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CHEMICAL CONSTITUENTS OF THE FRUIT PEEL FROM WHITE FLESH *CITRUS GRANDIS* (L.) OSBECK

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ABSTRACT

Citrus grandis commonly known as pomelo, shaddock or limau bali belongs to the family Rutaceae. The aim of this study is to identify the phytochemical components present in white flesh *C. grandis* fruit peels using solvent extraction and hydro distillation methods. Identification of phytochemical compounds was conducted using the GC-MS analysis and Nuclear Magnetic Resonance (NMR) spectroscopic techniques. Hexadecanoic acid and 9,12-Octadecadienoic acid (Z,Z) are 2 major compounds elucidated from hexane and ethyl acetate fractions, respectively; while limonene was identified as a major compound in essential oil. White powder obtained during methanol extraction was confirmed as naringin using NMR spectroscopic technique.

KEYWORDS: ***Citrus grandis*, naringin, hexadecanoic acid, 9,12-Octadecadienoic acid (Z,Z), limonene**

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INTRODUCTION

Citrus fruits are recognized for their economical value and pharmaceutical properties. Generally, 50-60% of the fruit becomes the waste fractions[1] which include albedo, flavedo, segment membrane and seed[2, 3, 4]. Citrus peels are a source of molasses, pectin and limonene[2]. Presence of alcohols, esters, sterols, terpenes, sesquiterpenes and aldehydes have been reported in the essential oil extracted from Citrus leaves, flower, juice and peels[5]. Peel of mature citrus fruit was found to be rich in carotenoids[6, 7]. Citrus peels are also known source of phenolic compounds, which include phenolic acids and flavonoids. Citrus contains a wide range of flavonoids constituents which has been proved to demonstrate antioxidant activities[8]. Scientifically, citrus are known to posses various bioactive compounds with pharmaceutical properties. It is known to exhibit anti-carcinogenic[9], antioxidant[10, 11, 12, 13, 14, 15], antimicrobial[16, 17, 18, 19, 20], antiplatelet[21], anticancer[22, 23] and antidiabetic[13, 24] activities. In view of the various reported compounds extracted from the *C. grandis* peel waste from around the world, it would be interesting to screen the phytochemical composition of locally cultivated white flesh *C. grandis* peel's essential oil and methanol crude extract, hexane and ethyl acetate fractions extracted following solvents in increasing order of polarity.

MATERIALS AND METHODS

Plant Collections

White flesh pomelo or *Citrus grandis* fruits were purchased from trusted vendors in Taiping, Perak. The fruits were brought to Herbal Processing Lab, Integrative Medicine Cluster, Advanced Medical and Dental Institute, USM for processing. A voucher of specimen (Referral number: MANO 2013-01) was deposited in the Herbarium Unit, Forest Research Institute Malaysia, Selangor, Malaysia. The fruits were washed under running tap water and distilled water to remove dirt. After patting them dry, the peels and pulps were separated manually using a sharp knife. The peels were then cut into small pieces. The fresh weights of the peels wet were recorded before they were oven dried at 40°C. Dried samples were pulverized into powder using mechanical grinder (Retch, Germany). The powder was kept in air-tight containers at room temperature until further use.

Preparation of Crude Extracts

A total of 2.4 kg of powdered peel was soaked in 24 litres of methanol (ratio of 1 g to 10 ml) for 3 days at room temperature. The mixture was frequently stirred. On the third day, the mixture was filtered and the filtrate was concentrated using a rotary evaporator (Eyela, USA) under reduced pressure to give the crude methanol extract in powder form. The residue was re-soaked again with methanol for another 3 days and the process was repeated for a third time. The residue after the final methanol extraction was left to dry in a fume hood.

Isolation and Characterisation of Major Compound

Solvent partitioning was conducted on the methanol crude extract. Approximately 800 g of the methanol extract was dissolved in methanol (ratio of 1 g to 2 ml). The resulting solution was suspended in distilled water (ratio of 1 ml to 2.5 ml) and partitioned successively with hexane (ratio of 1 ml to 3.5 ml) followed by ethyl acetate (ratio of 1 ml to 3.5 ml) for three times each. The resulting organic fractions were evaporated to dryness separately using a rotary evaporator under reduced pressure to obtain the hexane, ethyl acetate and water fractions. The ethyl acetate fraction which showed a major spot on TLC was subjected to further fractionation and purification. For this, exactly 10 g ethyl acetate fraction was chromatographed over the silica gel column, eluting with chloroform-methanol system at 5% interval to yield 300 subfractions in 20 ml test tubes. The thin layer chromatographically homogenous subfractions were further pooled and concentrated to give 10 subfractions designated as CGE1-CGE10. (CGE9 and CGE10 showed the same major compound, and can be pooled further as CGE9) Subfraction CGE9 afforded a single major compound which was identified on the basis of NMR spectroscopic analysis and comparison of the ^{1}H- and ^{13}C-NMR data with literature values.

NMR spectroscopic analysis

^{1}H- and ^{13}C-NMR spectra were recorded in ppm (δ) in CD_3OD, employing a Bruker DRX 300 spectrometer operating at 300 MHz for ^{1}H and 75 MHz for ^{13}C. Column chromatography was performed with silica gel 60 (0.040-0.063 mm, Merck). TLC was performed on precoated silica gel 60 F_{254} plates (0.2 mm thick, Merck) with chloroform:methanol (7:3) and a single spot were detected by UV illumination, and by spraying with 10% sulphuric acid (H_2SO_4) followed by heating.

Preparation of crude water extract

Six hundred grammes of the dried residue were refluxed with 6 litres of distilled water (ration of 1 g to 10 ml) for 6 hours. The mixture was filtered and the filtrate was concentrated using a rotary evaporator under reduced pressure prior to freeze drying to obtain crude water extract.

Preparation of Essential Oil

The fruits were washed under running tap water and distilled water to remove dirt. After patting them dry, the peels and pulps were separated manually using a sharp knife. The fruits peel's wet weight were recorded. The fresh fruit peels were cut into small pieces and subjected to hydro distillation using Clevenger type apparatus for 6 hours. The oil was dried over anhydrous sodium sulphate. The purified essential oil was stored in vial at 4°C until further use.

Chemical profile of Citrus grandis Solvent Extracts

Phytochemical components of essential oil, methanol crude extract, hexane and ethyl acetate fractions were analysed. GC-MS analysis was carried out on an Agilent system equipped with Mass Spectrometer detector and

split/splitless injection system. The GC was fitted with a HP-5MS capillary column (30 m X 250 m; film thickness: 0.25 m). The temperature program was as follows: injector temperature 280°C, initial oven temperature at 50°C, then increased at 25°C/min to 300°C and was hold for 10min. Helium was used as the carrier gas at 17.69 psi pressure with flow 2.1ml/min. Samples were solved in methanol and 1 µl aliquot were injected automatically. MS spectra of separated components were identified based on WILEY and NIST Libraries for botanical compounds.

Identification of Volatile Compound in Essential Oil Using GC and GC-MS Analysis

GC analysis was carried out using Shimadzu GC 2010 equipped with flame ionization detector (FID) using capillary column DB-5 (30 m x 0.25 mm, film thickness 0.25 µm). Helium was used as carrier gas. Temperature for injector and detector was maintained at 250°C. The column was programmed at 60°C for 10 minutes, then increased at 3°C/min until 230°C and held for 1 minute. While GC/MS analysis was conducted on Agilent Technologies 7890A/5975C MSD system with similar condition as described in GC programmes using HP-5MS capillary column (30 m X 250 m; film thickness: 0.25 m). Helium was used as carrier gas at flow rate 1.0mL/min and the ion-source temperature was programmed at 280°C. Samples were dissolved in hexane and 1 µl were injected to the GC port. MS spectra of separated components were identified by matching their mass spectra with reference spectra in the database (HPCH2205.L; WILEY7Nist05.L; NIST05a.L). The chemical compounds were expressed as percentages obtained by peak-area normalization, all relative response factors being taken as one.

RESULTS

GC-MS analysis of Citrus grandis

Total yield obtained from crude extract was presented in Table 1 for crude and water extract while Table 2 listed total yield of essential oil extracted from fresh *C. grandis* fruit peels. Highest yield was obtained for crude methanol extract (27.3%) while of hexane and acetyl acetate fractions showed low yield with 0.42% and 1.38%, respectively. Crude water extract and aqueous extract gives a moderate yield. As for essential oil, hydro distillation for 6 hours using fresh *C. grandis* fruit peels afforded a total 9.6 ml of oil. The GC-MS analysis of crude methanol extract, hexane fraction and ethyl acetate fraction of *C. grandis* fruit peels revealed the presence of hundreds of compounds. However, only a few compounds were positively identified using WILEY and NIST Libraries with 80-99% matching. The GC-MS analysis of crude methanol extract of *C. grandis* fruit peels identified a total of 25 compounds out of hundreds of compounds found present in the extract. The main major compound found in the extract was 2-furancarboxaldehyde, 5(hydroxymethyl) (11.12%) (Figure 1 and Table 3). A total of 36 compounds were identified in hexane fraction of *C. grandis* fruit peels accounting for 84.25% of total components present (Figure 2 and Table 4). Main components found in the extract were hexadecanoic acid (47.64%), clionasterol (21.56%), stigmasta-5,22-dien-3-ol (3 beta,22e) (4.34%) and ergost-5-en-3-ol (3 beta) (3.08%). Similarly, 23 compounds or 48.28% of total components present in ethyl acetate fraction of *C. grandis* fruit peels were positively identified. 9,12-octadecadienoic acid (Z,Z) (17.48%), hexadecanoic acid (10.80%) and clionasterol (6.74%) were among major compound identified (Figure 2 and Table 5). The GC and GC-MS analysis of essential oil of *C.grandis* fruit peel led to the identification of 99.11% active components. Fourteen compounds were identified from the essential oil with limonene (93.78%) as major compound. Other constituents in the essential oil were α-terpineol (1.35%), myrcene (1.28%) and linalool (1.08%) (Figure 4 and Table 6). Isolation and Characterisation of Major Compound The isolated white amorphous compound designated as CGE9 showed a single spot and exactly matched with R_f of reference standard of naringin on TLC plate (R_f = 0.45, developed with chloroform-methanol, 7:3). It gave a dark UV active spot at 254 nm and a brownish yellow spot after spraying with 10% sulphuric acid followed by heating. It was further characterised as naringin by NMR spectroscopy and confirmed by comparing spectral data with those in the published literature (Table 7).

Table 1
Total yield of crude extracts and fractions

Wet weight (kg)	Dry weight (g)	Extracts	Total Yield Obtained	
			g	%
4.52	600	Crude methanol extract	164.0	27.3
		Hexane fraction	2.54	0.42
		Ethyl acetate fraction	8.32	1.38
		Aqueous fraction	93.84	15.64
		Crude water extract from residue after methanol extraction	97.2	16.2

Table 2
Total yield of essential oil extracts

Batch	Weight of sample (g)	Day	Volume of oil (ml)	Yield (%)
1	881.0	1	2.2	0.62
		2	1.3	0.37
2	1118.0	1	3.6	0.81
		2	2.5	0.56

Figure 1
GC-MS Chromatogram of Methanol extract of Citrus grandis fruit peels

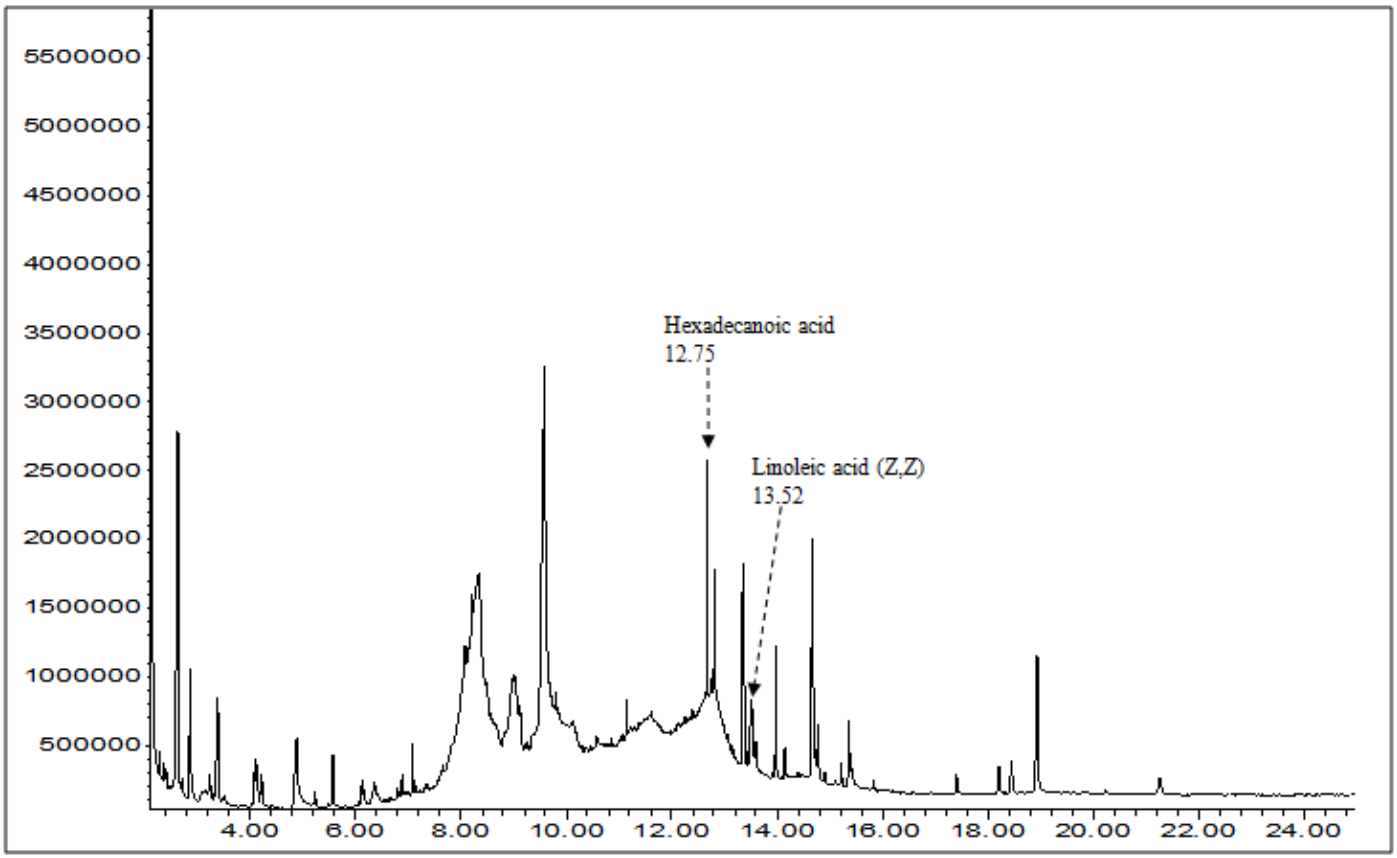


Table 3
GC-MS analysis of Methanol extract of Citrus grandis fruit peels

No.	Retention time (minutes)	Compounds name	% of total
1	2.36	Acetic acid, hydroxy, methyl ester or Methyl glycolate	0.53
2	3.221	2-hexanone or Hexan-2-one or MBK	0.32
3	4.089	2-Furancarboxaldehyde or Furfuran or 2-furaldehyde	0.47
4	4.215	2-Furancarboxaldehyde or Furfural or 2-Furaldehyde	0.44
5	4.874	2-Furanmethanol or Furfuryl alcohol	1.78
6	6.085	Ethanone,1-(2 furanyl) or 2-Acetylfuran or 2-furyl Methyl ketone	0.04
7	6.12	Gamma butyrolactone or 1,2-Butanolide	0.20
8	6.358	2-hydroxycyclopent-2-en-1-one	0.37
9	6.883	5 Methyl Furfural	0.15
10	7.149	Phenol or Izal or Benzenol	0.08
11	9.586	2-Furancarboxaldehyde, 5(hydroxymethyl) or HMF	11.12
12	12.758	Palmitic acid or Hexadecanoic acid	1.30
13	13.346	9,12-Octadecadienoic acid (z,z) methyl ester or Methyl linoleate	0.85
14	13.374	9,12,15-octadecatrienoic acid, methyl ester (z,z,z)	1.01
15	13.444	Octadecanoic acid, methyl ester or Methyl stearate	0.08
16	13.521	Linoleic acid	0.99
17	13.598	Osthol or	0.22
18	13.927	7-Methoxy-8-(2-oxo-3-methylbutyl) coumarin	0.04
19	13.976	7-Methoxy-8(2-oxo-3-methylbutyl) coumarin	0.69
20	15.363	9,12-Octadecadienoic acid (z,z) 2,3-dihydroxypropyl ester	0.42
21	15.391	9,12,15-Octadecatrien-1-ol	0.47
22	17.414	Vitamin E	0.16
23	18.219	Ergost-5-en-3-ol (3 beta)	0.35
24	18.457	Trans-stigmasta-5,22-dien-3-beta-ol	0.38
25	18.948	Stigmast-5-en-3-ol (3 beta, 24s) or Clionasterol	1.62

Figure 2
GC-MS Chromatogram of Hexane extract of Citrus grandis fruit peels

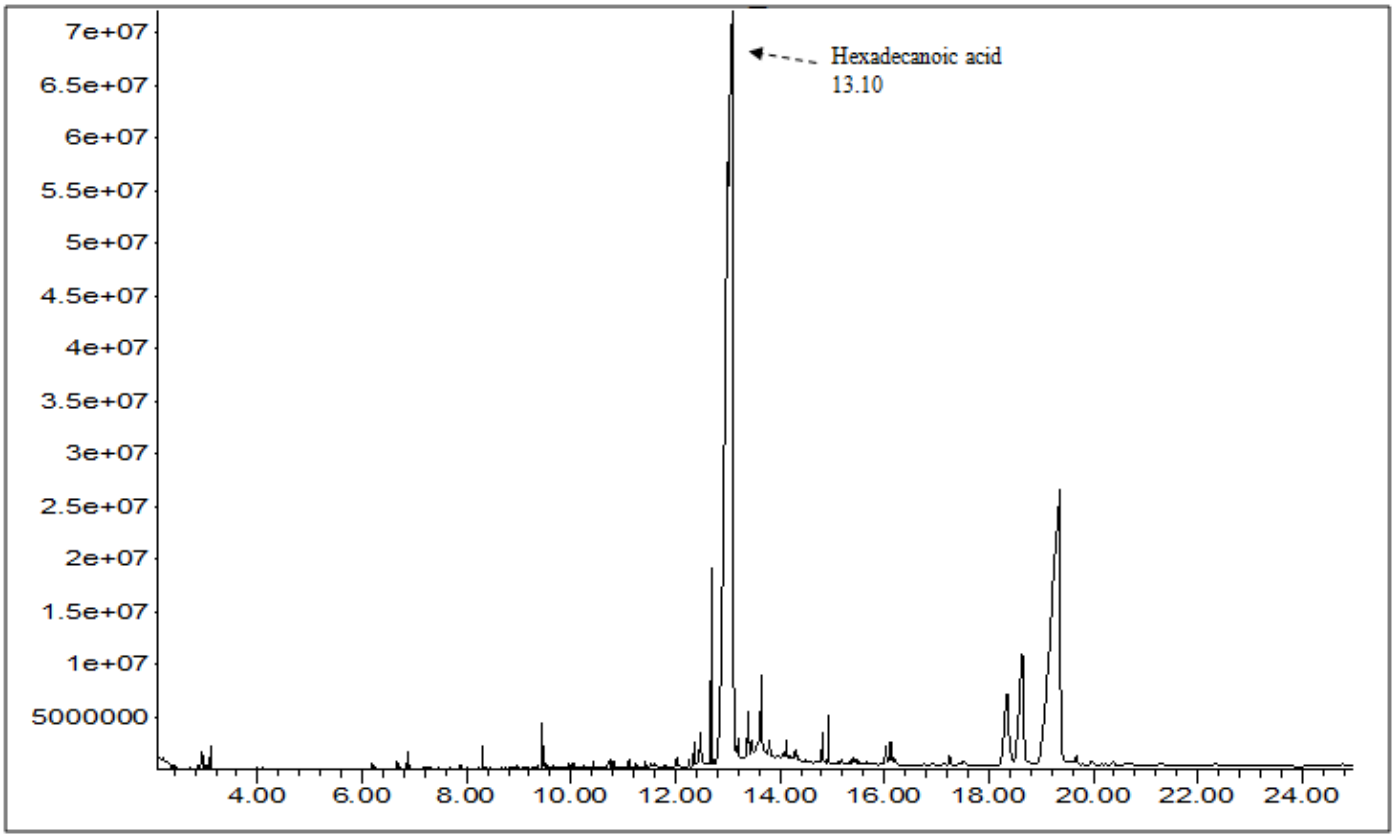


Table 4
GC-MS analysis of Hexane extract of Citrus grandis fruit peels

No	Retention time (minutes)	Compunds name	Composition (%)
1	2.927	2-Hexanone or Hexan-2one or MBK OR Methyl n butyl ketone	0.28
2	3.018	3-hexanol or Hexan-3-ol or Ethylpropylcarbinol	0.06
3	5.308	Ethanone,1-(1-cyclohexen-1-yl) or 1-Cyclohexen-1-yl methyl ketone	0.02
4	5.427	2-Hexanone, 4-methyl or 4-methyl-2 -hexanone	0.01
5	7.296	Octanal	0.06
6	7.457	Heptane	0.02
7	7.885	2 octenal	0.04
8	8.956	Octanoic acid or Caprylic acid	0.04
9	9.138	Trans,Trans-nona-2,4-dienal or 2,4-Nonadienal (E,E)	0.02
10	9.453	Decenal	0.28
11	9.488	4-Bromo-2-chlorophenol or Phenol,4-bromo-2-chloro	0.09
12	9.789	2,4-Decadienal or heptenyl Acrolein	0.03
13	10.083	Decanoic acid or Capric acid	0.02
14	10.23	Tetradecane	0.03
15	10.58	1,2-benzenedicarboxylic acid, dimethyl ester (CAS)	0.03
16	10.881	Dodecanoic acid, methyl ester or Methyl laurate	0.03
17	11.281	1,2-Benzenedicarboxylic acid, diethyl ester or Ethyl phthalate	0.01
18	11.323	Globulol	0.02
19	12.261	Pentadecanoic acid, methyl ester or methyl pentadcanoate	0.07
20	12.359	2-Pentadecanone,6,10,14-trimethyl	0.28
21	12.478	Pentadecanoic acid or Pentadecylic acid	0.78
22	12.688	Hexadecanoic acid, methyl ester or Methyl palmitate	1.48
23	13.101	Hexadecanoic acid or Palmitic acid or Palmitinic acid	47.64
24	13.395	10-Octadecenoic acid, methyl ester	1.15
25	13.801	O-(4-Bromo-2-chlorophenyl)-O-Ethyl Ester or Propylthio phos	0.64
26	14.319	4,8,12,16-Tetramethylheptadecan-4-olide	0.35
27	14.817	Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl) ethyl ester	0.52
28	14.929	1,2-Benzenedicarboxylic acid, 3-nitro	0.44
29	15.132	Tricosanoic acid, methyl ester or methyl tricosanoate	0.08
30	15.398	(z,z)3,13-octadecadien-1-ol	0.19
31	15.825	Pentacosanoic acid, methyl ester	0.15
32	17.442	Vitamin E	0.14
33	17.512	Cholest-5-en-3-ol (3 beta) or Lanol or Dythol or Kathro	0.27
34	18.352	Ergost-5-en-3-ol (3 beta)	3.08
35	18.647	Stigmasta-5,22-dien-3-ol (3 beta,22e)	4.34
36	19.361	Stigmast-5-en-3-ol(3 beta,24S) or Clionasterol	21.56

Figure 3
GC-MS Chromatogram of Ethyl Acetate extract of Citrus grandis fruit peels

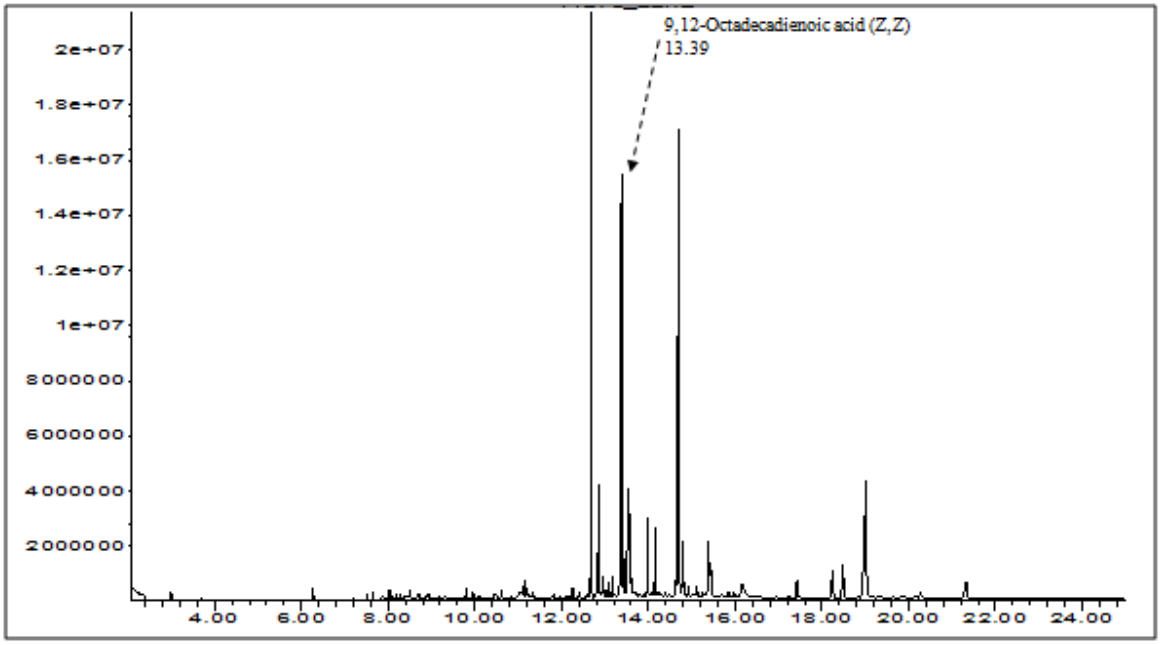


Table 5
GC-MS analysis of Ethyl Acetate extract of Citrus grandis fruit peels

No.	Retention Time (minutes)	Compounds name	Composition (%)
1	2.752	2H-Pyran-3,4-dihydro-6-methyl	0.02
2	6.274	Propanedioic acid, dimethyl ester or Dimethtyl malonate	0.31
3	8.039	Linalool Oxide or 2-Furanmethanol, 5-ethenyltetrahydro-alpha-alpha-5	0.32
4	8.928	Benzoic acid or Retardex or Tenn-Plas	0.52
5	10.118	Ethanol,2-(P-methoxyphenyl)	0.14
6	12.261	Pentadecanoic acid, methyl ester	0.17
7	12.695	Hexadecanoic acid, methyl ester or Methyl palmitate	10.80
8	12.947	Hexadecanoic acid, ethyl ester	0.41
9	13.073	Heptadecanoic acid, methyl ester or Methyl heptadecanoate	0.30
10	13.395	9,12-Octadecadienoic acid (Z,Z)	17.48
11	13.451	Octadecanoic acid, methyl ester or Methyl stearate	0.59
12	13.99	7-Methoxy-8-(2-oxo-3-methylbutyl) coumarin	1.68
13	14.788	Hexadecanoic acid,2,3-dihydroxypropyl ester	1.69
14	15.125	Tricosanoic acid, methyl ester or methyl tricosanoate	0.55
15	15.384	9,12-Octadecadienoic acid (Z,Z),2-hydroxy-1-(hydroxymethyl)ethyl ester	1.57
16	15.412	9,12,15-Octadecatrienoic acid, methyl ester (Z,Z,Z)	1.73
17	15.811	Pentacosanoic acid, methyl ester	0.19
18	15.846	2,6,10,14,18,22-Tetracosahexaene,2,6,10,15,19,23-hexamethyl	0.26
19	16.168	Naringenin or 4H-1-Benzopyran-4-one,2,3-dihydro-5,7-dihydroxy-2(4-hydroxyph)	1.01
20	16.938	beta Tocopherol or 2H-1-Benzopyran-6-ol,3,4-dihydro-2,5,8-trimethyl-2-(4,8,12)	0.12
21	17.428	Vitamin E	0.56
22	18.247	Ergost-5-en-3-ol (3 beta) or Delta 5 Ergostenol	1.12
23	19.018	Stigmast-5-en-3-ol(3 beta, 24S) or Clionasterol	6.74

Figure 4
GC-MS Chromatogram of Essential Oil of Citrus grandis fruit peels

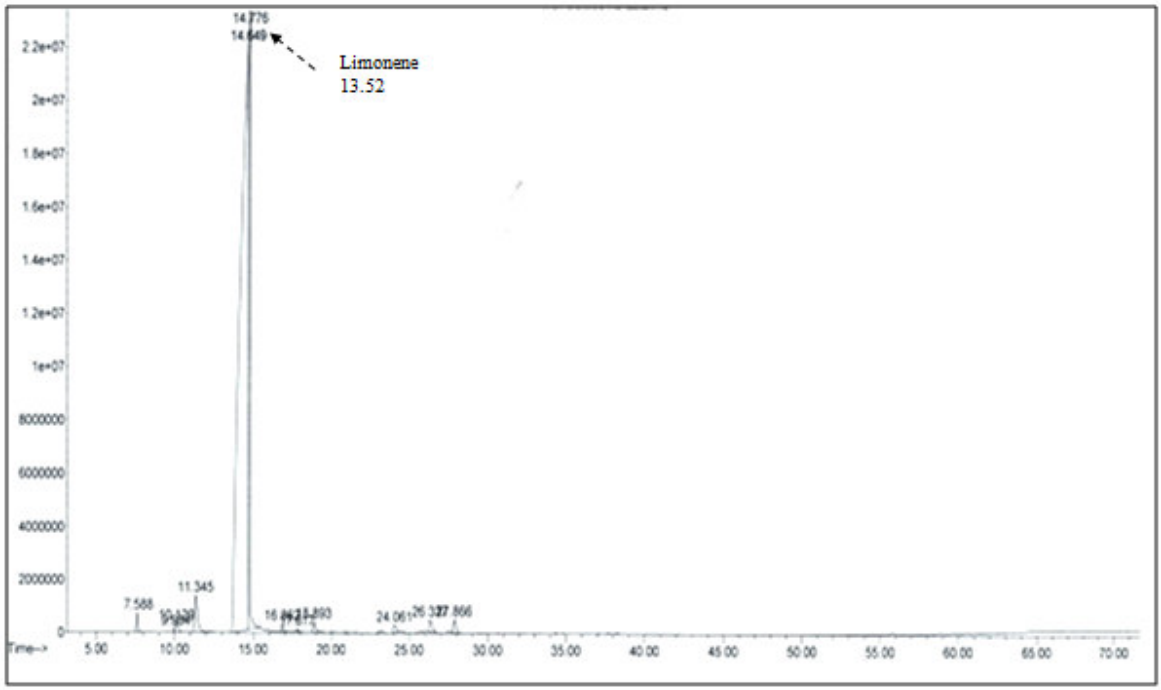


Table 6
GC-MS analysis of essential oil of C.grandis fruit peels

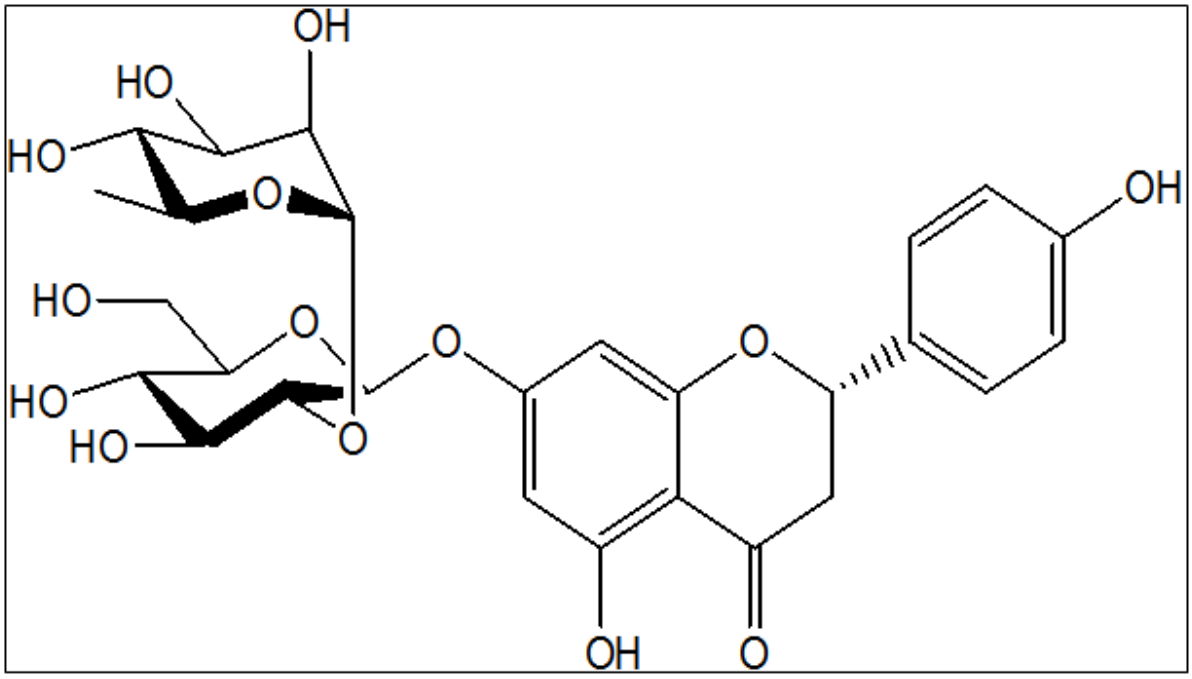
No.	Retention time (minutes)	Chemical name	% of total
1	4.544	α-Pinene	0.29
2	4.857	Camphene	0.02
3	4.864	Sabinene	0.00
4	6.067	β-Pinene	0.33
5	6.865	Myrcene	1.28
6	9.431	Limonene	93.78
7	13.446	*Cis*-Linalool Oxide	0.05
8	14.715	*Trans*-Linalool Oxide	0.23
9	16.889	Linalool	1.08
10	20.278	Terpinen-4-ol	0.32
11	23.016	α-terpineol	1.35
12	27.262	Neral	0.17
13	27.888	Geraniol	0.11
14	28.327	Geranial	0.10

Table7
^{1}H- and ^{13}C-NMR spectral data of CGE9

	Proton (δ_H)		Carbon (δ_C)	
	CGE9	Literature (*)	CGE9	Literature (*)
1	-	-	-	
2	5.34 brd (12.8)	5.34 brd (13)	80.7	80.7
3	3.14 ddd (17, 12.8, 6) 2.71 brdd (17, 2.6)	3.13 ddd (17, 13, 6) 2.73 brdd (17, 3)	43.9	44.1
4	-	-	198.5	198.5
5	-	-	164.9	164.9
6	6.12 d (2)	6.14 d (2)	97.8	97.8
7	-	-	166.5	166.5
8	6.14 d (2)	6.16 d (2)	96.7	96.7
9	-	-	164.6	164.6
10	-	-	104.9	104.9
1'	-	-	130.8	130.8
2'	7.29 d (8.5)	7.30 d (9)	129.1	129.1
3'	6.79 d (8.5)	6.80 d (9)	116.3	116.3
4'	-	-	159.1	159.0
5'	6.79 d (8.5)	6.80 d (9)	116.3	116.3
6'	7.29 d (8.5)	7.30 d (9)	129.1	129.1
1"	5.05 d (8)	5.07 d (8)	99.3	99.4
2"	3.52-3.67 m	3.63 dd (8, 7)	79.0	78.9
3"	3.52-3.67 m	3.58 dd (10, 7)	78.9	79.0
4"	3.32-3.44 m	3.38 dd (10, 9)	72.1	71.2
5"	3.32-3.44 m	3.42 m (10, 6, 2)	78.1	78.1
6"	3.81-3.91 m	3.85 brdd (11, 2) 3.68 m	62.2	62.2
1"'	5.22 d (1.5)	5.24 d (2)	102.5	102.5
2"'	3.81-3.91 m	3.93 dd (3, 2)	72.1	72.1
3"'	3.52-3.67 m	3.58 dd (10, 3)	71.2	72.1
4"'	3.32-3.44 m	3.38 dd (10, 10)	73.8	73.9
5"'	3.81-3.91 m	3.88 dq (10, 6)	70.0	70.0
6"'	1.24 d (6)	1.28 d (6)	18.2	18.2

**** http://www.agr.hokudai.ac.jp/ms-nmr/assign/naringin.htm***

Figure 5
Structure of CGE9



DISCUSSION

Investigation into locally cultivated white flesh *Citrus grandis* fruit peel extracts reveals the present of various compounds as well as the presence of crystalline powder which was later revealed to be naringin. NMR spectroscopy confirms the presence of Naringin as major compound in methanolic crude extract of *C. grandis* fruit peel. These findings are in accordance with several reports[26, 26, 27] which confirms naringin's presence in *C. grandis*. Naringin are found in abundance in the peel together with limonin and nomilin which releases the bitter taste[26, 27]. In addition to peel, naringin was also found in juices[28, 29] Naringin is a flavonoid extracted mainly from Citrus fruit peel[30], roots of *Cudrania cochinchinensis* var. *geronatogea*[31] and aerial parts of *Thymus herba barona*[32]. The compound has been industrially used as beverages, stabilizers, sweeteners, perfumes and vegetable oils in bakery products[33]. Many studies found evidence of biological activities such as antioxidant[34, 35, 36], antimicrobial[37], antiviral[38], anti-inflammatory[35,36] anticarcinogenic[39], neuroprotective[40],hepatoprotective[41], cardioprotective[42], hypercholesterolemic[43], lipid lowering effect[44] and cytotoxic and apoptosis effect[45]. Beside naringin which has been singled out as major compound, hexadecanoic acid and 9,12-octadecadienoic acid (Z,Z) are the other 2 major compounds elucidated from hexane and ethyl acetate fraction, respectively. Hexadecanoic acid, n-hexadeconoic acid or palmitic acid is a saturated fatty acid[46], which was also reported presence in other plant extract such as *Panax ginseng* shoot, *Mitracarpus scaber* shoot, *Eryngium foetidum* leaf, *Solanum tuberosum* leaf, *Myristica fragrans* seed and *Rheum palmatum* rhizome[47]. Oil from *Elaeis oleifera* and *Elaeis guineensis* are known to be a rich source of palmitic acid and has been applied as headache, cancer and rheumatism cure according to traditional medicine[48]. According to Rahuman *et al*. (2000)[49], pure active compound of n-hexadeconoic acid extracted from *Feronia lemonia* leaves displayed effective larvicidal activity when tested against fourth instar *Culex quinquefasciatus*, *Anopheles stephensi* and *Aedes aegypti* larvae. The larvicidal activity of n-hexadecanoic acid was also confirmed by Naik *et al*. (2014)[50] when the compound extracted from leaves of *Pongamia pinnata* was tested against *Ae. albopictus*. 9,12-octadecadienoic acid (Z,Z) is also known as linoleic or linolic acid[51]. Rahuman *et al*. (2008)[52] also demonstrated the mosquito larvicidal activity of linoleic acid. Linoleic acid extracted from *Citrullus colocynthis* using bioassay-guided fractionation was found to be potent when tested against *Ae. aegypti*, *An. stephensi*, and *C. quinquefasciatus* larvae. Essential oil of locally cultivated white flesh *C. grandis* fruit peel contains limonene, linalool, α-terpineol, neral and α-pinen. Similar chemical components were also reported presence in essential oil of Indonesian's cultivar[53]). Presence of limonene as major compound in *C. grandis* has been reported by researchers in Tunisia[54], Thailand[15] and Singapore[55] with slight differences in composition.

CONCLUSION

This study found hundreds phytochemical compounds in locally cultivated white flesh *C. grandis* fruit peel with the aid of GC-MS analysis and Nuclear Magnetic Resonance

(NMR) spectroscopic techniques. Information gained from this study is useful for further bioactivity and toxicity studies.

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