Composition and Antimicrobial Activities of Essential Oils in the Peel of Citrus Fruits

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Volatile components of the essential oils of Satsuma mandarin (*C. unshiu*), Dangyuza (*C. grandis*), Yuza (*C. junos*), Byungkyul (*C. playtymamma*), Jinkyul (*C. sunki*), and Hakyul (*C. natsudaidai*) grown in Jeju Island were isolated from the fruit peels by hydro distillation and determined by GC-MS. GC-MS analysis identified 58 compounds, with main components being d-limonene (64.01~79.34%), β-myrcene (3.01~26.53%), γ-terpinene (0.11~12.88%), β-pinene (0.78~4.74%), and α-pinene (1.01~2.55%). Differences in compositions and contents of the essential oils were observed among citrus varieties. Effects of citrus oils on growth inhibitions of *Escherchia coli*, *Staphyllococcus epidermidis*, and *Candida albicans* were investigated using disc diffusion assay and minimal inhibitory concentration (MIC) assay. The essential oils inhibited growths of the test organisms, exhibiting higher levels of activity against Gram-positive *S. epidermidis* (MIC values 0.04~0.17 mg/mL), whereas Gram-negative *E. coli* was moderately resistant (MIC values 1.66~20.30 mg/mL). MIC of citrus essential oils ranged from 0.82~23.69 mg/mL against *C. albicans*. The essential oils obtained from *C. sunki*, *C. grandis*, and *C. playtymamma* showed the highest antimicrobial activities against *S. epidermidis* and *C. albicans*, indicating their potential as natural antimicrobial agents.

Key words: *antimicrobial, citrus fruits, gas chromatography-mass spectrometry, volatile compound*

Citrus is currently the most produced fruit in the world due to its good taste and aroma. Citrus oils are mainly used in the beverage and the food industries, and are further applied to the manufacture of soaps, detergents and perfumes. Recent studies on the biological activities of these oils suggest the potential uses of these natural materials in pharmaceutical preparations, perfumery, cosmetics, and agronomic fields [Caccioni *et al.*, 1998; Choi *et al.*, 2000; Ruberto and Rapissarda, 2002].

The satuma mandarin and other Jeju indigenous citrus varieties belong to the family *Rutaceae*. Citrus fruits have often been used for culinary and their peels have been traditionally prescribed for the treatment of cough, and sore throat. Jinkyul (*Citrus sunki* Hort. ex Tanaka), Hakyul (*Citrus natsudaidai* Hay), Yuza (*Citrus junos* Sieb. ex Tanaka), Dangyuza (*Citrus grandis* L. Osbeck), and Byungkyul (*Citrus playtymamma* Hort. ex. Tanaka) are citrus varieties indigenous to Jeju. Jinkyul species have been used for medicinal purposes and are labeled as dried orange peel. Yuza and Dangyuza, lemon-like sour citrus fruits, were brought into Korea from the central China more than 1000 years ago. Since then, they have been cultivated and consumed as raw fruits, as well as used in cooking and in beverages as condiments due to their distinct flavor and taste. Polyphenolic compounds are known to be rich in Citrus peel. Although the citrus peel oils from *Citrus unshiu* were analyzed, revealing 51~107 components including dl-limonene, myrcene, pinene, and terpinene, no reports have made on those from other citrus varieties [Kim *et al.*, 1999]. Methanolic extract of citrus peels also exhibited very strong antioxidant activity [Rehman, 2006].

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Several studies have reported on the volatile components of the essential oils extracted from the peels of the citrus species [Sawamura, 2000; Dugo, 1993; Lota *et al.*, 2001]. Volatile chemical compounds of citrus essential oils are among the most distinctive components for identification and evaluation of varieties. Previous studies showed the components of the essential oils of fruits vary depending on the environmental origin, variety, and preparation methods [Njoroge *et al.*, 2005].

Antibacterial and antifungal properties of essential oils as well as the oil constituents are well documented [Sawamura, 2000; Couladis *et al.*, 2002]. Positive relationship between monoterpene (excluding limonene) and sesquiterpene contents of the oils and fungal growth-inhibiting activities was reported using *Penicillium digitatum* and *P. italicum* [Caccioni *et al.*, 1998]. The volatile oil of certain plant species was reported to possess strong antibacterial activities due to the presence of α-pinene, β-pinene, and terpinene in the volatile oils of the peels of the citrus species [Alliginnis *et al.*, 2001]. Essential oils or some of their constituents have found applications as antimicrobial agents for food preservatives, in clinical microbiology, and in pharmaceutical preparations.

Many protocols for controlling the growth of food-borne pathogens, skin-resident pathogens, and food spoilage bacteria have been also developed using essential oils as natural food preservatives [Hao *et al.*, 1998]. We examined the antibacterial and antifungal effects of the citrus essential oil from the citrus peels for use as a functional material for the manufacture of food and cosmetics products. Published reports on the volatile components citrus fruits grown in Jeju Island are scarce. The present study was undertaken to investigate the volatile flavor components of the peel oils from six Jeju Citrus varieties and their antimicrobial activities.

Materials and Methods

The oil preparation. All the samples collected were fully matured Jeju citrus fruits. Satsuma mandarin (*C. unshiu* Marc. Var. Miyakawa), Jinkyul (*C. sunki* Hort. ex Tanaka), Hakyul (*C. natsudaidai* Hay), Dangyuza (*C. grandis* L. Osbeck), Yuza (*C. junos* Sieb. ex Tanaka), and Byungkyul (*C. playtymamma* Hort. ex. Tanaka) were collected from September 2005 to February 2006. Satsuma mandarin and Hakyul were harvested from the orchard at Ara-dong. Jinkyul, Yuza, Dangyuza, and Byunkyul were obtained from the habitat and principal producing regions located at Doryun-dong. The distilled oils were used for this research. The peels of fruits were kept in a deep-freezer before use. The citrus peels were distilled for 6 h using the simultaneous steam distillation apparatus to obtain the essential oil. The yield of essential oil (%) was calculated as follows:

$$\text{Yield of essential oil (\%)} = \frac{\text{Volume of essential oil (mL)}}{\text{Fruit peel sample (g)}} \times 100$$

Anhydrous sodium sulphate was used to absorb the little water contained in the essential oils. The samples were analyzed by injecting 1 μL of 1 : 5 (v/v) solution of essential oil in dichloromethane (MERCK).

GC/MS analysis. Essential oils were analyzed by GC/MS on a Agilent Technologies 6890N equipped with 5973 network mass selective detector, split/splitless injector, autosampler, column HP-5MS (30 m×0.25 mm, I.d., 0.25 μm film thickness). The oven temperature was programmed from 60 to 200°C at 2°C/min. The carrier gas was Helium at a flow rate of 1 mL/min. The GC-MS was carried out on a 6890 N mass spectrometer operating in the EI mode at 70 eV. Limonene was purchased from Sigma. Chemical constituents were identified by comparing their retention times and mass spectra with those obtained from an authentic sample, Wiley libraries spectra, and literature [Adams, 1995].

Antimicrobial activity assay. The bacterial strains used in this study were: *Escherchia coli* ATCC25922, *Staphyllococcus epidermidis* KCTC3958, and *Candida albicans* KCTC7965. Bacterial strains were cultured overnight at 37°C in LB agar and Cornebacterium agar. Yeast was cultured at 30°C overnight in yeast malt agar.

Antimicrobial activities of the essential oil against some bacteria and yeast strains were determined by the paper disc assay and broth dilution method. The disc diffusion method was employed to determine the antimicrobial activities of the essential oils. Briefly, a suspension of the tested microorganism (0.1 mL of 10^8 cells per mL) was spread on the solid media plates. Filter paper discs (8 mm in diameter) were impregnated with 40 μL of the oil and placed on the inoculated plates. These plates were incubated at 37°C for 24 h for bacteria and at 30°C for yeast. The diameters of the inhibition zones were measured in millimeters (mm). All tests were performed in triplicates.

The minimum inhibitory concentrations (MICs) were determined for the essential oils by the broth dilution method. The antibacterial activities were examined after incubation at 37°C for 24 h (bacteria) or at 30°C for 24 h (candida). The antimicrobial activities were determined using the dilution techniques [Janssen *et al.*, 1987]. MICs were determined as the lowest concentration of growth in the broth visible to the naked eye.

Results and Discussion

Chemical composition of the essential oils. The distilled essential oils from Satsuma mandarin (*C. unshiu*), Dangyuza (*C. grandis*), Yuza (*C. junos*), Byungkyul (*C. playtymamma*), Jinkyul (*C. sunki*), and Hakyul (*C. natsudaidai*) were obtained in yields of 1.7, 1.9, 1.8, 2.5, 1.5, and 1.7% (v/w), respectively. The oil constituents and their classifications (based on the functional grouping) are presented in Table 1. The components were further categorized into monoterpene hydrocarbons, sesquiterpene hydrocarbons, alcohols, ketones, esters, and others for comparative convenience (Table 1). The gas-chromatographic analysis of the essential oils showed that their chemical compositions were close to those reported by other authors [Shaw, 1979; Minh Tu *et al.*, 2002].

A total of 58 different volatile compounds were separated from the peel oils of the six citrus varieties. The components of Satsuma mandarin, Jinkyul, Hakyul, Yuza, Dangyuza, and Byungkyul essential oils amounted to 99.16 (area percent), 99.12, 99.04, 97.29, 97.40%, and 98.46%, respectively, of the total oil volatiles (Table 1).

Thirty-eight components were identified from the Satsuma mandarin distilled oil (Table 1). The hydrocarbon group made up most of the oil (90.94%), with limonene the highest at 76.02%. Other prominent monoterpene hydrocarbons were γ-terpinene (7.40%), myrcene (3.11%), α-pinene (2.10%), β-pinene (0.93%), and terpinolene (0.53%). Alcohols were the second major group estimated at 5.06%. Among the identified alcohol compounds, terpineol was the major compound. Esters and ketones were contained in trace amounts.

In the essential oil of Jinkyul 32 compounds were identified. Except for the presence of 1-phellandrene, cis-geraniol, and β-citral, the essential oil composition of Jinkyul was similar to that of Satsuma mandarin. The significant difference was that the contents of β-pinene and β-myrcene of Jinkyul were much higher than those found in other varieties. Monoterpene hydrocarbons were the most dominant chemical group among the volatiles of Jinkyul (91.18%) peel oils. The most abundant compound was limonene (72.47%), followed by β-pinene (14.74%), myrcene (9.76%), linalool (2.07%), α-pinene (1.43%), sabinene (1.00%), and α-terpineol (0.17%). Contents of β-pinene, linalool, and β-myrcene increased, wherease that of α-terpineol showed a decreasing tendency during maturation (data not shown).

The composition of Hakyul, consisting of 38 compounds, was very similar to those of Satsuma mandarins, except for 1-phellandrene, cis-geraniol, β-citral, and junipene. The most abundant compound was limonene (79.34%), followed by γ-terpinene (7.56%), β-myrcene (3.01%), α-pinene (2.18%), β-pinene (1.05%), nerol (0.36%), sabinene (0.34%), and α-terpineol (0.23%). Content of limonene was higher than those of other citrus species followed by γ-terpinene and Yuza. In addition, a small amount of nerol component was detected.

A number of studies on the Japanese and Korean Yuza have been carried out to examine their volatile components [Song *et al.*, 1999]. The composition, consisting of 44 compounds, was the same as that of Satsuma mandarin except for the presence of trans β-farnesene, 1-phellandrene, trans-geraniol, and α-terpinene (Table 1). The most abundant compound was limonene (64.01%), followed by γ-terpinene (12.88%), linalool (2.75%), myrcene (2.71%), α-pinene (2.55%), β-pinene (1.30%), 1-phellandrene (1.02%), α-terpineol (0.89%), and sabinene (0.29%). Contents of linalool and γ-terpinene were higher than those of other citrus species. Linalool was the major component among the monoterpene alcohols.

Twenty-nine components were identified in the Dangyuza distilled oil, showing nearly the same peel oil composition as observed in Byungkyul (Table 1). The most abundant compound was limonene (66.04%), followed by myrcene (26.53%), α-pinene (1.04%), β-ocimene (0.67%), Germacrene D (0.41%), and sabinene (0.26%). Content of β-myrcene was higher than those of other citrus species. The limonene content was considerably lower than that that of Vietnamese pummelo (*Citrus grandis* Osbeck) [Hao *et al.*, 1998], except, β-myrcene and α-pinene occurred in high proportions, 26.53 and 1.04%, respectively. The Vietnamese pummelo grown in Japan contained considerable amounts of γ-terpinene (6.35%) and terpinolene (0.68%) [Sawamura *et al.*, 1991]. However, contents of γ-terpinene and terpinolene were lower in the Dangyuza sample.

In the case of Byungkyul, the composition, consisting of 34 compounds, was nearly the same as the Dangyuza peel oil composition. The most abundant compound was limonene (68.39%), followed by myrcene (23.95%), α-pinene (1.01%), linalool (1.00%), β-pinene (0.78%), sabinene (0.34%), and α-terpineol (0.10%).

Studies also showed that the chemical constituents of essential oils from commercially cultivated citrus species varied with the locality and variety. Limonene contents of the essential oils of citrus varieties growing in Jeju were 64~79%, similar to those of the citrus fruit varieties of other countries. Moufida and Marzouk (2003) investigated the amount of volatile compounds found in the varieties of blood oranges, sweet orange, lemon, bergamot, and bitter orange, and reported that the limonene contents in the juice of these citrus fruits were 63.2, 88.2, 78.8, 72.9, and 90.3%, respectively [Moufida & Marzouk, 2003]. Minh Tu *et al.* (2002) reported that

Table 1. Composition of the essential oils of citrus varieties

			AREA[1] (%)					
NO.	Components	R/T	SM	JK	HK	Y	DY	BK
1	2-Hexenal	3.94	-	-	tr[2]	tr	-[3]	-
2	α-Thujene	5.66	0.48	tr	0.57	0.70	tr	tr
3	α-Pinene	5.87	2.10	1.43	2.18	2.55	1.04	1.01
4	Campene	6.32	tr	tr	-	tr	tr	tr
5	Sabinene	7.12	0.34	1.00	0.34	0.29	0.26	0.34
6	β-Pinene	7.24	0.93	4.74	1.05	1.30	-	0.78
7	β-Myrcene	7.91	3.11	9.76	3.01	2.71	26.53	23.95
8	Octaldehyde	8.17	0.24	-	0.26	-	-	0.23
9	1-Phellandrene	8.27	-	0.14	-	1.02	0.10	-
10	α-Terpinene	8.76	0.15	0.06	0.09	0.51	-	-
11	dl-Limonene	9.57	76.02	72.47	79.34	64.01	66.04	68.39
12	β-Ocimene	10.15	0.24	1.41	0.47	0.58	0.67	0.69
13	γ-Terpinene	10.59	7.40	0.11	7.56	12.88	tr	tr
14	cis-Linalool oxide	11.21	-	-	0.09	tr	0.16	-
15	α-Terpinolene	11.97	0.53	0.06	0.72	1.16	0.11	tr
16	Linalool	12.55	1.07	2.07	-	2.75	0.21	1.00
17	Nonanal	12.79	0.07	tr	0.09	tr	-	-
18	cis-Limonene oxide	14.26	0.10	-	0.23	0.04	tr	0.06
19	β-Terpineol	14.26	-	-	-	0.07	-	-
20	trans-Limonene oxide	14.52	0.06	-	0.12	-	tr	-
21	6-Octenal	15.41	0.04	-	0.03	-	0.23	0.03
22	4-Terpineol	16.66	0.10	0.19	0.11	0.45	tr	0.05
23	α-Terpineol	17.43	0.20	0.17	0.23	0.89	0.06	0.10
24	Decalaldehyde	18.42	0.19	0.07	0.26	0.07	-	0.13
25	trans-Carveol	19.09	tr	-	tr	-	-	tr
26	cis-Geraniol	19.73	-	tr	-	tr	-	-
27	β-Citronellal	19.77	-	-	-	-	tr	-
29	2-Cyclohexen-1-carboxaldehyde	21.16	0.06	-	0.11	-	-	0.13
30	trans-Geraniol	21.33	-	-	-	0.08	tr	-
31	2,6-Octadienal	22.27	-	-	0.09	-	0.08	0.16
32	Thymol	23.63	-	-	-	tr	-	-
33	α-Terpinene	26.20	-	-	-	0.09	tr	tr
34	δ-Elemene	26.21	0.06	0.07	-	-	-	-
35	trans-(+)-Carveol	27.83	0.07	-	0.14	-	-	-
36	Nerol	28.07	-	-	0.36	-	-	tr
37	Geranyl acetate	28.08	tr	tr	-	-	-	-
38	α-Copaene	28.44	0.17	0.19	0.08	0.11	tr	0.05
39	β-Cubebene	29.35	0.19	0.24	0.05	tr	-	0.10
40	β-Elemene	29.49	0.78	0.97	0.09	0.08	-	tr
28	β-Citral	20.48	-	0.14	-	-	0.08	0.18
41	Zingiberene	30.44	-	-	-	tr	-	-
42	Limonene acetate	30.75	0.06	-	0.07	-	-	-
43	β-Caryophyllene	30.98	0.18	0.37	0.09	0.49	0.07	0.13
44	α-Humulene	32.98	0.29	0.33	0.03	0.11	0.01	0.02
45	trans β-Farnesene	33.56	-	-	-	1.25	-	tr
46	Germacrene D	34.65	0.51	0.45	0.29	0.41	0.41	0.26
47	α-Selinene	35.45	-	-	0.17	0.05	-	-
48	Bicyclogermacrene	35.55	0.07	0.32	-	1.42	tr	tr

Table 1. (continued)

NO.	Components	R/T	AREA[1] (%) SM	JK	HK	Y	DY	BK
49	α-Muurolene	35.87	-	-	-	0.05	-	-
50	Valencene	36.04	1.66	1.83	-	-	-	-
51	Cyclohexane	36.01	-	-	0.10	0.11	-	-
52	α-Farnesene	36.61	1.27	0.11	0.36	0.05	-	0.32
53	δ-Cadinene	37.22	0.24	0.34	0.12	0.51	0.04	0.07
54	Germacrene B	38.94	0.09	0.23	-	0.35	tr	tr
55	(+)Spathulenol	40.13	tr	-	tr	0.31	-	-
56	r-Eudesmol	43.18	-	-	-	0.08	-	-
57	t-Cadinol	44.45	-	-	-	0.14	-	-
58	Naphthalenone	52.18	-	-	0.12	0.36	-	-
	Monoterpenes		90.94	91.18	95.35	85.71	95.82	95.32
	Sesquiterpens		6.06	5.45	2.04	6.51	0.71	1.10
	Alcohols		1.53	2.47	0.70	4.24	0.48	1.18
	Aldehydes		0.53	-	0.75	0.07	0.39	0.86
	Ketones		-	-	0.13	0.36	-	-
	Esters		0.10	0.02	0.07	-	-	-
	Others		-	-	-	0.40	-	-
	Total identified		99.16	99.12	99.04	97.29	97.40	98.46

[1]Determined as GC-MS area percent [2]tr = trace(<0.05%) [3]-: not detected
SM: Satsuma Mandarins; JK: JinKyul; HK: HaKyul; Y: Yuza; DY: DangYuza; BK: ByungKyul

the contents of limonene were 93.9, 94.7, 95.1, and 71% in the volatile constituents of Vietnamese pummelo, orange, tangerine, and lime peel oil, respectively. Dugo confirmed the importance of limonene to the aroma of citrus fruit; the percentage of limonene varied from 50% in lemon to 93% in bitter orange and 97% in the grapefruit aroma [Dugo, 1993].

Although myrcene has previously been known as a minor constituent, recent studies showed it to be a prominent component of several types of sweet orange oils [Sawamura, 2000; Shaw, 1979], constituting major portions in Dangyuza and Byungkyul. The contents of β-myrcene in Dangyuza and Byungkyul were higher than those found in the other citrus varieties including the sweet oranges as reported previously, and myrcene was not detected in the valencia oil [Njoroge *et al.*, 2005].

Variations in the quantitative levels of the minor volatile compounds among different types of citrus essential oils could be attributed to the differences in varieties and environmental factors. Influence of the extent of fruit maturity and sample preparation methods may contribute significantly to the variations in the volatile compositions.

γ-Terpinene and citral have been mentioned as important compounds, and their quantities may contributed to the special flavor of the lime cold-pressed oil. The γ-terpinene contents of yuza, satsuma mandarins, and Hakyul, detected in high proportions of 12.88, 7.40, and 7.56%, respectively were higher than those found in other varieties [Nagy and Shaw, 1990].

The γ-terpinene in citrus essential oil exhibited potent antioxidant activity [Takahashi *et al.*, 2003]. Citrus volatile components such as geraniol, terpinolene, and γ-terpinene showed marked scavenging activities [Choi *et al.*, 2000]. Geraniol was detected in Jinkyul, Yuza, and Byungkyul.

Belletti *et al.* (2004) reported that the most effective essences were characterized by the highest concentration of some terpenes, such as citral, beta-pinene, and p-cymene [Belletti *et al.*, 2004]. β-citral was detected at 0.14% of the essential oil in Jinkyul, and β-pinene was detected in most citrus species. Their contribution to the aroma differences may be due to the quantitative differences in the amounts of limonene, β-pinene, γ-terpinene, β-myrcene, among others. Although the action mechanism of the terpenes is not yet fully understood, it is presumed to involve the disruption of the membrane by the lipophilic compounds [Cowan, 1999]. A higher content of γ-terpinene in oils was confirmed to have higher lipolytic effect [Choi, 2006].

Antimicrobial activity. The results of the antimicrobial activity (Table 2) showed that the essential oil of citrus varieties exhibited antimicrobial activities against the bacteria tested. Similar results have been reported on other Gram-positive and -negative bacteria using the disc

Table 2. Antimicrobial activity of the citrus essential oils as determined by the diffusion method

M/O	Inhibition zones (mm)[a]					
	C. unshiu	*C. sunki*	*C. natsudaidai*	*C. junos*	*C. grandis*	*C. playtymamma*
E. coli	14.5 ± 0.71	16.0 ± 1.41	15.5 ± 0.71	11.5 ± 0.71	13.5 ± 0.71	11.5 ± 0.71
S. epidermidis	15.0 ± 0.01	21.5 ± 2.12	22.0 ± 1.41	21.5 ± 0.71	24.0 ± 1.41	21.5 ± 3.54
C. albicans	19.0 ± 1.0	19.0 ± 1.0	20.7 ± 2.08	16.5 ± 2.12	26.0 ± 2.83	23.7 ± 7.02

[a]Average values (triplicate) ± standard deviation.

Table 3. Determination of MIC (Minimum Inhibitory Concentration) of the citrus oils

M/O	MIC (mg/mL)					
	C. unshiu	*C. sunki*	*C. natsudaidai*	*C. junos*	*C. grandis*	*C. playtymamma*
E. coli	20.30	1.66	2.60	6.69	4.10	4.32
S. epidermidis	0.04	0.04	0.17	0.04	0.08	0.17
C. albicans	23.69	0.83	13.89	20.06	0.82	0.86

diffusion method [Fisher and Phillips, 2006; Fisher *et al.*, 2007; Mizhahi *et al.*, 2006]. The data are mean values of triplicates. The results of the bioassays (Table 3) showed that the essential oils of the citrus exhibited strong to moderate activities against all tested bacteria (MIC value 0.04~23.69 mg/mL). Results obtained from the disc diffusion method, followed by the measurements of MIC, indicated that *S. epidermidis*, a skin-pathogen microorganism, had the highest sensitivity among the microorganisms tested, with the lowest MIC values (0.04 mg/mL) in the oils isolated from Satsuma mandarin, Jinkyul, and Yuza. (Table 3). *E. coli* and *C. albicans* were also sensitive to the oil with MIC values of 1.66~20.30, and 0.82~23.69 mg/mL, respectively.

The essential oil exhibited higher levels of activity against the Gram-positive tested bacteria : *S. epidermidis* (MIC values 0.04~0.17 mg/mL), while the Gram-negative strain, *E. coli*, appeared to be moderately resistant (MIC values 1.66~20.30 mg/mL). Overall citrus oils were more effective on Gram-positive bacteria than on Gram-negative, similar to the results obtained from other citrus essential oils [Fisher and Philips, 2006]. Another interesting observation was the strong activities observed against *Staphylococcus* and *candida* in the citrus oils of Jinkyul, Dangyuza, and Byungkyul varieties, indicating citrus essential oil may have a significant effect on the inhibition of bacteria and candida. Plant essential oils and their components are known to exhibit antimicrobial activities [Cavaleiro *et al.*, 2006; Cha *et al.*, 2007; Craske *et al.*, 2005; Flamini *et al.*,1999; Jo *et al.*, 2004]. The high percentages of α-pinene, β-pinene, and linalool in the essential oil are known to be associated with the antibacterial activity [Chalchat *et al.*, 2000; Couladis *et al.*, 2003; Fisher and Philips, 2006; Ulubelen *et al.*, 1994].

Important variations in the volatile compositions among the peel oils of the six citrus varieties were identified. The contents of β-pinene and β-myrcene in the Jinkyul, Dangyuza and Byungkyul species were higher than those of other citrus varieties, which led to the consideration that these compositions may have antimicrobial activity. These results could provide useful chemical information applicable to the improvement and utilization of various varieties of citrus indigenous fruits based on the essential oil compositions.

In this study the constituents of the citrus variety essential oils were isolated by the steam distillation method. The common characteristic of the essential oils in this work was the high content of monoterpene hydrocarbons. This work suggests a possible use of the essential oils in the food, cosmetics, and pharmaceutical industries as natural components for use as antimicrobial agents.

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