

# Analysis of Volatile Components of Tieguanyin and Dongding Oolong Teas by Simultaneous Distillation Extraction Coupled with Gas Chromatography-Mass Spectrometry

J.S. ZHOU<sup>1,†</sup>, S.D. LV<sup>1,†</sup>, D.H. JIANG<sup>2</sup>, X.D. WU<sup>2</sup>, M. LIAN<sup>1</sup>, C. WANG<sup>1</sup> and Q.X. MENG<sup>1,\*</sup>

<sup>1</sup>Faculty of Life Science and Technology, Kunming University of Science and Technology, Kunming, P.R. China <sup>2</sup>Pu'er Comprehensive Technical Testing Center, National Pu'er Tea Quality Supervision and Inspection Center, Pu'er, P.R. China

\*Corresponding author: Fax: +86 871 65920570; Tel: +86 871 65920541; E-mail: qxmeng@scbg.ac.cn, shidonglv@163.com †These authors contributed equally to this work and should be considered co-first authors

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The difference of volatile component was studied by simultaneous steam of volatile compounds were identified and esters compounds, <i>etc.</i> Among includes phytol, nerolidol, linalool, of Dongding oolong tea. The SDE/GC- In comparison, there were remarkal distinguishing these two oolong teas	at in Tieguanyin (from Fujian province) distillation extraction coupled with gas in these two kinds of oolong teas and n them, alcohols are the most abundant <i>etc.</i> In addition, nitrogens ( <i>viz.</i> , indole a MS is proven to be a suitable technique oble differences in flavor and aroma co with similar appearance and quality ch	and Dongding oolong tea (from Taiwan pro- chromatography-mass spectrometry (GC-MS nainly including alcohols, hydrocarbons, ald components in Tieguanyin and Dongding o und pyrazines compounds) existed in higher of to extract and analyze the volatile componen mposition of the two types of oolong tea, w naracteristics.	vince) in China S). A total of 84 ehydes, ketones olong teas, also concentration in ts of oolong tea. vere helpful for

Keywords: Oolong tea, Steam distillation extraction, Volatile component, GC-MS.

#### INTRODUCTION

Oolong tea is a semi-fermented tea goes through an intermediate process involving withering, rolled, brief oxidation and drying. Because of undergoing semi-fermentation process, tea leaves refer to natural reactions induced by oxidative enzymes. The fermentation degree of oolong tea is mostly in the range of 20-80  $\%^{1,2}$ , among Tieguanyin and Dongding oolong teas are the two typical oolong tea samples produced from Fujian and Taiwan province of China. And the fermentation degrees of them are approximately 20-40  $\%^3$ .

The original purpose of tea fermentation was to enhance the flavor of tea. Therefore, flavor is the most important element for tea evaluation<sup>4</sup>. In China, Tieguanyin and Dongding oolong teas are two kinds of famous oolong teas with slight fermentation degree. Because of the degree of fermentation is relatively close, from the point of sensory evaluation, these two kinds of oolong teas have similar appearance characteristics, taste and flavor characteristics. In fact, the difference of production areas, elevation and climate, processing techniques will result in different chemical compositions and eventually affect the quality and characteristics of the tea<sup>5,6</sup>. Whereas it is almost impossible to find out these differences by simply using sensory evaluation methods. To date, no study has been reported on chemical difference in Tieguanyin and Dongding oolong teas by using instrumental analysis methods. Therefore, it is necessary to study the volatile composition of tea with similar appearance characteristics and further find out the aroma differences between them and therefore distinguish them objectively.

Till now, many extraction techniques have been developed to analyze the volatile components in tea. These techniques mainly including supercritical fluid extraction, steam distillation, liquid-liquid extraction, accelerated solvent extraction and simultaneous distillation extraction (SDE)<sup>7-9</sup>, *etc.* Due to the main advantages of simplifying experimental procedures, relatively low cost, saving organic solvents and high uptake, steam distillation extraction has been widely used for analyzing the volatile components of various foods<sup>10,11</sup>.

In this study, we attempt to find out some volatile components in tea that could be used as an indicator for distinguishing oolong teas with similar appearance and flavor characteristics and we also hope to find some volatile compounds which may associate with producing area, processing technology and climate, *etc*. Our study will also provide a scientific role on the special flavor quality assessment of oolong teas.

# EXPERIMENTAL

**Tea samples:** In this work, Tieguanyin collected from Fujian province and Dongding oolong tea collected from Taiwan province in China, these samples were produced in 2013.

**Extraction of volatile compounds:** The preparation of tea extract and chromatographic conditions for analyzing volatile compounds were developed and validated according to reported method<sup>12-14</sup>. Briefly, 20 g tea powder was weighed and extracted with 400 mL boiling water for 3 h by the Likens-Nickerson steam distillation extraction with 40 mL dichloro-ethane heated at 40 °C by using a water bath as the solvent. The dichloroethane was dehydrated with 5 g anhydrous sodium sulphate and then concentrated to 1 mL by using a rotary evaporator. Finally, the sample essential oils were stored at 4 °C for analysis.

**GC-MS analysis:** An Agilent 7890B GC sytem coupled with an Agilent 5977A mass selective detector (MSD) was used to perform the analysis (Agilent Technologies, Palo Alto, CA, USA). An Agilent HP-5MS capillary column (30 m × 0.25 mm inner diameter, 0.25 µm film thickness) was equipped and the helium (percentage purity > 99.999 %) flow rate was 1 mL/min. The injector temperature was 250 °C and 1 µL was injected with the injection port operated at a split ratio of 1:5. The GC oven temperature was held at 50 °C for 5 min and programmed from 50 to 210 °C at 3 °C/min, this temperature was held for 3 min and then increased to 230 °C at 15 °C/min. The mass spectrometer was operated in an electron-impact mode of 70 eV with a source temperature of 230 °C and a quadrupole set of 150 °C, the mass scan range was 30-500 atomic mass units (amu) and solvent delay time was 3 min.

**Data analysis:** Identifications of the peaks were made by searching National Institute of Standards and Technology (NIST) 08. L MS library (a match quality of 85 % minimum was used as a criterion). The relative percentages of the detected peaks were obtained by peak-area normalization and all relative response factors being taken as one.

## **RESULTS AND DISCUSSION**

Analysis of volatile compounds between tieguanyin and dongding oolong tea: In total ion chromatogram (TIC) of tested tea samples, the identification of peaks was carried out by NIST searching. A total of 84 aroma compounds were identified in two kinds of oolong teas and their TICs were presented in Fig. 1 and the information of these compounds are tabulated in Table-1.

A total of 62 volatile compounds were identified in Tieguanyin oolong tea and jointly represented of 98.58 % of the total extracts. These identified compounds mainly including phytol (50.04 %), nerolidol (11.22 %), dihydrojasmone lactone (6.41 %), indole (4.64 %), benzylcarboxaldehyde (2.64 %), phenylethyl alcohol (2.45 %), perhydrofarnesyl acetone (2.42 %), methyl jasmonate (1.93 %), dihydroactinidiolide (1.85 %) and linalool (1.29 %), *etc.* 

A total of 75 volatile compounds were identified in Tieguanyin oolong tea and jointly represented of 95.60 % of the total extracts. These identified compounds mainly including indole (11.32 %), nerolidol (10.27 %), 3,7-dimethylocta-1,5,7-triene-3-ol (7.15 %), linalool (5.38 %), benzylcarboxaldehyde (4.54 %),  $\beta$ -ionone (3.26 %), dihydroactinidiolide (2.94 %), hexanal (2.79 %), perhydrofarnesyl acetone (2.16 %) and benzyl cyanide (2.05 %), *etc.* 

GC-MS ANALYSIS RESULTS OF AROMA COMPONENTS IN THE TWO KINDS OF OOLONG TEAS						
No Retention tim	Detention times	Compounds	Match degree (%)	Relative percentage content (%) <sup>a</sup>		
	Retention time			Tieguanyin	Dongding oolong	
1	3.526	1-Pentanol	86	0.09	0.41	
2	3.591	(Z)-2-Penten-1-ol	93	0.13	0.80	
3	4.232	Hexanal	90	0.50	2.79	
4	4.428	2-Methyltetrahydrofuran-3-one	87	-	0.56	
5	4.636	N-Ethylpyrrole	87	-	0.31	
6	4.879	2-Methylpyrazine	89	-	0.46	
7	5.206	Furfural	91	0.09	1.59	
8	5.865	trans-2-Hexenal	94	0.20	0.46	
9	5.965	Leaf alcohol	86	0.08	-	
10	7.342	2-Heptanone	87	-	0.13	
11	7.746	Heptanal	93	0.09	0.39	
12	8.084	2,5-Dimethyl pyrazine	87	-	0.27	
13	8.150	2-Acetylfuran	85	-	0.97	
14	10.292	Benzaldehyde	95	0.24	1.10	
15	10.542	5-Methyl furfural	90	-	0.40	
16	11.343	1-Octen-3-ol	87	0.07	0.29	
17	11.598	2,3-Octandione	85	0.13	-	
18	11.723	Heptanoic acid	86	0.12	1.14	
19	11.883	2-Pentylfuran	88	-	0.75	
20	12.144	(E,E)-2,4-Heptadienal	94	0.10	0.16	
21	12.310	2-Ethyl-5-methylpyrazine	91	-	0.19	
22	12.465	Octanal	90	0.09	-	
23	13.604	Dipentene	95	-	0.18	
24	13.907	Benzyl alcohol	97	0.36	0.64	
25	14.352	Benzylcarboxaldehyde	94	2.64	4.54	
26	14.649	1-Ethylpyrrole-2-carboxaldehyde	90	-	1.45	

TABLE-1

28   14.922 $\gamma$ Hexalactone   85   0.17   0.47     29   15.462   Actyl benzene   90   0.017   0.21     31   16.216   2-Ethyl-3,5-dimethylpyrazine   90   -   0.44     32   16.625   Linalool oxide II   90   0.22   1.17     33   16.934   ( <i>E.F.</i> )-3,5-Octaden-2-one   87   -   0.16     34   17.43   Linalool   97   1.29   5.38     35   17.462   3,7-Dimethylocta-1,5.7-ritene-3-ol   86   0.89   7.15     36   17.783   Phenylethyl alcolodi   96   0.67   2.05     38   20.554   Linalool oxide III   90   0.32   0.67     39   20.774   Linalool oxide II   90   0.52   1.15     41   21.569 $\alpha$ -Terpinol   86   0.45   1.40     42   21.712   Methyl salicylate   98   -   0.37     43   21.854   G-Methylbenzyl acctate   95   -   0.19     44   21.985   Safranal </th <th>27</th> <th>14.690</th> <th>3,7-Dimethyl-1,3,6-octatriene</th> <th>93</th> <th>0.09</th> <th>-</th>	27	14.690	3,7-Dimethyl-1,3,6-octatriene	93	0.09	-
29     15.462     Åæyt benzene     90     0.07     0.21       30     15.842     Linalool oxide I     90      0.44       32     16.625     Linalool oxide I     90      0.117       33     16.934     (££)-3.5-Octailen-2-one     87      0.16       34     17.243     Linalool     97     1.29     5.38       35     17.462     3.7-Dimethylocti -1.5.7-rinen-3-ol     86     0.89     7.15       36     17.783     Phenylethylacholo     94     2.45     1.24       37     19.077     Benzyl cymide     96     0.16     1.15       38     20.554     Linalool oxide II     90     0.23     0.67       40     21.480     1.3.5.8-Undecateracene     96     0.16     1.15       41     21.569 $o$ -Terpineol     86     0.45     1.40       42     21.712     Methyl bangraj actate     95     -     0.19       43     21.884     coApriniadehyde	28	14.922	γ- Hexalactone	85	0.17	0.47
30   15.842   Linabol oxide I   90   0.31   1.54     31   16.216   2-Eithyl-3.5-dimetrylpyzzine   90   0.22   1.17     33   16.625   Linalool oxide II   90   0.22   1.17     33   16.634   ( <i>E,E)</i> -3.5-Octadien-2-one   87   -   0.16     34   17.243   Linalool   97   1.29   5.38     35   17.462   3.7-Dimethylocta-1.5.7-riene-3-ol   86   0.89   7.15     36   17.783   Phenylethyl alcohol   94   2.45   1.24     37   19.077   Benzyl cyanide   96   0.57   2.05     38   20.554   Linalool oxide II   90   0.32   0.67     40   21.480   1.3.5.8-Undereaterane   96   0.16   1.15     41   21.569   -C-terpineol   86   0.45   1.40     42   21.712   Methyl salicyl acte   98   -   0.37     43   21.854   -G-Methyl Methyl acte   98   -   0.37     44   21.985   Safr	29	15.462	Acetyl benzene	90	0.07	0.21
31   16.216   2-Eutyl-3.5-Octadien-2-one   90   -   0.44     32   16.625   Linalool oxide II   90   0.22   1.17     33   16.934 $(F,E)$ -3,5-Octadien-2-one   87   -   0.16     34   17.243   Linalool   97   1.29   5.38     35   17.462   3.7-Dimethyloct-1.5,7-riene-3-ol   86   0.89   7.15     36   17.783   Phenylethyl alcohol   94   2.45   1.24     37   19.077   Benzyl cyanide   96   0.67   2.05     38   20.554   Linalool oxide III   90   0.52   1.79     40   21.480   1.3,5.8-Undecatetraene   96   0.16   1.15     41   21.690 $\alpha$ -Terpinecol   86   0.45   1.40     42   21.712   Methyl salicylate   95   -   0.19     43   21.854 $\alpha$ -Methyl-3-aninopropinitrile   85   0.32   0.87     44   22.984   Captrinaldehyde   90   -   0.16   1.152     45	30	15.842	Linalool oxide I	90	0.31	1.54
32   16.625   Linalool oxide II   90   0.22   1.17     33   16.934   (E,E)-3,5-Octadien-2-one   87   -   0.16     34   17.243   Linalool   97   1.29   5.38     35   17.462   3,7-Dimethylocta-1,5,7-triene-3-ol   86   0.89   7.15     36   17.783   Phenylethyl alcohol   94   2.45   1.24     37   19.077   Benzyl cyanide   96   0.57   2.05     38   20.554   Linalool oxide III   90   0.32   0.67     40   21.480   1,3,5,8-Undecatemane   96   0.16   1.15     41   21.890 $\alpha$ -Terpineol   86   0.45   1.40     42   21.712   Methylyslavij acetae   95   -   0.19     44   21.985   Safranal   98   -   0.37     45   22.384   Caprinaldehyle   90   -   0.26     46   22.994   2-Methyl-3-aminopropinitrile   85   0.32   0.87     47   26.312   Indole <t< td=""><td>31</td><td>16.216</td><td>2-Ethyl-3,5-dimethylpyrazine</td><td>90</td><td>-</td><td>0.44</td></t<>	31	16.216	2-Ethyl-3,5-dimethylpyrazine	90	-	0.44
33   16.934 $(EE)$ -3.5-Octadien-2-one   87   -   0.16     34   17.243   Linalool   97   1.29   5.88     35   17.462   3,7-Dimethylotca-1,5,7-triene-3-ol   86   0.89   7.15     36   17.783   Phenylethyl alcohol   94   2.45   1.24     37   19.077   Benzyl cyanide   96   0.57   2.05     38   20.554   Linalool oxide IV   90   0.52   1.79     40   21.480   1.5,58-Indecenteraene   96   0.16   1.15     41   21.569 $\alpha$ -Terpineol   86   0.445   1.40     42   21.712   Methyl alicylate   98   -   0.25     43   21.854 $\alpha$ -Methylbenzyl acetae   95   -   0.19     44   21.985   Safranal   98   -   0.26     45   22.388   Caprinaldehyde   90   -   0.26     46   22.994   2-Methyl-3-aminopropointirite   85   0.32   0.87     47   26.312   Indole	32	16.625	Linalool oxide II	90	0.22	1.17
34     17.243     Linalool     97     1.29     5.38       35     17.462     3,7-Dimethylocta-1,5,7-trine-3-ol     86     0.89     7.15       36     17.783     Phenylethyl alcohol     94     2.45     1.24       37     19.077     Benzyl cyanide     96     0.57     2.05       38     20.554     Linalool oxide II     90     0.23     0.667       39     20.774     Linalool oxide IV     90     0.52     1.79       40     21.480     1.3.55-Undecatertacene     96     0.16     1.15       41     21.569     α-Terpineol     86     0.45     1.40       42     21.712     Methyl binzyl acetate     95     -     0.19       43     21.884     Caprinaldehyde     90     -     0.26     6       46     22.994     2-Methyl-3-aminopropionitrile     85     0.32     0.87       47     26.312     Indole     95     4.64     11.32       48     27.410     (£.2+2-2-4.D	33	16.934	(E,E)-3,5-Octadien-2-one	87	-	0.16
35     17.462     3,7-Dimethylach-15.7-rinne-3-ol     86     0.89     7.15       36     17.783     Phenylethyl alcohol     94     2.45     1.24       37     19.077     Benzyl cyanide     96     0.57     2.05       38     20.554     Linalool oxide II     90     0.23     0.67       39     20.774     Linalool oxide IV     90     0.23     1.79       40     21.480     1.3.55.Undecatetraene     96     0.16     1.15       41     21.569     a-Terpineol     86     0.45     1.40       42     21.712     Methyl salicylate     98     -     0.25       43     21.884     c-Methylbarzyl acetate     95     -     0.17       45     22.388     Caprinaldehyde     90     -     0.22     0.87       46     22.994     2-Methyl-3-aminopropoinitrile     85     0.32     0.87       47     26.312     Indole     95     4.64     1.32       48     27.410     (E.E.P.2	34	17.243	Linalool	97	1.29	5.38
36   17.783   Phenylethyl alcohol   94   2.45   1.24     37   19.077   Benzyl cyanide   96   0.57   2.05     38   20.554   Linalool oxide III   90   0.23   0.67     39   20.774   Linalool oxide IV   90   0.52   1.79     40   21.480   1.3.58-Undextetrame   96   0.16   1.15     41   21.599 $\alpha$ -Terpineol   86   0.45   1.40     42   21.112   Methyl salicylate   98   -   0.25     43   21.854 $\alpha$ -Methylbenzyl acetate   95   -   0.19     44   21.985   Safranal   98   -   0.37     45   22.384   Caprindlehyde   90   -   0.26     46   22.994   2-Methyl-3-aminopropionitrile   85   0.32   0.87     47   26.312   Indolo   95   4.64   11.32     48   27.410   ( <i>E_E)</i> -2.4-Decadicnal   90   -   0.17     49   28.899   1.1.6-Trimethyl-1.2-dihydronaphthalene </td <td>35</td> <td>17.462</td> <td>3,7-Dimethylocta-1,5,7-triene-3-ol</td> <td>86</td> <td>0.89</td> <td>7.15</td>	35	17.462	3,7-Dimethylocta-1,5,7-triene-3-ol	86	0.89	7.15
37   19.077   Berzyl cyanide   96   0.57   2.05     38   20.554   Linalool oxide III   90   0.23   0.67     39   20.774   Linalool oxide IV   90   0.52   1.79     40   21.480   1.3.5.8-Undecatetraene   96   0.16   1.15     41   21.56 $\alpha$ -Terpincol   86   0.45   1.40     42   21.712   Methyl salicylate   98   -   0.25     43   21.854 $\alpha$ -Methylbenzyl acctate   95   -   0.19     44   21.985   Safranal   98   -   0.26     46   22.994   2-Methyl-3-minopropionitrile   85   0.32   0.87     47   26.312   Indole   95   4.64   11.32     48   27.410 $(E.b)^2.4$ -Decadienal   90   -   0.24     50   29.107   3.7-Dimethyl-6-octadienoic acid   90   0.07   0.46     51   29.754   Decanoic acid   85   0.12   0.31     52   30.301   3-Hexenyl hexanoate	36	17.783	Phenylethyl alcohol	94	2.45	1.24
38     20.554     Linatool oxide III     90     0.23     0.67       39     20.774     Linalool oxide IV     90     0.52     1.79       40     21.480     1.3.5.8-Undecatetrane     96     0.16     1.15       41     21.569 $\alpha$ -Terpineol     86     0.45     1.40       42     21.1712     Methyl salicylate     98     -     0.19       43     21.854 $c^{-Methylbenzyl acetae     95     -     0.19       44     21.985     Safranal     98     -     0.25       45     22.388     Caprinaldehyde     90     -     0.24       46     22.994     2-Methyl-3-aminopropionitrile     85     0.32     0.87       47     26.312     Indole     95     4.64     11.32       48     27.410     (E.EP_2.4)-Decadienal     90     -     0.24       50     29.107     3.7-Dimethyl-6-octadienotic acid     90     0.07     0.46       51     29.754     Decanoic acid     $	37	19.077	Benzyl cyanide	96	0.57	2.05
3920.774Linalool oxide IV900.521.794021.4801.3.5.8-Undecatetrance960.161.154121.569 $c.Terpincol860.451.404221.712Methyl salicylate98-0.254321.854c.Methylbenzyl acctate95-0.194421.985Safranal98-0.374522.388Caprinaldehyde90-0.264622.9942-Methyl-3-aminoproprionitrile850.320.874726.312Indole954.6411.324827.410(E.E)^2A-Decadienal90-0.174928.8991.1.6-Trimethyl-1-2-dihydronaphthalene90-0.245029.1073.7-Dimethyl-6-octadienoic acid900.070.465129.754Decanoic acid850.30-5230.303-Hexenyl hexanoate860.090.235530.977Jasmone980.221.205632.194\sigma-Ionone950.090.495833.286Geranylacetone910.230.645934.591\beta-Ionone966.411.516134.953\delta-Decanoide86-0.296235.251Pentadecane970.230.645934.591\beta-Ionone870.600.6264$	38	20.554	Linalool oxide III	90	0.23	0.67
4021.4801,3,5.8-Undecatetraene960.161.154121.509 $\alpha$ -Terpineol860.451.404221.712Methyl salicylate98-0.254321.854 $\alpha$ -Methylbenzyl acetate95-0.194421.985Safranal98-0.374522.388Caprinaldehyde90-0.264622.9942-Methyl-3-aminopropionitrile850.320.874726.312Indole954.6411.324827.410(E,E)-2,4-Decadienal90-0.174928.8991,1,6-Trimethyl-1,2-dihydronaphtalene90-0.245029.1073.7-Dimethyl-6-caciateric aciad900.070.465129.754Decanoic acid850.120.315230.3303-Hexenyl hexanoate860.090.235330.371β-Damascenone98-0.775430.538Hexyl hexanoate860.090.495732.366Geranylactone910.230.645934.591 $\beta$ -Ionone860.723.266034.900Dihydrojasmone lactone966.411.516134.953Farnesene870.600.626235.221Penadocane91-0.296335.553Farnesene870.600.62<	39	20.774	Linalool oxide IV	90	0.52	1.79
41   21.569 $\alpha$ -Terpineol   86   0.45   1.40     42   21.712   Methyl salicylate   98   -   0.25     43   21.854 $\alpha$ -Methylbenzyl actate   95   -   0.19     44   21.985   Safranal   98   -   0.37     45   22.388   Caprinaldehyde   90   -   0.26     46   22.994   2-Methyl-3-aminopropionitrile   85   0.32   0.87     47   26.312   Indole   95   4.64   11.32     48   27.410 $(E,E)$ -2.4-Decadienal   90   -   0.24     50   29.107   3.7-Dimethyl-6-octatienoic acid   90   0.07   0.46     51   29.754   Decanoic acid   85   0.12   0.31     52   30.30   3-Hexenyl hexanoate   86   0.09   0.23     53   30.371 $\beta$ -Damascenone   98   -   0.77     54   30.538   Hexyl hexanoate   86   0.09   0.23     55   30.977   Iasmone   95   <	40	21.480	1,3,5,8-Undeeatetraene	96	0.16	1.15
42     21.712     Methylaticylate     98     -     0.25       43     21.854     α-Methylbenzyl acetate     95     -     0.19       44     21.985     Safranal     98     -     0.37       45     22.388     Caprinaldehyde     90     -     0.26       46     22.994     2-Methyl-3-aminopropionitrile     85     0.32     0.87       47     26.312     Indole     95     4.64     11.32       48     27.410     ( <i>E.E)</i> -2.4-Decadienal     90     -     0.24       50     29.107     3.7-Dimethyl-1-2-dihydronaphthalene     90     -     0.24       51     29.754     Decanoic acid     85     0.12     0.31       52     30.371     β-Damascenone     98     -     0.77       54     30.538     Hexyl hexanoate     86     0.09     0.43       55     30.977     Jasmone     98     0.22     1.20       55     30.977     Jasmone     98     0.22	41	21.569	α-Terpineol	86	0.45	1.40
1311.1211.11.11.11.11.11.11.11.11.11.11.11.11.	42	21.712	Methyl salicylate	98	-	0.25
44     2.10.51     0.54 (a) (b) (a) (a) (a) (a) (a)     2.5     0.57       45     22.388     Caprinal (e) (a)     90     -     0.26       46     22.994     2-Methyl-3-aminopropionitrile     85     0.32     0.87       47     26.312     Indole     95     4.64     11.32       48     27.410     ( <i>E,E)</i> -2.4-Decadienal     90     -     0.17       49     28.899     1,1.6-Trimethyl-1,2-dihydronaphthalene     90     -     0.24       50     29.107     3.7-Dimethyl-6-octadienoic acid     90     0.07     0.46       51     29.754     Decanoic acid     85     0.12     0.31       52     30.331     β-Damascenone     98     -     0.77       54     30.538     Hexyl hexanoate     86     0.09     0.23       55     30.977     Jasmone     98     0.22     1.20       55     32.194     α-Ionone     86     0.72     3.26       60     34.901     Dihydrojasmone lactone <td< td=""><td>43</td><td>21.854</td><td>a-Methylbenzyl acetate</td><td>95</td><td>_</td><td>0.19</td></td<>	43	21.854	a-Methylbenzyl acetate	95	_	0.19
45   21.363   Caprinaldehyde   90   -   0.26     46   22.994   2-Methyl-3-aminopropionitrile   85   0.32   0.87     47   26.312   Indole   95   4.64   11.32     48   27.410   ( <i>E,E</i> )-2.4-Decadienal   90   -   0.24     50   29.107   3.7-Dimethyl-6-octadienoic acid   90   0.07   0.46     51   29.754   Decanoic acid   85   0.12   0.31     52   30.330   3-Hexenyl hexanoate   85   0.30   -     53   30.371   β-Damascenone   98   -   0.77     54   30.538   Hexyl hexanoate   86   0.09   0.23     55   30.977   Jasmone   98   0.22   1.20     56   32.194   α-Ionone   95   0.09   0.49     57   32.366   Geranylacetone   91   0.23   0.64     59   34.591   β-Ionone   86   0.72   3.26     60   34.900   Dihydrojasmone lactone   96   6	44	21.054	Safranal	08		0.17
4.522.500Capitality90-0.204622.9942.Methyl-3.aminopropionitrile850.320.874726.312Indole954.6411.324827.410 $(E,E)$ -2,4-Decadienal90-0.174928.8991,1.6-Trimethyl-6-octadienoic acid900.070.465129.1073,7-Dimethyl-6-octadienoic acid900.070.465129.754Decanoic acid850.30-5230.3303-Hexenyl hexanoate850.30-5330.371 $\beta$ -Damascenone98-0.775430.538Hexyl hexanoate860.090.235530.977Jasmone980.221.205632.194 $\alpha$ -Ionone950.090.495732.366Coumarin870.180.845833.286Geranylacetone910.230.645934.591 $\beta$ -Ionone86-0.296134.903bihydrojasmone lactone966.411.516134.953 $\delta$ -Decanolide86-0.296235.553Farnesene870.600.626436.200Dihydrojasmone lactone911.2210.276639.031 $\alpha$ -Naphthalenol900.210.726739.102Hexadecane980.170.5168 <td< td=""><td>44</td><td>21.965</td><td>Sallallal</td><td>90</td><td>-</td><td>0.57</td></td<>	44	21.965	Sallallal	90	-	0.57
4622.99422.99422.9940.320.374726.312Indole954.6411.324827.410 $(E,E)$ -2.4-Decadienal90-0.174928.8991,1.6-Trimethyl-1.2-dihydronaphthalene90-0.245029.1073.7-Dimethyl-6-octalienoic acid900.070.465129.754Decanoic acid850.120.315230.3303-Hexenyl hexanoate850.30-5330.371 $\beta$ -Damascenone98-0.775430.538Hexyl hexanoate860.090.235530.977Jasmone950.090.495632.194 $\alpha$ -Ionone950.090.495732.366Coumarin870.180.845833.286Geranylacetone910.230.645934.591 $\beta$ -Ionone86-0.296134.953 $\delta$ -Decanolide86-0.296235.253Farnesene870.600.626436.200Dihydroactinidiolide961.852.946537.743Nerolidol9111.2210.276639.031 $\alpha$ -Naphthalenol900.210.726630.031 $\alpha$ -Naphthalenol910.510.597143.0312.6,10,14*Tertamethylpentadecane960.370.9772 <t< td=""><td>45</td><td>22.300</td><td>2 Mathal 2 amin annonionitrila</td><td>90</td><td>-</td><td>0.20</td></t<>	45	22.300	2 Mathal 2 amin annonionitrila	90	-	0.20
$47$ $20.312$ $11000$ $95$ $4.04$ $11.32$ $48$ $27.410$ $(E,E)-2,4-Decadienal90 0.245029.1073.7-Dimethyl-6-octadienoic acid900.070.465129.754Decanoic acid850.120.315230.3303-Hexenyl hexanoate850.30 5330.371\beta-Damascenone98 0.775430.538Hexyl hexanoate860.090.235530.977Jasmone980.221.205632.194\alpha-Ionone950.090.495732.366Coumarin870.180.845833.286Geranylacetone910.2330.64594.591\beta-Ionone86-70.296235.253Farnesene870.600.626436.200Dihydrojasmone lactone966.411.516134.933\delta-Decanolide86 0.296335.553Farnesene870.600.626436.200Dihydroactinidiolide961.852.946537.743Nerolidol9111.2210.276639.031\alpha-Naphthalenol900.210.726639.031\alpha-Napht$	40	22.994	2-methyl-3-aninopropionitrite	83 05	0.32	0.87
48   27,410   (L,L)-2,4-Decadential   90   -   0.17     49   28,899   1.1,6-Trimethyl-1.2-dihydronaphthalene   90   -   0.24     50   29,107   3,7-Dimethyl-6-octadienoic acid   90   0.07   0.46     51   29,754   Decanoic acid   85   0.12   0.31     52   30,30   3-Hexenyl hexanoate   85   0.30   -     53   30,371   β-Damascenone   98   -   0.77     54   30,538   Hexyl hexanoate   86   0.09   0.23     55   30.977   Jasmone   98   0.22   1.20     56   32,194   -0-Ionone   95   0.09   0.49     57   32,366   Coumarin   87   0.18   0.84     58   33,286   Geranylacetone   91   0.23   0.64     59   34,591   β-Ionone   86   -   0.29     61   34,953   &Decanolide   86   -   0.29     62   35,253   Farnesene   87   0.60	47	20.512	(EE) 2.4 Decedience	95	4.04	0.17
49   28.899   11,6-1111ethyl-1,2-uthydrohaphthatene   90   -   0.24     50   29.107   3,7-Dimethyl-6-octadienoic acid   90   0.07   0.46     51   29.754   Decanoic acid   85   0.12   0.31     52   30.330   3-Hexenyl hexanoate   85   0.30   -     53   30.371   β-Damascenone   98   -   0.77     54   30.538   Hexyl hexanoate   86   0.09   0.23     55   30.977   Jasmone   98   0.22   1.20     56   32.194   α-Ionone   95   0.09   0.49     57   32.366   Geranylacetone   91   0.23   0.64     58   33.286   Geranylacetone   91   0.23   0.64     59   34.591   β-Ionone   86   0.72   3.26     60   34.900   Dihydrojasmone lactone   96   6.41   1.51     61   34.953   &Decanolide   86   -   0.29     63   35.553   Farnesene   87   0.	48	27.410	( <i>E,E</i> )-2,4-Decadienal	90	-	0.17
5029.10739.7-Dimetry10-octadientols acid900.070.465129.754Decanoic acid850.120.315230.3303-Hexeny1 hexanoate850.30-5330.371 $\beta$ -Damascenone98-0.775430.538Hexy1 hexanoate860.090.235530.977Jasmone980.221.205632.194α-Ionone950.090.495732.366Coumarin870.180.845833.286Geranylacetone910.230.645934.591β-Ionone860.723.266034.900Dihydrojasmone lactone966.411.516134.953δ-Decanolide86-0.296235.221Pentadecane91-0.296335.553Farnesene870.600.626436.200Dihydrojasmonate961.852.946537.743Nerolidol9111.2210.276639.031α-Naphthalenol900.210.726739.102Hexadecane980.170.516840.6392.Phenethyl hexanoate860.30-6940.889Methyl jasmonate991.930.697143.0312.6,10,14-Tetramethylpentadecane970.210.597143.0312.6	49	28.899	1,1,6-1rimetnyi-1,2-dinydronaphtnaiene	90	-	0.24
51   29,754   Decanoic acid   85   0.12   0.31     52   30,330   3-Hexenyl hexanoate   85   0.30   -     53   30,371   β-Damascenone   98   -   0.77     54   30,538   Hexyl hexanoate   86   0.09   0.23     55   30,977   Jasmone   98   0.22   1.20     56   32,194   α-lonone   95   0.09   0.49     57   32,366   Coumarin   87   0.18   0.84     58   33,286   Geranylacetone   91   0.23   0.64     59   34,591   β-lonone   86   0.72   3.26     60   34,900   Dihydrojasmone lactone   96   6.41   1.51     61   34,953   & Decanolide   86   -   0.29     63   35,553   Farnesene   87   0.60   0.62     64   36,200   Dihydroactinidiolide   96   1.85   2.94     65   37,743   Nerolidol   91   1.12.2   10.27	50	29.107	3,7-Dimethyl-6-octadienoic acid	90	0.07	0.46
52   30.330   3-Hexenyl nexanoate   85   0.30   -     53   30.371   β-Damascone   98   -   0.77     54   30.538   Hexyl hexanoate   86   0.09   0.23     55   30.977   Jasmone   98   0.22   1.20     56   32.194   α-Ionone   95   0.09   0.49     57   32.366   Coumarin   87   0.18   0.84     58   33.286   Geranylacetone   91   0.23   0.64     59   34.591   β-Ionone   86   0.72   3.26     60   34.900   Dihydrojasmone lactone   96   6.41   1.51     61   34.953   δ-Decanolide   86   -   0.29     62   35.553   Farnesene   87   0.60   0.62     64   36.200   Dihydrocitnidiolide   96   1.85   2.94     65   37.743   Nerolidol   91   11.22   10.27     66   39.031   α-Naphthalenol   90   0.21   0.72	51	29.754	Decanoic acid	85	0.12	0.31
53   30.371   β-Damascenone   98   -   0.77     54   30.538   Hexyl hexanoate   86   0.09   0.23     55   30.977   Jasmone   98   0.22   1.20     56   32.194   α-Ionone   95   0.09   0.49     57   32.366   Coumarin   87   0.18   0.84     58   33.286   Geranylacetone   91   0.23   0.64     59   34.591   β-Ionone   86   0.72   3.26     60   34.900   Dihydrojasmone lactone   96   6.41   1.51     61   34.953   δ-Decanolide   86   -   0.29     62   35.221   Pentadecane   91   -   0.29     63   35.553   Farnesene   87   0.60   0.62     64   36.200   Dihydroactinidiolide   96   1.85   2.94     65   37.743   Nerolidol   91   11.22   10.27     66   39.031   α-Naphthalenol   90   0.21   0.72	52	30.330	3-Hexenyl hexanoate	85	0.30	-
54   30.538   Hexyl hexanoate   86   0.09   0.23     55   30.977   Jasmone   98   0.22   1.20     56   32.194   α-Ionone   95   0.09   0.49     57   32.366   Coumarin   87   0.18   0.84     58   33.286   Geranylacetone   91   0.23   0.64     59   34.591   β-Ionone   86   0.72   3.26     60   34.900   Dihydrojasmone lactone   96   6.41   1.51     61   34.953   δ-Decanolide   86   -   0.29     63   35.553   Farnesene   87   0.60   0.62     64   36.200   Dihydroactinidiolide   96   1.85   2.94     65   37.743   Nerolidol   91   11.22   10.27     66   39.031   α-Naphthalenol   90   0.21   0.72     67   39.102   Hexadecane   98   0.17   0.51     68   40.639   2-Phenethyl hexanoate   86   0.30   - <td>53</td> <td>30.371</td> <td>β-Damascenone</td> <td>98</td> <td>-</td> <td>0.77</td>	53	30.371	β-Damascenone	98	-	0.77
55   30.977   Jasmone   98   0.22   1.20     56   32.194   α-Ionone   95   0.09   0.49     57   32.366   Coumarin   87   0.18   0.84     58   33.286   Geranylacetone   91   0.23   0.64     59   34.591   β-Ionone   86   0.72   3.26     60   34.900   Dihydrojasmone lactone   96   6.41   1.51     61   34.953   δ-Decanolide   86   -   0.29     62   35.253   Farnesene   87   0.60   0.62     64   36.200   Dihydroactinidiolide   96   1.85   2.94     65   37.743   Nerolidol   91   11.22   10.27     66   39.031   α-Naphthalenol   90   0.21   0.72     67   39.102   Hexadecane   98   0.17   0.51     68   40.639   2-Phenethyl hexanoate   86   0.30   -     69   40.889   Methyl jasmonate   99   1.93   0.69 <td>54</td> <td>30.538</td> <td>Hexyl hexanoate</td> <td>86</td> <td>0.09</td> <td>0.23</td>	54	30.538	Hexyl hexanoate	86	0.09	0.23
$56$ $32.194$ $\alpha$ -Ionone $95$ $0.09$ $0.49$ $57$ $32.366$ Coumarin $87$ $0.18$ $0.84$ $58$ $33.286$ Geranylacetone $91$ $0.23$ $0.64$ $59$ $34.591$ $\beta$ -Ionone $86$ $0.72$ $3.26$ $60$ $34.900$ Dihydrojasmone lactone $96$ $6.41$ $1.51$ $61$ $34.953$ $\delta$ -Decanolide $86$ - $0.29$ $62$ $35.221$ Pentadecane $91$ - $0.29$ $63$ $35.553$ Farnesene $87$ $0.60$ $0.62$ $64$ $36.200$ Dihydroactinidiolide $96$ $1.85$ $2.94$ $65$ $37.743$ Nerolidol $91$ $11.22$ $10.27$ $66$ $39.031$ $\alpha$ -Naphthalenol $90$ $0.21$ $0.72$ $67$ $39.102$ Hexadecane $86$ $0.30$ - $69$ $40.889$ Methyl jasmonate $99$ $1.93$ $0.69$ $70$ $42.806$ Heptadecane $97$ $0.21$ $0.59$ $71$ $43.031$ $2.6,10,14$ -Tetramethylpentadecane $97$ $0.23$ - $73$ $44.972$ Benzyl benzoate $97$ $0.22$ - $74$ $45.121$ Paranaphtalene $94$ $0.13$ $0.28$ $75$ $46.320$ Octadecane $95$ $0.08$ $0.37$	55	30.977	Jasmone	98	0.22	1.20
$57$ $32.366$ Coumarin $87$ $0.18$ $0.84$ $58$ $33.286$ Geranylacetone $91$ $0.23$ $0.64$ $59$ $34.591$ $\beta$ -Ionone $86$ $0.72$ $3.26$ $60$ $34.900$ Dihydrojasmone lactone $96$ $6.41$ $1.51$ $61$ $34.953$ $\delta$ -Decanolide $86$ $ 0.29$ $62$ $35.221$ Pentadecane $91$ $ 0.29$ $63$ $35.553$ Farnesene $87$ $0.60$ $0.62$ $64$ $36.200$ Dihydroactinidiolide $96$ $1.85$ $2.94$ $65$ $37.743$ Nerolidol $91$ $11.22$ $10.27$ $66$ $39.031$ $\alpha$ -Naphthalenol $90$ $0.21$ $0.72$ $67$ $39.102$ Hexadecane $98$ $0.17$ $0.51$ $68$ $40.639$ $2$ -Phenethyl hexanoate $86$ $0.30$ $ 69$ $40.889$ Methyl jasmonate $99$ $1.93$ $0.69$ $70$ $42.806$ Heptadecane $97$ $0.21$ $0.59$ $71$ $43.031$ $2,6,10,14$ -Tetramethylpentadecane $96$ $0.37$ $0.97$ $72$ $43.583$ Geranylgeraniol $85$ $0.23$ $ 73$ $44.972$ Benzyl benzoate $97$ $0.22$ $ 74$ $45.121$ Paranaphtalene $94$ $0.13$ $0.28$ $75$ $46.320$ Octadecane $95$ $0.08$ $0.37$	56	32.194	α-Ionone	95	0.09	0.49
5833.286Geranylacetone910.230.645934.591 $\beta$ -Ionone860.723.266034.900Dihydrojasmone lactone966.411.516134.953 $\delta$ -Decanolide86-0.296235.221Pentadecane91-0.296335.553Farnesene870.600.626436.200Dihydroactinidiolide961.852.946537.743Nerolidol9111.2210.276639.031 $\alpha$ -Naphthalenol900.210.726840.6392-Phenethyl hexanoate860.30-6940.889Methyl jasmonate991.930.697042.806Heptadecane970.210.597143.0312,6,10,14-Tetramethylpentadecane960.370.977243.583Geranylgeraniol850.23-7344.972Benzyl benzoate970.22-7445.121Paranaphtalene940.130.287546.320Octadecane950.080.37	57	32.366	Coumarin	87	0.18	0.84
5934.591β-Ionone860.723.266034.900Dihydrojasmone lactone966.411.516134.953δ-Decanolide86-0.296235.221Pentadecane91-0.296335.553Farnesene870.600.626436.200Dihydroactinidiolide961.852.946537.743Nerolidol9111.2210.276639.031α-Naphthalenol900.210.726840.6392-Phenethyl hexanoate860.30-6940.889Methyl jasmonate991.930.697042.806Heptadecane970.210.597143.0312.6,10,14-Tetramethylpentadecane960.370.977243.583Geranylgeraniol850.23-7344.972Benzyl benzoate970.22-7445.121Paranaphtalene940.130.287546.320Octadecane950.080.37	58	33.286	Geranylacetone	91	0.23	0.64
60   34.900   Dihydrojasmone lactone   96   6.41   1.51     61   34.953   &Decanolide   86   -   0.29     62   35.221   Pentadecane   91   -   0.29     63   35.553   Farnesene   87   0.60   0.62     64   36.200   Dihydroactinidiolide   96   1.85   2.94     65   37.743   Nerolidol   91   11.22   10.27     66   39.031   ox-Naphthalenol   90   0.21   0.72     67   39.102   Hexadecane   98   0.17   0.51     68   40.639   2-Phenethyl hexanoate   86   0.30   -     69   40.889   Methyl jasmonate   99   1.93   0.69     70   42.806   Heptadecane   97   0.21   0.59     71   43.031   2,6,10,14-Tetramethylpentadecane   96   0.37   0.97     72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22<	59	34.591	β-Ionone	86	0.72	3.26
61   34.953   &Decanolide   86   -   0.29     62   35.221   Pentadecane   91   -   0.29     63   35.553   Farnesene   87   0.60   0.62     64   36.200   Dihydroactinidiolide   96   1.85   2.94     65   37.743   Nerolidol   91   11.22   10.27     66   39.031   &-Naphthalenol   90   0.21   0.72     67   39.102   Hexadecane   98   0.17   0.51     68   40.639   2-Phenethyl hexanoate   86   0.30   -     69   40.889   Methyl jasmonate   99   1.93   0.69     70   42.806   Heptadecane   96   0.37   0.97     72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22   -     74   45.121   Paranaphtalene   94   0.13   0.28     75   46.320   Octadecane   95   0.08   0.37	60	34.900	Dihydrojasmone lactone	96	6.41	1.51
62   35.221   Pentadecane   91   -   0.29     63   35.553   Farnesene   87   0.60   0.62     64   36.200   Dihydroactinidiolide   96   1.85   2.94     65   37.743   Nerolidol   91   11.22   10.27     66   39.031 $\alpha$ -Naphthalenol   90   0.21   0.72     67   39.102   Hexadecane   98   0.17   0.51     68   40.639   2-Phenethyl hexanoate   86   0.30   -     69   40.889   Methyl jasmonate   99   1.93   0.69     70   42.806   Heptadecane   97   0.21   0.59     71   43.031   2,6,10,14-Tetramethylpentadecane   96   0.37   0.97     72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22   -     74   45.121   Paranaphtalene   94   0.13   0.28     75   46.320   Octadecane   95   0.08	61	34.953	δ-Decanolide	86	-	0.29
63   35.553   Farnesene   87   0.60   0.62     64   36.200   Dihydroactinidiolide   96   1.85   2.94     65   37.743   Nerolidol   91   11.22   10.27     66   39.031 $\alpha$ -Naphthalenol   90   0.21   0.72     67   39.102   Hexadecane   98   0.17   0.51     68   40.639   2-Phenethyl hexanoate   86   0.30   -     69   40.889   Methyl jasmonate   99   1.93   0.69     70   42.806   Heptadecane   97   0.21   0.59     71   43.031   2,6,10,14-Tetramethylpentadecane   96   0.37   0.97     72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22   -     74   45.121   Paranaphtalene   94   0.13   0.28     75   46.320   Octadecane   95   0.08   0.37	62	35.221	Pentadecane	91	-	0.29
64   36.200   Dihydroactinidiolide   96   1.85   2.94     65   37.743   Nerolidol   91   11.22   10.27     66   39.031 $\alpha$ -Naphthalenol   90   0.21   0.72     67   39.102   Hexadecane   98   0.17   0.51     68   40.639   2-Phenethyl hexanoate   86   0.30   -     69   40.889   Methyl jasmonate   99   1.93   0.69     70   42.806   Heptadecane   97   0.21   0.59     71   43.031   2,6,10,14-Tetramethylpentadecane   96   0.37   0.97     72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22   -     74   45.121   Paranaphtalene   94   0.13   0.28     75   46.320   Octadecane   95   0.08   0.37     76   26.10.14   Tetramethylende   91   0.13   0.28	63	35.553	Farnesene	87	0.60	0.62
65 $37.743$ Nerolidol91 $11.22$ $10.27$ 66 $39.031$ $\alpha$ -Naphthalenol90 $0.21$ $0.72$ 67 $39.102$ Hexadecane98 $0.17$ $0.51$ 68 $40.639$ 2-Phenethyl hexanoate86 $0.30$ -69 $40.889$ Methyl jasmonate99 $1.93$ $0.69$ 70 $42.806$ Heptadecane97 $0.21$ $0.59$ 71 $43.031$ $2,6,10,14$ -Tetramethylpentadecane96 $0.37$ $0.97$ 72 $43.583$ Geranylgeraniol85 $0.23$ -73 $44.972$ Benzyl benzoate97 $0.22$ -74 $45.121$ Paranaphtalene94 $0.13$ $0.28$ 75 $46.320$ Octadecane95 $0.08$ $0.37$	64	36.200	Dihydroactinidiolide	96	1.85	2.94
66 $39.031$ $α$ -Naphthalenol $90$ $0.21$ $0.72$ $67$ $39.102$ Hexadecane $98$ $0.17$ $0.51$ $68$ $40.639$ 2-Phenethyl hexanoate $86$ $0.30$ - $69$ $40.889$ Methyl jasmonate $99$ $1.93$ $0.69$ $70$ $42.806$ Heptadecane $97$ $0.21$ $0.59$ $71$ $43.031$ $2,6,10,14$ -Tetramethylpentadecane $96$ $0.37$ $0.97$ $72$ $43.583$ Geranylgeraniol $85$ $0.23$ - $73$ $44.972$ Benzyl benzoate $97$ $0.22$ - $74$ $45.121$ Paranaphtalene $94$ $0.13$ $0.28$ $75$ $46.320$ Octadecane $95$ $0.08$ $0.37$	65	37.743	Nerolidol	91	11.22	10.27
67   39.102   Hexadecane   98   0.17   0.51     68   40.639   2-Phenethyl hexanoate   86   0.30   -     69   40.889   Methyl jasmonate   99   1.93   0.69     70   42.806   Heptadecane   97   0.21   0.59     71   43.031   2,6,10,14-Tetramethylpentadecane   96   0.37   0.97     72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22   -     74   45.121   Paranaphtalene   94   0.13   0.28     75   46.320   Octadecane   95   0.08   0.37	66	39.031	$\alpha$ -Naphthalenol	90	0.21	0.72
68   40.639   2-Phenethyl hexanoate   86   0.30   -     69   40.889   Methyl jasmonate   99   1.93   0.69     70   42.806   Heptadecane   97   0.21   0.59     71   43.031   2,6,10,14-Tetramethylpentadecane   96   0.37   0.97     72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22   -     74   45.121   Paranaphtalene   94   0.13   0.28     75   46.320   Octadecane   95   0.08   0.37	67	39.102	Hexadecane	98	0.17	0.51
69   40.889   Methyl jasmonate   99   1.93   0.69     70   42.806   Heptadecane   97   0.21   0.59     71   43.031   2,6,10,14-Tetramethylpentadecane   96   0.37   0.97     72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22   -     74   45.121   Paranaphtalene   94   0.13   0.28     75   46.320   Octadecane   95   0.08   0.37	68	40.639	2-Phenethyl hexanoate	86	0.30	-
70   42.806   Heptadecane   97   0.21   0.59     71   43.031   2,6,10,14-Tetramethylpentadecane   96   0.37   0.97     72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22   -     74   45.121   Paranaphtalene   94   0.13   0.28     75   46.320   Octadecane   95   0.08   0.37	69	40.889	Methyl jasmonate	99	1.93	0.69
71   43.031   2,6,10,14-Tetramethylpentadecane   96   0.37   0.97     72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22   -     74   45.121   Paranaphtalene   94   0.13   0.28     75   46.320   Octadecane   95   0.08   0.37	70	42.806	Heptadecane	97	0.21	0.59
72   43.583   Geranylgeraniol   85   0.23   -     73   44.972   Benzyl benzoate   97   0.22   -     74   45.121   Paranaphtalene   94   0.13   0.28     75   46.320   Octadecane   95   0.08   0.37	71	43.031	2,6,10,14-Tetramethylpentadecane	96	0.37	0.97
73 44.972 Benzyl benzoate 97 0.22 -   74 45.121 Paranaphtalene 94 0.13 0.28   75 46.320 Octadecane 95 0.08 0.37	72	43.583	Geranylgeraniol	85	0.23	-
74     45.121     Paranaphtalene     94     0.13     0.28       75     46.320     Octadecane     95     0.08     0.37       76     26.10.14     Texample length     91     0.26     0.01	73	44.972	Benzyl benzoate	97	0.22	-
75     46.320     Octadecane     95     0.08     0.37       76     46.652     2.610.14     Tetemethelbergele     21     2.610     2.610	74	45.121	Paranaphtalene	94	0.13	0.28
	75	46.320	Octadecane	95	0.08	0.37
10  40.052  2.0.10.14- Tetrametnyl nexadecene 91 0.26 0.61	76	46.652	2,6,10,14- Tetramethyl hexadecene	91	0.26	0.61
77 47.619 Caffeine 97 0.28 -	77	47.619	Caffeine	97	0.28	-
78     47.851     Perhydrofarnesyl acetone     98     2.42     2.16	78	47.851	Perhydrofarnesyl acetone	98	2.42	2.16
79 50.261 Farnesyl acetone 90 0.33 0.49	79	50.261	Farnesyl acetone	90	0.33	0.49
80 50.551 Methyl hexadecanoate 99 0.22 1.37	80	50.551	Methyl hexadecanoate	99	0.22	1.37
81 51.222 Isophytol 90 0.31 0.22	81	51.222	Isophytol	90	0.31	0.22
82 55.763 Methyl linoleate 99 0.52 0.85	82	55.763	Methyl linoleate	99	0.52	0.85
83 55.959 Methyl linolenate 99 0.94 1.73	83	55.959	Methyl linolenate	99	0.94	1.73
84 56.451 Phytol 91 50.04 1.45	84	56.451	Phytol	91	50.04	1.45
a. Not detected	a. Not dete	cted				

The degree of fermentation could cause a change of volatile flavor components **1**. As the result, there were considerable amounts of alcohols such as phytol, nerolidol, phenylethyl alcohol, linalool in the Tieguanyin oolong tea. There were higher amounts of 3,7-dimethylocta-1,5,7-triene-3-ol, indole,

linalool, jasmone,  $\beta$ -ionone detected in the Dongding oolong tea, whereas the Tieguanyin produced by light fermentation processing showed significantly lower amounts of volatile components. In addition, 22 volatile components including 2,5-dimethyl pyrazine, 2-acetylfuran, 2-methyltetrahydrofuran-



Fig. 1. GC-MS TIC of aroma components in the two kind of oolong teas (A: Tieguanyin oolong tea, B: Dongding oolong tea)

3-one, N-ethylpyrrole, 5-methyl furfural, 2-pentylfuran and methyl salicylate, *etc.* were only detected in the Dongding oolong tea. In all, the differences between the oolong teas might be resulted from different varieties, geographical regions and processing method, *etc.* 

Analysis of chemical differences of aroma compounds in Tieguanyin and Dongding oolong teas: The aroma compounds comparison result in two different oolong teas was shown in Fig. 2. As can be seen in Fig. 2, there were great differences in the content of aroma components between the tested samples. The alcohols were the most abundant aroma components in the Tieguanyin oolong tea (69.10 %), while only 35.14 % was identified in the Dongding oolong tea. Meanwhile, the content of nitrogens in Dongding oolong tea (17.36%) was higher than in the Tieguanyin oolong tea (5.81%). The total contents of lactone in Tieguanyin oolong tea (8.43 %) were greater than those in Dongding oolong tea (5.21 %). The content of esters in the Tieguanyin oolong tea and the Dongding oolong tea was close and were identified 4.52 and 5.31 %, respectively. In addition, the result showed that the hydrocarbons, aldehydes and ketones existed at the lower contents in the Tieguanyin oolong tea than those in the Dongding oolong tea. The content of acids and furans were relatively lower in the two tested tea samples.



Fig. 3 Comparison of aroma components in two kinds of oolong tea

Although Tieguanyin and Dongding oolong tea have similar shape and taste characteristics, the results showed that these two kinds of tea existed notable differences on the content and the composition of main volatile components. This shows a certain degree of advantages of modern instrumental analysis and the defective of sensory evaluation. It is well known that presence of the innumerable compounds in tea and their multidimensional contribution in determining the final quality of tea<sup>15</sup>, so it is remarkably important to understand of the chemical information existed in tea. In the further work, more samples and the combination with multivariate statistical methods will be applied to further explore the difference between these two kinds of oolong teas.

## Conclusion

In this work, steam distillation extraction coupled with GC-MS was developed for the determination of the aroma components of Tieguanyin and Dongding oolong tea. By using the developed method, 84 volatile components were detected in the two tested oolong tea samples. The alcohols existed at the higher contents in the Tieguanyin oolong tea (69.10 %) than in the Dongding oolong tea (35.14 %). Whereas the content of nitrogens in Dongding oolong tea was nearly three folds than that in the Tieguanyin oolong tea. The hydrocarbons, aldehydes and ketones existed at the higher contents in the Dongding oolong tea than those in the Tieguanyin oolong tea.

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#### REFERENCES

- Y.J. Chen, P.C. Kuo, M.L. Yang, F.Y. Li and J. Tzen, *Food Res. Int.*, 53, 732 (2013).
- J. Lin, P. Zhang, Z. Pan, H. Xu, Y. Luo and X. Wang, Food Chem., 141, 259 (2013).
- C. Ma, Y. Qu, Y. Zhang, B. Qiu, Y. Wang and X. Chen, *Food Chem.*, 152, 285 (2014).
- D. Huo, Y. Wu, M. Yang, H. Fa, X. Luo and C. Hou, *Food Chem.*, 145, 639 (2014).
- J. Lee, D.H. Chambers, E. Chambers, K. Adhikari and Y. Yoon, *Molecules*, 18, 10024 (2013).
- 6. Z. Yang, S. Baldermann and N. Watanabe, Food Res. Int., 53, 585 (2013).
- L. Zhang, Z. Zeng, C. Zhao, H. Kong, X. Lu and G. Xu, J. Chromatogr. A, 1313, 245 (2013).
- 8. H. Sereshti, S. Samadi and M. Jalali-Heravi, *J. Chromatogr. A*, **1280**, 1 (2013).
- K. Jumtee, H. Komura, T. Bamba and E. Fukusaki, J. Biosci. Bioeng., 112, 252 (2011).
- 10. W. Zhuang, J. Cai and Q. Su, Asian J. Chem., 17, 2789 (2005).
- 11. L. Du, J. Li, W. Li, Y. Li, T. Li and D. Xiao, *Food Res. Int.*, **57**, 61 (2014).
- K. Wang, F. Liu, Z. Liu, J. Huang, Z. Xu, Y. Li, J. Chen, Y. Gong and X. Yang, *Int. J. Food Sci. Technol.*, 46, 1406 (2011).
- S.D. Lv, Y.S. Wu, C.W. Li, Y.Q. Xu, L. Liu and Q.X. Meng, J. Agric. Food Chem., 62, 1810 (2014).
- S.D. Lv, Y.S. Wu, Y.Z. Song, J.S. Zhou, M. Lian, C. Wang, L. Liu and Q.X. Meng, *Food Anal. Methods*, 8, 321 (2015).
- R. Banerjee (Roy), B. Tudu, L. Shaw, A. Jana, N. Bhattacharyya and R. Bandyopadhyay, *J. Food Eng.*, **110**, 356 (2012).