	1291	0.2	1.4
δ-Elemene	1333	0.2	1.3
β-Bourbonene	1380	<0.1	
β-Elemene	1386	6.4	0.9
<i>Trans</i> -caryophyllene	1413	1.7	1.4
γ-Elemene	1429	0.8	1.5
Aromadendrene	1441	0.3	1.7
α-Humulene	1447	0.7	1.4
AR-Curcumene	1468	0.6	1.3
Germacrene D	1472	0.6	1.7
β-Selinene	1477	0.5	1.5
α-Zingiberene	1484	0.9	1.4
α-Selinene	1487	0.2	2.1
Curzerene	1489	6.2	1.3
β-Bisabolene	1494	0.1	2.6
Germacrene A	1498	0.3	2.1
β-Sesquiphellandrene	1511	1.0	1.9
<i>Trans</i> -calamenene	1519	0.4	2.4
Germacrene B	1549	2.1	2.3
Caryophyllene oxide	1570	1.0	2.3
<i>epi</i> -Curzerenone	1580	26.9	1.9
<i>cis</i> -β-Elemenone	1582	2.4	2.3
<i>Trans</i> -β-elemenone	1591	0.4	2.7
Curzerenone	1596	4.6	2.5
<i>iso</i> -Curcumenol	1615	9.7	2.4
ar-Turmenone	1651	2.7	2.6
β-Turmenone	1662	2.3	2.7
Germacrone	1681	12.4	2.5
Unknown 1	1716	2.2	2.8
Unknown 2	1749	3.6	2.7
Unknown 3	1765	1.5	2.7
Monoterpene hydrocarbon	–	1.2	
Oxygenated monoterpenes	–	0.3	
Sesquiterpene hydrocarbons	–	16.8	
Oxygenated sesquiterpenes	–	68.6	
Total identified		87.1	

Unknown 1: *I* = 1716, *m/z* (relative intensity): 230 [*M*⁺] (23), 163 (100), 122 (97), 175 (82), 91 (68), 39 (50), 77 (45), 150 (33), 215 (21), 187 (13); unknown 2: *I* = 1749, 230 [*M*⁺] (14), 122 (100), 94 (27), 81 (21), 150 (17), 39 (16), 215 (14), 65 (12), 162 (7), 197 (4); unknown 3: *I* = 1765, 230 [*M*⁺] (14), 122 (100), 81 (36), 150 (35), 94 (26), 39 (17), 215 (16), 65 (13), 162 (7), 201 (4).

Table 2
Mass data of the identified compounds from *Curcuma sichuanensis* X. X. Chen

Compound	Relative intensity	Mass data ^a
α -Pinene	0943	136 (M^+ , 8), 121 (15), 105 (12), 93 (100), 77 (28), 67 (9), 53 (10), 41 (22), 27 (13)
Camphene	0954	136 (M^+ , 15), 121 (64), 107 (28), 93 (100), 79 (37), 67 (34), 53 (25), 41 (59), 27 (44)
β -Pinene	0976	136 (M^+ , 8), 121 (11), 107 (6), 93 (100), 79 (28), 77 (28), 69 (36), 53 (14), 41 (61), 27 (22)
<i>p</i> -Cymene	1010	134 (M^+ , 30), 119 (100), 103 (4), 91 (19), 77 (5), 65 (7), 58 (7), 51 (4), 41 (8)
Limonene	1021	136 (M^+ , 16), 121 (17), 107 (20), 93 (46), 79 (22), 68 (100), 53 (24), 41 (32), 39 (34), 27 (28)
α -Terpinolene	1076	136 (M^+ , 68), 121 (78), 105 (19), 93 (100), 91 (48), 79 (47), 67 (24), 53 (20), 41 (45), 27 (32)
<i>Trans</i> -pinocarveol	1126	134 (M^+ , 29), 119 (23), 109 (34), 92 (98), 83 (88), 79 (30), 77 (29), 70 (100), 55 (92), 41 (97), 27 (36)
Camphor	1136	152 (M^+ , 28), 137 (4), 108 (39), 95 (100), 83 (32), 81 (74), 69 (39), 55 (38), 41 (79), 27 (35)
Isoborneol	1148	154 (M^+ , 2), 136 (11), 121 (13), 110 (16), 95 (100), 82 (11), 67 (12), 55 (14), 41 (21), 27 (7)
Endo-borneol	1154	154 (M^+ , 1), 139 (5), 121 (4), 110 (16), 95 (100), 82 (6), 67 (9), 55 (11), 41 (27)
<i>p</i> -Cymen-8-ol	1162	150 (M^+ , 8), 135 (45), 115 (3), 105 (2), 91 (12), 77 (4), 65 (8), 51 (4), 43 (100)
α -Terpineol	1173	154 (M^+ , 1), 136 (32), 121 (40), 107 (4), 93 (50), 81 (28), 67 (14), 59 (100), 55 (14), 43 (46), 27 (17)
Myrtenol	1181	152 (M^+ , 3), 134 (2), 119 (16), 108 (32), 91 (47), 79 (100), 67 (12), 55 (9), 41 (15)
Bornyl acetate	1272	196 (M^+ , 3), 154 (14), 136 (55), 121 (50), 108 (18), 95 (100), 80 (18), 67 (16), 55 (18), 43 (72)
2-Undecanone	1278	170 (M^+ , 1), 155 (2), 141 (1), 85 (8), 71 (27), 58 (88), 43 (100), 29 (20), 27 (20)
4-Vinyl-2-methoxy-phenol	1285	150 (M^+ , 100), 135 (81), 107 (24), 77 (31), 63 (5), 51 (8), 39 (13), 29 (2)
2-Undecanol	1291	172 (M^+), 154 (2), 140 (1), 126 (2), 111 (3), 97 (8), 83 (14), 69 (20), 55 (32), 45 (100), 29 (21)
δ -Elemene	1333	204 (M^+ , 5), 189 (3), 175 (1), 161 (23), 136 (68), 121 (100), 105 (18), 93 (84), 77 (25), 67 (9), 53 (16), 41 (50), 27 (17)
β -Bourbonene	1380	204 (M^+ , 3), 189 (1), 161 (36), 123 (70), 105 (14), 91 (15), 81 (100), 67 (6), 55 (8), 41 (17), 27 (7)
β -Elemene	1386	204 (M^+ , 8), 189 (21), 175 (6), 161 (30), 147 (34), 133 (20), 121 (34), 107 (48), 93 (73), 81 (100), 68 (81), 53 (51), 41 (94), 27 (42), 15 (4)
<i>Trans</i> -caryophyllene	1413	204 (M^+ , 14), 189 (12), 175 (7), 161 (23), 148 (21), 133 (59), 120 (31), 105 (35), 93 (82), 79 (52), 68 (81), 55 (35), 41 (100), 27 (29)
γ -Elemene	1429	204 (M^+ , 16), 189 (11), 161 (36), 147 (12), 136 (20), 133 (28), 121 (100), 107 (45), 93 (69), 93 (40), 67 (34), 41 (63)
Aromadendrene	1441	204 (M^+ , 62), 189 (38), 175 (8), 161 (88), 147 (32), 133 (47), 121 (54), 105 (64), 91 (78), 79 (56), 69 (61), 41 (100)
α -Humulene	1447	204 (M^+ , 12), 189 (4), 161 (5), 147 (20), 121 (34), 107 (16), 93 (100), 80 (34), 67 (13), 53 (12), 41 (26), 27 (9)
ar-Curcumene	1468	202 (M^+ , 24), 187 (3), 159 (4), 145 (18), 132 (86), 119 (100), 105 (46), 91 (24), 77 (10), 69 (8), 41 (20), 27 (6)
Germacrene D	1472	204 (M^+ , 16), 161 (100), 133 (19), 120 (22), 119 (30), 105 (45), 91 (42), 81 (30), 79 (31), 77 (28), 55 (25), 41 (37)
β -Selinene	1477	204 (M^+ , 89), 189 (63), 175 (22), 161 (58), 147 (37), 133 (40), 121 (68), 105 (90), 93 (95), 81 (78), 67 (64), 55 (62), 41 (100), 29 (31)
α -Zingiberene	1484	204 (M^+ , 71), 189 (6), 175 (1), 161 (100), 147 (23), 133 (44), 119 (49), 109 (14), 93 (55), 77 (21), 69 (49), 55 (13), 41 (41), 27 (7)
α -Selinene	1487	204 (M^+ , 60), 189 (100), 175 (32), 161 (36), 147 (30), 133 (58), 121 (24), 119 (22), 107 (44), 105 (40), 93 (50), 81 (38), 67 (22), 41 (36)
Curzerene	1489	216 (M^+ , 53), 201 (20), 187 (8), 159 (10), 148 (40), 133 (13), 108 (100), 91 (22), 79 (20), 77 (18), 65 (8), 41 (33)
β -Bisabolene	1494	204 (M^+ , 24), 189 (4), 161 (16), 147 (3), 135 (11), 119 (16), 109 (24), 93 (70), 79 (24), 69 (100), 55 (14), 41 (69), 27 (8)
Germacrene A	1498	204 (M^+ , 16), 189 (25), 161 (27), 147 (30), 133 (23), 119 (29), 107 (61), 105 (58), 93 (77), 81 (67), 68 (100), 67 (92), 53 (57), 41 (86)
β -Sesquiphellandrene	1511	204 (M^+ , 14), 161 (25), 147 (4), 133 (19), 120 (16), 109 (17), 105 (16), 93 (46), 97 (44), 77 (21), 69 (100), 55 (29), 41 (68)
<i>Trans</i> -calamenene	1519	202 (M^+ , 12), 159 (100), 144 (10), 129 (11), 128 (10), 115 (8), 105 (8), 91 (6), 77 (3), 65 (2), 51 (2), 41 (13)
Germacrene B	1549	204 (M^+ , 22), 189 (17), 161 (26), 147 (18), 133 (28), 121 (100), 107 (56), 105 (62), 93 (76), 81 (56), 79 (54), 67 (62), 55 (34), 41 (71)
Caryophyllene oxide	1570	220 (M^+ , 1), 205 (4), 161 (9), 149 (11), 135 (12), 121 (28), 109 (37), 93 (62), 91 (61), 79 (80), 69 (45), 55 (40), 43 (98), 41 (100)
<i>epi</i> -Curzerenone	1580	230 (M^+ , 13), 215 (4), 162 (8), 135 (8), 122 (100), 94 (35), 91 (8), 77 (8), 66 (18), 65 (20), 53 (12), 41 (12)
<i>cis</i> - β -Elemenone	1582	218 (M^+ , 7), 203 (6), 175 (9), 161 (6), 150 (25), 135 (88), 121 (82), 107 (100), 93 (55), 86 (36), 79 (20), 67 (49), 53 (26), 41 (54)
<i>Trans</i> - β -elemenone	1591	218 (M^+ , 1), 203 (8), 175 (9), 161 (4), 150 (24), 135 (92), 121 (76), 107 (100), 93 (48), 86 (36), 79 (24), 67 (54), 53 (26), 41 (54)
Curzerenone	1596	230 (M^+ , 42), 215 (18), 162 (16), 135 (12), 122 (100), 94 (38), 91 (14), 77 (8), 66 (20), 65 (18), 53 (10), 41 (16)
<i>iso</i> -Curcumenol	1615	234 (M^+ , 14), 219 (13), 201 (10), 191 (100), 173 (28), 147 (36), 145 (35), 133 (39), 121 (96), 105 (86), 93 (42), 91 (40), 79 (28), 77 (26), 67 (29), 53 (18), 41 (23)
ar-Turmenone	1651	216 (M^+ , 16), 201 (12), 132 (16), 119 (48), 105 (10), 98 (8), 91 (18), 83 (100), 77 (7), 65 (6), 55 (24), 41 (12)
β -Turmenone	1662	218 (M^+ , 3), 200 (5), 157 (4), 135 (2), 120 (34), 119 (32), 105 (76), 91 (28), 83 (100), 77 (25), 65 (8), 56 (4)
Germacrone	1681	218 (M^+ , 27), 203 (9), 175 (21), 161 (6), 147 (11), 135 (84), 121 (36), 107 (100), 91 (26), 79 (18), 67 (48), 53 (10), 41 (15)

^a (m/z) Relative intensity shown in parenthesis, and the ion of relative intensity 100 was used for the quantification.

the corresponding authentic standards and library mass spectra. Comparison of their mass spectra with that of *epi-curzerenone* indicated that they have the same molecular ion at *m/z* 230 as well as fragment ions at *m/z* 122, 150 and 215. Therefore, these three unknown might be the isomers of *epi-curzerenone* existing in the plant extract.

The results of the volatile components detected in *C. sichuanensis* X. X. Chen were summarized into two major groups of compounds, i.e., the sesquiterpene and monoterpenes. The total percentages of monoterpene hydrocarbon, oxygenated monoterpenes, sesquiterpene hydrocarbons and oxygenated sesquiterpenes existed in *C. sichuanensis* X. X. Chen are listed in Table 1. The total percentage of the sesquiterpene group (85.4%) was more than 55 times higher than that of the monoterpene group (1.5%), indicating that the sesquiterpene was the dominant group in the essential oil of *C. sichuanensis* X. X. Chen. The result was comparable to those reported previously [7–14].

Comparison of the results from this study with those reported previously [7,8,13,14] indicated that the identity of chemical components and their quantity are different from *C. sichuanensis* and *C. wenyujin*. It was reported by Chen et al. that detection of the DNA polymorphism in *C. sichuanensis* and *C. wenyujin* by using RAPD could not differentiate the two *Curcuma* sp. [20]. The DNA results suggested that these two species should be combined into one. Different outcome, however, was reported by Cao and Komatsu [21] who used a trn K nucleotide sequencing approach for the rapid and simple molecular identification of six plants including *Curcuma C. sichuanensis*, *Curcuma C. wenyujin* and *Curcuma C. longa* collected in Sichuan Province. The study showed significant difference in trn K sequences between *C. sichuanensis* and *C. wenyujin* [21]. The present study confirmed the difference observed by Cao and Komatsu with the analytical results of chemical components.

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