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Analysis of Volatile Compounds in the Root Peel, Stem Peel, and Fruit Peel of Pomegranate (*Punica granatum*) by TD GC/MS

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Abstract

Volatile components in the root peels, stem peels, and fruit peels of pomegranate (Punica granatum) were analyzed by thermal desorption gas chromatography/mass spectrometry (TD GC/MS). Twenty-four compounds including 17 hydrocarbons, 1 aldehyde, 1 ketone, 2 heterocyclics, and 3 others were identified in the root peels. Thirty compounds including 5 hydrocarbons, 8 alcohols, 3 aldehydes, 2 ketones, 11 esters, and 1 other were identified in the stem peels. Sixty-two compounds including 10 hydrocarbons, 18 alcohols, 6 aldehydes, 4 ketones, 1 carboxylic acid, 17 esters, 1 heterocyclic, and 5 others were identified in the fruit peels. Monoterpene hydrocarbons such as α-pinene (13.49%), 2-β-pinene (16.31%), δ-3-carene (22.94%), and dl-limonene (17.33%) were found to be the major volatile compounds in the root peels. The main volatile compound in the stem peels and fruit peels was ethanol of alcohol, which represented 40.76% and 42.12% of the total concentration of volatiles, respectively. Other compounds dominating the stem peels and fruit peels were all acetic acids and ethyl ester of ester, which represented 21.29% and 19.59% of the total concentration of volatiles, respectively.

Keywords: *Volatile compound, root peel of pomegranate, stem peel of pomegranate, fruit peel of pomegranate, thermal desorption gas chromatography/mass spectrometry*

1. Introduction

Numerous plants have been demonstrated to produce pesticidal compounds as a chemical defense mechanism against either predation or infection [1]. Aromatic plants are among the most efficient insecticides of botanical origin, and essential oils often constitute the bioactive fraction of plant extracts [2]. Over 2,000 species of plants are known to possess some insecticidal activity. In many cases, the plants have a history of usage as folk remedies and are still used to kill or repel insects [3]. Investigations in several countries confirm that some plant essential oils not only repel insects but also have contact and fumigant insecticidal actions against specific pests and fungicidal actions against some important plant pathogens [4]. Plant essential oils in general have been recognized as an important natural resource of insecticides [5]. Generally, they are safe to humans and other mammals [6]. The pomegranate (*Punica granatum L.*) belongs to the punicaceae family, and it is grown in many countries, especially in the Mediterranean region, Iran, India, Pakistan, Afghanistan, Saudi Arabia, and the subtropical areas of South America [7]. It is widely used for therapeutic formulae, cosmetics, and food seasoning. Since ancient times, the pomegranate has been regarded as a "healing food" with numerous beneficial effects in several diseases [8]. The decoction of the root has been found beneficial in fevers and chronic debility due to malaria [9]. Pomegranate peels have been used in traditional medicine for treating diarrhea and dysentery [10–13]. In Yemen and other countries of the Arabian Peninsula, dried peels have been traditionally used

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for treating diarrhea and stomachache and for healing wounds. In this regard, astringency is a known pharmacological property of tannins [14, 15]. Pomegranate flowers (or gulnar) have been extensively used in Ayurvedic and Unani systems of medicine [16]. The flowers are anti-diabetic [17] and strongly astringent. The flower has also been used for the treatment of injuries from falls and gray hair in young men in traditional Chinese medicine [18]. The root and stem barks are reported to have astringent and anti-helmintic activity [19]. Likewise, pomegranate has been used for centuries in many cultures for the prevention and treatment of a wide number of health disorders (e.g., inflammation, diabetes, diarrhea, dysentery, dental plaque) and to combat intestinal infections and malarial parasites [20]. Root peels, stem peels, and branch peels of the pomegranate tree have been known to effectively stamp out noxious insects. The different parts of the pomegranate have been known as reservoirs of bioactive compounds with potential biological activities. The pomegranate, especially the leaves of the pomegranate, has been shown to decrease the dyslipidemia of obesity and cardiovascular risk factors [22]. Anti-parasitic, anti-microbial, and anti-oxidant activities of pomegranate leaf extract have also been reported [23–25]. Several papers have reported on the ability of pomegranate leaf extract to fight obesity [26], cancer, and other human diseases [27]. As mentioned above, a number of studies on the anti-oxidation [27], anti-microbial [28], anti-cancer [29], anti-obesity [30], and anti-inflammatory activities [31, 32] of the pomegranate have been reported. In addition, the effects are known to be caused by polyphenol in the pomegranate. However, few studies have reported on the insecticidal effect or analyzed the volatile compounds in the pomegranate. Therefore, the goal of this study is to discover the insecticidal volatile compounds in the pomegranate and to develop insecticidal textiles using the compounds. As a part of that, this study aims to analyze the volatile compounds in the root peels, stem peels, and fruit peels of the pomegranate. Future research will focus on the insecticidal effect of volatile compounds against the house dust mite.

2. Materials and Methods

2.1. Materials

A pomegranate tree was purchased from a pomegranate farm in Goheung in November 2012. The roots and stems of the pomegranate tree were separated, washed carefully to remove adhering extraneous substances, and dried with kitchen towel. Fresh, high-quality pomegranates (fruits) were bought from the local market in November 2012. The fruits were washed, dried with kitchen towel, and peeled. Each sample (root peels, stem peels, and fruit peels) was packed in a polyethylene bag and stored at -18℃ until required.

2.2. Analysis of Volatile Compounds in the Root peels, Stem Peels, and Fruit Peels of Pomegranates [33]

2.2.1. Sample Preparation

Sample grinding**:** Each sample was first cut to a uniform length (<5 ㎜) to ensure the efficiency of extraction.

Tenax tube**:** Tenax tubes for volatile adsorption were cooled to room temperature (after thermal desorption for 4 hours while supplying air at 350℃ using thermal desorption equipment of Aux-controller 163 (Gerstel) of high purity), sealed, and used. They were kept in a separate enclosed place to prevent pollution of the atmosphere.

Sample treatment: For sample treatment, 30g of each sample were packed in 3L Tedlar bags, which were then filled with high-purity nitrogen (2L). Then, they were kept in an oven at 32℃ for 2 days. The blank test was treated in the same conditions as each sample after filling with high-purity nitrogen (2L). Next, 1L of each pretreated sample was adsorbed in a Tenax tube and used as a sample for analysis.

2.2.2. Sample Analysis of Volatile Compounds:

Volatile compounds were analyzed by the conditions of Table 1 using thermal desorption gas chromatography/mass spectrometry (TD GC/MS, GC: Agilent 6890N, G1530N, and 2975 MASS).

Table 1. Analytical Conditions of TD GC/MS for Analysis of Volatile Compounds

Gas Chromatography	
Inlet	250℃
Column	DB-1MS (60m×0.25 ㎜×0.25 ㎛)
Flow gas	Helium, Velocity : 25 ㎝/sec
Split ratio	30:1
Oven	50℃/5min, 10℃/min, 260℃/15min
Scan mode	Scan
Scan range	25 to 550 AMU
TDS2, CIS	
TDS2 Desorption temp.	50℃/0.5min, 20℃/min, 230℃/10min
CIS Temp.	-80℃
CIS Desorption temp.	-80℃/0.5min, 10℃/min, 250℃/5min, 300℃/3min
CIS Packing	Tenax TA

3. Results and Discussion

3.1. Volatile Compounds in the Root Peels of Pomegranate

The total ion chromatogram of volatile compounds in the root peels of pomegranates is presented in Figure 1. As shown by Figure 1, peaks in the 13–15-minute range appeared frequently. The major compounds were monoterpene hydrocarbons such as α-pinene, 2-beta-pinene, and dl-limonene, as revealed by Table 2. Peaks in the 13–16-minute range appeared less frequently. The major compounds were also monoterpene hydrocarbons such as α-thujene, camphene, and sabinene. Peaks in the 21–22-minute range, unlike in the stem peels and fruit peels, presented. The major compounds were α-amorphene (monoterpene hydrocarbon) and trans-caryophyllene (sesquiterpene hydrocarbon).

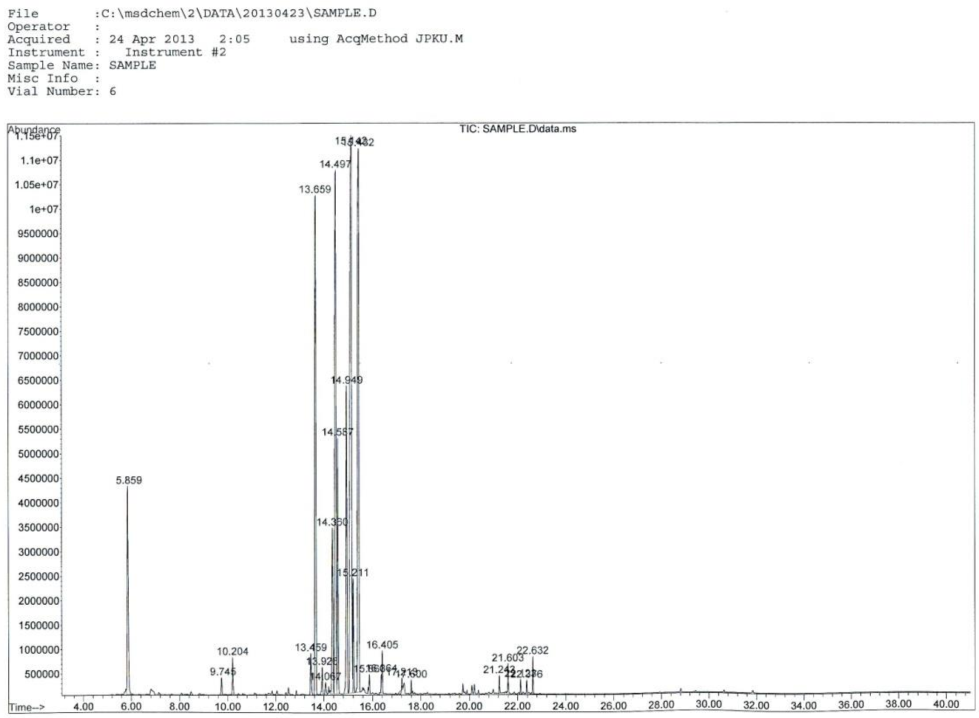

Figure 1. Total Ion Chromatogram of Volatile Compounds in the Root Peels of Pomegranates Analyzed by TD GC/MS

Volatile compounds in the root peels of pomegranates were analyzed by TD GC/MS. As shown in Table 2, 24 compounds were identified. The main volatile compounds were monoterpene hydrocarbons such as α-pinene (13.49%), 2-β-pinene (16.31%), δ-3-carene (22.94%), and dl-limonene (17.33%). The volatile compounds were grouped into six main chemical groups, including 17 hydrocarbons, 1 aldehyde, 1 ketone, 2 heterocyclics, and 3 others. Terpenoids are typical compounds in fruits, vegetables, herbs, spices, and wine [34]. Terpenoids are secondary metabolites of plants abundantly occurring in nature along with alkaloids and flavonoids [33]. Terpenoids represent a form of essential oils, and they are classified according to their isoprene unit (e.g., mono-, sesqui-, di-, and tri-terpene) [34]. They are commonly used as additives not only in the food industry but also in the cosmetic industry [35]. The natural pesticidal properties of some monoterpenes make them useful as potential alternative pest control agents as well as good lead compounds for the development of safe, effective, and fully biodegradable pesticides. Monoterpenes possess many pesticidal activities, including insecticidal [36, 37], herbicidal [38, 39], fungicidal [40, 41], and bactericidal [42, 43] properties. The insecticidal activity of *E. globulus* oil containing 1,8-cineole (33.6%), α-pinene (16.9%), D-limonene (5.5%), and linalool acetate (3.4%) as principal components was assessed against the larvae and pupae of the housefly [44]. The major monoterpene of *E. globulus* oil, 1,8-cineole, showed activity as an antifeedant and ovipositional repellent against adult *Aedes aegypti* [45]. Thymol, camphene, α-pinene, ρ-cymene, and γ-terpinene showed good insecticidal activity against *Tribolium castaneum* adults [46]. Kim et al. [47] stated that 1,8-

cineoleand camphene had larvicidal activity against *C. pipiens pallens*. Some monoterpenes also possess a toxic effect against *C. pipiens* [48]. Moreover, some monoterpenes exhibit a toxic effect toward *Ae. aegypti* L. and *Ae. albopictus* [49]. Thus, many studies on the insecticidal effects of essential oils have been reported.

Table 2. Volatile Compounds in the Root Peels of Pomegranates Analyzed by TD GC/MS

Peak No.	Compound	Group	tR(min.)	Normalized peak area (%)
1	furan(CAS)	IV	5.86	5.44
2	toluene	I	9.75	0.35
3	hexanal(CAS)	II	10.20	0.69
4	alpha-thujene	I	13.46	0.98
5	alpha-pinene, (-)-	I	13.66	13.49
6	camphene	I	13.93	0.56
7	phenol(CAS)	V	14.06	0.31
8	sabinene	I	14.36	4.02
9	2-beta-pinene	I	14.50	16.31
10	beta-myrcene	I	14.59	4.93
11	1-phellandrene	I	14.95	7.50
12	delta-3-carene	I	15.14	22.94
13	o-cymene	I	15.21	1.79
14	dl-limonene	I	15.43	17.33
15	gamma-terpinene	I	15.87	0.29
16	alpha-terpinolene	I	16.36	0.36
17	alpha-terpinolene	I	16.41	0.71
18	camphor	I	17.21	0.03
19	cyclopentasiloxane, decamethyl-	V	17.60	0.17
20	alpha-amorphene	I	21.24	0.29
21	trans-caryophyllene	I	21.60	0.47
22	5-acetamido-4, 7-dioxo-4,7-dihydrobenzofurazan	III	22.13	0.22
23	phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl	V	22.38	0.19
24	dihydropyran	IV	22.63	0.60

I :hydrocarbon, II: aldehyde, III: ketone, IV: heterocyclic, V: other

3.2. Volatile Compounds in the Stem Peels of Pomegranates

The total ion chromatogram of volatile compounds in the stem peels of pomegranates is shown in Figure 2. As shown in Figure 2, peaks in the 5–7-minute range appeared frequently. The main compounds were ethanol and 2-methyl-1-propanol of alcohol and acetic acid and ethyl ester of ester, as revealed by Table 3. Peaks in the 8–9-minute range presented, unlike in the root peels. The compounds were 3-methyl-1-butanol of alcohol and propanoic acid; ethyl ester, propanoic acid, 2-methyl, ethyl ester, and acetic acid 2-methylpropyl ester of ester; and propanamide, n,n-dimethyl- of other.

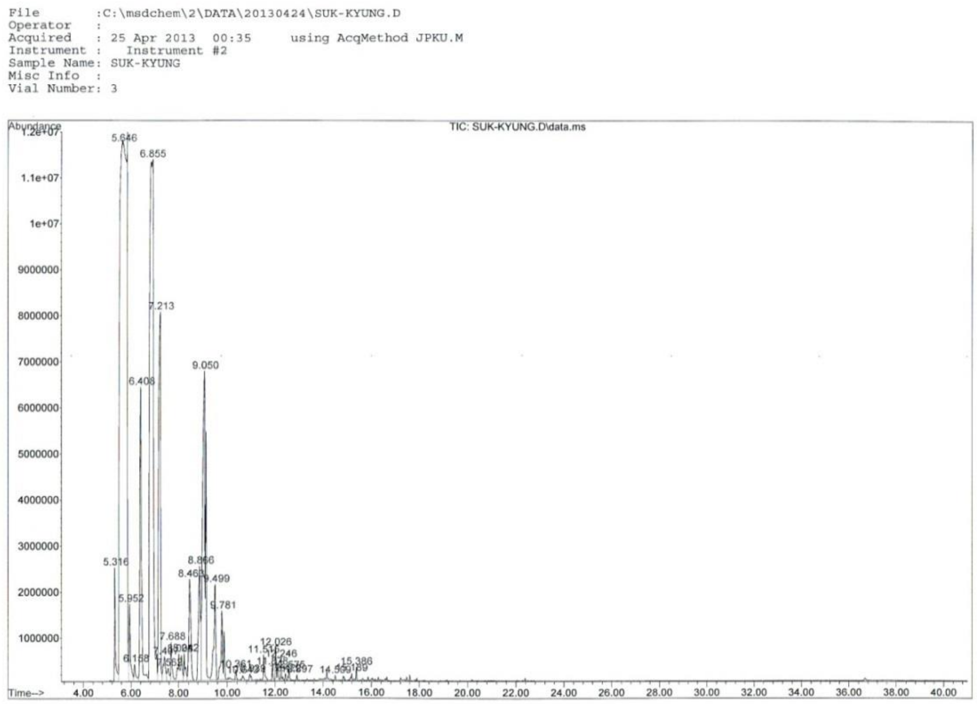

Figure 2. Total Ion Chromatogram of Volatile Compounds in the Stem Peels of Pomegranates Analyzed by TD GC/MS

Volatile compounds in the stem peels of pomegranates were analyzed by TD GC/MS. As shown in Table 3, 30 compounds were identified. The main volatile compound was ethanol of alcohol, which represented 40.76% of the total concentration of volatiles. Other compounds dominating the stem peels were as follows: (i) acetic acid, ethyl ester (21.29%) of ester and (ii) 1-propanol, 2-methyl-(8.30%) and 1-butanol, 3-methyl-(9.37%) of alcohol. The stem peels, unlike the root peels, contained only two monoterpenes: p-cymene and beta-thujene. The volatile compounds were grouped into six main chemical groups, including 5 hydrocarbons, 8 alcohols, 3 aldehydes, 2 ketones, 11 esters, and 1 other.

Table 3. Volatile Compounds in the Stem Peels of Pomegranates Analyzed by TD GC/MS

Peak No.	Compound	Group	tR(min.)	Normalized peak area (%)
1	acetaldehyde	Ⅲ	5.31	1.21
2	ethanol(CAS)	Ⅱ	5.64	40.76
3	acetic acid, methyl ester	Ⅴ	5.95	1.09
4	propanal, 2-methyl-	Ⅲ	6.16	0.31
5	1-propanol(CAS)	Ⅱ	6.41	5.03
6	acetic acid, ethyl ester(CAS)	Ⅴ	6.85	21.29
7	1-propanol, 2-methyl-(CAS)	Ⅱ	7.21	8.30
8	butanal, 3-methyl-(CAS)	Ⅲ	7.40	0.60
9	sulfurous acid, dibutyl ester(CAS)	Ⅴ	7.56	0.31
10	1-butanol(CAS)	Ⅱ	7.69	0.46
11	1-penten-3-ol	Ⅱ	8.01	0.93
12	2-butanone, 3-hydroxy-	Ⅳ	8.24	0.41
13	propanoic acid, ethyl ester(CAS)	Ⅴ	8.46	2.21
14	propanamide, n, n-dimethyl-	Ⅵ	8.87	2.32
15	1-butanol, 3-methyl-	Ⅱ	9.05	9.37
16	propanoic acid, 2-methyl-, ethyl ester(CAS)	Ⅴ	9.50	1.86
17	acetic acid, 2-methylpropyl ester(CAS)	Ⅴ	9.78	1.54
18	butanoic acid, ethyl ester(CAS)	Ⅴ	10.36	0.11
19	octane(CAS)	Ⅰ	10.64	0.09
20	propane, 1-(1-ethoxyethoxy)-	Ⅰ	10.94	0.12
21	butanoic acid, 2-methyl-, ethyl ester	Ⅴ	11.51	0.35
22	1-hexanol	Ⅱ	11.88	0.14
23	1-butanol, 3-methyl-, acetate(CAS)	Ⅴ	12.03	0.43
24	2-heptanone(CAS)	Ⅳ	12.25	0.20
25	styrene	Ⅰ	12.42	0.06
26	2-heptanol	Ⅱ	12.57	0.14
27	propanoic acid, 2-methyl-, 2-methylpropyl ester(CAS)	Ⅴ	12.90	0.06
28	hexanoic acid, ethyl ester(CAS)	Ⅴ	14.51	0.07
29	p-cymene	Ⅰ	15.19	0.12
30	beta-thujene	Ⅰ	15.39	0.10

I:hydrocarbon,II:alcohol, III:aldehyde, IV:ketone, V:ester, VI:other

3.3. Volatile Compounds in the Fruit Peels of Pomegranates

The total ion chromatogram of volatile compounds in the fruit peels of pomegranates is shown in Figure 3. Peaks in the 57-minute range appeared frequently as in the stem peels. The main compounds, as in the stem peels, were ethanol and 2-

methyl-1-propanol of alcohol and acetic acid, ethyl ester of ester, as revealed by Table 4. Peaks in the 8–9-minute range presented as in the stem peels. The compounds were 3-methyl-1-butanol of alcohol, propanoic acid, ethyl ester, propanoic acid, 2-methyl, ethyl ester, and acetic acid 2-methylpropyl ester of ester, and propanamide, n,n-dimethyl- of other.

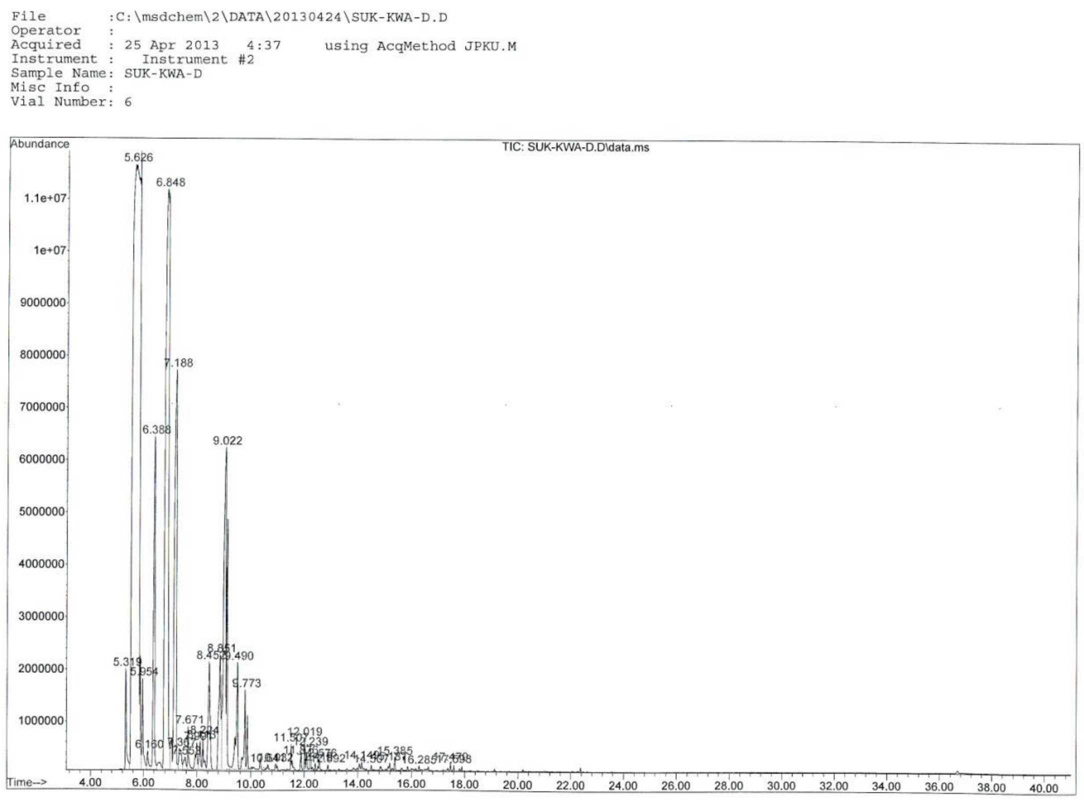

Figure 3. Total ion Chromatogram of Volatile Compounds in the Fruit Peels of Pomegranates Analyzed by TD GC/MS

Volatile compounds in the fruit peels of pomegranates were analyzed by TD GC/MS. As shown in Table 4, 62 compounds were identified. The main volatile compound was ethanol of alcohol (42.12%) as in the stem peels. Other compounds dominating the fruit peels, as in the stem peels, were as follows: (i) acetic acid, ethyl ester (19.59%) of ester and (ii) 1-propanol, 2-methyl-(8.57%) and 1-butanol, 3-methyl-(7.06%) of alcohol. The fruit peels contained four monoterpenes: beta-thujene, o-cymene, beta-phellandrene, and gamma-terpinene. The volatile compounds were grouped into seven main chemical groups, including 10 hydrocarbons, 18 alcohols, 6 aldehydes, 4 ketones, 1 carboxylic acid, 17 esters, 1 heterocyclic, and 5 others.

Table 4. Volatile Compounds in the Fruit Peels of Pomegranates Analyzed by TD GC/MS

Peak No.	Compound	Group	tR(min.)	Normalized peak area (%)
1	acetaldehyde	Ⅲ	5.32	1.08
2	ethanol(CAS)	Ⅱ	5.63	17.69
3	ethanol(CAS)	Ⅱ	5.65	8.21
4	ethanol(CAS)	Ⅱ	5.70	5.85
5	ethanol(CAS)	Ⅱ	5.75	2.68
6	ethanol(CAS)	Ⅱ	5.81	7.69
7	formic acid, ethyl ester	Ⅵ	5.85	1.06
8	acetic acid, methyl ester	Ⅵ	5.95	1.11
9	propanal, 2-methyl-	Ⅲ	6.16	0.24
10	1-propanol	Ⅱ	6.40	4.43
11	propanal, 2-methyl-(CAS)	Ⅲ	6.57	0.12
12	acetic acid, ethyl ester(CAS)	Ⅵ	6.84	14.98
13	acetic acid, ethyl ester(CAS)	Ⅵ	6.89	4.61
14	acetic acid	Ⅴ	7.07	0.48
15	1-propanol, 2-methyl-(CAS)	Ⅱ	7.21	8.57
16	butanal, 3-methyl-(CAS)	Ⅲ	7.35	0.27
17	butanal, 3-methyl-(CAS)	Ⅲ	7.41	0.28
18	butanal, 2-methyl-	Ⅲ	7.51	0.10
19	propane, 1-(ethenyloxy)-2-methyl-(CAS)	Ⅰ	7.55	0.18
20	1-butanol(CAS)	Ⅱ	7.67	0.46
21	2-pentanone(CAS)	Ⅳ	7.94	0.19
22	1-penten-3-ol	Ⅱ	7.99	0.26
23	3-pentanone(CAS)	Ⅳ	8.12	0.41
24	2-butanone, 3-hydroxy-(CAS)	Ⅳ	8.22	0.28
25	2-butanol(CAS)	Ⅱ	8.29	0.12
26	propanoic acid, ethyl ester(CAS)	Ⅵ	8.45	2.02
27	propanamide, n, n-dimethyl-	Ⅷ	8.85	2.14
28	1-butanol, 3-methyl-	Ⅱ	9.04	7.06
29	1-butanol, 3-methyl-(impure)	Ⅱ	9.11	2.19
30	beta-thujene	Ⅰ	9.40	0.47
31	propanoic acid, 2-methyl-, ethyl ester(CAS)	Ⅵ	9.50	1.27
32	1-pentanol(CAS)	Ⅱ	9.66	0.11
33	acetic acid, 2-methylpropyl ester(CAS)	Ⅵ	9.78	0.85
34	carbonic acid, diethyl ester(CAS)	Ⅵ	9.87	0.41
35	butanoic acid, ethyl ester(CAS)	Ⅵ	10.35	0.10
36	octane(CAS)	Ⅰ	10.64	0.06

37	ethane, 1,2-diethoxy-(CAS)	Ⅰ	10.93	0.07
38	furan, tetrahydro-2-(methoxymethyl)-	Ⅶ	10.99	0.03
39	butanoic acid, 2-methyl-, ethyl ester	Ⅵ	11.51	0.16
40	butanoic acid, 3-methyl-, ethyl ester(CAS)	Ⅵ	11.55	0.04
41	1-hexanol(CAS)	Ⅱ	11.87	0.15
42	1-butanol, 3-methyl-, acetate(CAS)	Ⅱ	12.02	0.23
43	1-butanol, 3-(1-ethoxyethoxy)-2-methyl-	Ⅱ	12.09	0.18
44	2-heptanone(CAS)	Ⅳ	12.24	0.16
45	styrene	Ⅰ	12.42	0.06
46	pentanoic acid, ethyl ester(CAS)	Ⅵ	12.53	0.03
47	2-heptanol	Ⅱ	12.57	0.10
48	butanoic acid, 2-methylpropyl ester(CAS)	Ⅵ	12.90	0.05
49	phenol	Ⅷ	14.06	0.08
50	1,3-dioxolane, 2-propyl-(CAS)	Ⅰ	14.15	0.09
51	hexanoic acid, ethyl ester(CAS)	Ⅵ	14.51	0.04
52	cyclotetrasiloxane, octamethyl-(CAS)	Ⅷ	14.84	0.01
53	1-hexanol, 2-ethyl-(CAS)	Ⅱ	15.14	0.04
54	o-cymene	Ⅰ	15.19	0.06
55	beta-phellandrene	Ⅰ	15.38	0.10
56	gamma-terpinene	Ⅰ	15.86	0.04
57	heptanoic acid, ethyl ester	Ⅵ	16.29	0.03
58	undecane	Ⅰ	16.64	0.03
59	benzoic acid, ethyl ester(CAS)	Ⅵ	17.47	0.06
60	cyclopentasiloxane, decamethyl-	Ⅷ	17.60	0.04
61	octanoic acid, ethyl ester(CAS)	Ⅵ	17.90	0.03
62	phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl	Ⅷ	22.38	0.03

I:hydrocarbon, II: alcohol, III: aldehyde, IV: ketone, V:carboxylic acid, VI:ester, VII: heterocyclic, VIII: other

3.4. Comparison of Chemical Groups of Volatile Compounds in the Root Peels, Stem Peels, and Fruit Peels of Pomegranates

The chemical groups of the volatile compounds in the root peels, stem peels, and fruit peels of pomegranates are shown in Table 5. Volatile compounds in the root peels were composed mainly of monoterpene hydrocarbons (91.53%), while volatile compounds in the stem peels and fruit peels were composed mainly of alcohols (65.13% and 66.13%, respectively). Moreover, in the case of the stem peels and fruit peels, esters that were not contained in the root peels were determined in 29.32% and 26.85%, respectively.

Table 5. Chemical Groups of Volatile Compounds in the Root Peels, Stem Peels, and Fruit Peels of Pomegranates

Group		Normalized peak area (%)		
		Root peels of pomegranates	Stem peels of pomegranates	Fruit peels of pomegranates
Hydrocarbons	Monoterpene	14 kinds(91.53)	2 kinds(0.22)	4 kinds(0.67)
	Sesquiterpene	1 kind(0.47)		
	Alkane		2 kinds(0.21)	5 kinds(0.43)
	Alkene	1 kind(0.35)	1 kind(0.06)	1 kind(0.06)
Alcohols			8 kinds(65.13)	18 kinds(66.02)
Aldehydes		1 kind(0.69)	3 kinds(2.12)	6 kinds(2.09)
Ketones		1 kind(0.22)	2 kinds(0.61)	4 kinds((1.04)
Esters			11 kinds(29.32)	17 kinds(26.85)
Carboxylic acids				1 kind(0.48)
Heterocyclics		2 kinds(6.04)		1 kind(0.03)
Others		3 kinds(0.67)	1 kind(2.32)	5 kinds(2.30)

4. Conclusions

Using TD GC/MS, the conclusions of the analysis of volatile compounds in the root peels, stem peels, and fruit peels of pomegranates are as follows.

1. Twenty-four compounds including 17 hydrocarbons, 1 aldehyde, 1 ketone, 2 heterocyclic acids, and 3 others were identified in the root peels. Thirty compounds including 5 hydrocarbons, 8 alcohols, 3 aldehydes, 2 ketones, 11 esters, and 1 other were identified in the stem peels. In addition, 62 compounds including 10 hydrocarbons, 18 alcohols, 6 aldehydes, 4 ketones, 17 esters, 1 carboxylic acid, 1 heterocyclic acid, and 5 others were identified in the fruit peels.
2. Volatile compounds in the root peels were composed mainly of monoterpene hydrocarbons (91.53%). Volatile compounds in the stem peels and fruit peels were composed mainly of alcohols (65.13% and 66.02%, respectively).
3. In the case of the stem peels and fruit peels, esters that were not contained in the root peels were determined in 29.32% and 26.85%, respectively.
4. The root peels had few common volatile compounds contained in the stem peels and fruit peels, while the stem peels and fruit peels contained many common volatile compounds.

As described above, the root peels of pomegranates contained a large amount of monoterpenes that are being used as flavorings and insecticides. Therefore, the root peels will affect insecticidal action against house dust mites as well as the development of aromatic materials. This area will continue to be researched.

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