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Full Length Research Paper

A comparison of volatile components of flower of page mandarin obtained by ultrasound-assisted extraction and hydrodistillation

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Traditional hydrodistillation (HD) and ultrasound-assisted extraction method (UAE) have been compared and evaluated for their quantitative and qualitative compositions of the isolated essential oil from fresh page mandarin flowers. Thirty-eight flower components and twenty-nine flower components in the UAE and HD method, respectively including: aldehydes, alcohols, ketons, monoterpenes, sesquiterpenes and other components were indentified and quantified. The major flavor components of oil obtained by UAE were β-sinensal, α-sinensal, linalool, limonene, sabinene, ocimene, (z)-β-farnesene and E,E-α-farnesene. The major flavor components of oil obtained by HD were β-sinensal, α-sinensal, linalool, limonene, sabinene, ocimene and terpinene-4-ol. The UAE method offers important advantages over HD method, namely: provides a higher amount of oxygenated compounds. It offers also the possibility for a better reproduction of natural aroma of the essential oil from page mandarin flowers than the HD method. UAE method showed the highest content of aldehydes and alcohols. Since the aldehydes and alcohols content of citrus oil is considered as one of the more important indicators of high quality, method apparently has a profound influence on Page Mandarin oil quality.

Key words: Page mandarin flower, ultrasound-assisted extraction, hydrodistillation, oxygenated components.

INTRODUCTION

Citrus hybrids are so variable as the result of hybridization of many fine-quality mandarins and grapefruits, and many of these varieties are now being used successfully for juice production and as fresh fruit. Page mandarin, that resulted from a cross between [(Dancy tangerine and Duncan grapefruit) and Clementine mandarin], is a new hybrid citrus crop and has been regarded as a citrus fruit with potential commercial value because of its attractive and pleasant aroma. In *Citrus L*. species essential oils occur in special oil glands in flowers, leaves, peel and juice. These valuable essential oils are composed of many compounds including: terpenes, sesquiterpenes, aldehydes, alcohols, esters and sterols. They may also be described as mixtures of hydrocarbons, oxygenated compounds and nonvolatile residue. The oxygenated compounds are highly odoriferous and, hence, the most valuable. Essential oils of Citrus are used commercially for flavoring foods, beverages, perfumes, cosmetics, medicines, etc. (Babazadeh, 2009). Up to now, numerous investigations have been performed aimed at identifying the aroma volatiles in the mandarin flower (Salem, 2003; Kharebava and Tsertsvadze, 1986; Yoshikawa et al., 1996). The quality of an essential oil may be calculated from the quantity of oxygenated compounds present in the oil (Babazadeh, 2009). Branched aldehydes and alcohols are important flavor compounds in many food products (Babazadeh, 2009). Different studies showed that the quantity of oxygenated compounds present in the oil, is variable and depends on many parameters as: rootstock (Babazadeh et al., 2009), harvesting time (Toncer et al., 2010), the part of the plant analyzed (Lota et al., 2001, 2000), the geographical origin of the plant (Alissandrakis et al., 2003) and the technique of extraction (Porto and Decort, 2009; Kimbaris et al., 2006; Bendahou et al., 2008; Presti et al., 2005). The main techniques used at industrial scale are cold pressing, hydrodistillation, extraction with organic solvent,

extraction with compressed CO_2 and extraction with ultrasound-assisted extraction (UAE). Hydrodistillation enable the isolation of the essential oil borne in the plant, however, it has disadvantages.

Hyrodistillation (HD) can thermally degrade and hydrolyze some of the oil components, which in some cases can lead to significant distortion of the composition of the oils found in the natural plants (Gaspar and Leeke, 2004). One of the simplest extraction techniques is the UAE method that is easy to perform in common laboratory equipment. In this method, the crushed sample is mixed with the suitable solvent and placed into UAE where the working temperature and extraction are set (Dobias et al., 2010). UAE is a good extraction method in comparison with the more traditional approaches due to its high efficiency, low energy requirements and low solvent consumption. This technique has been used systematically in the extraction of substances with low molecular weights and bioactive compounds from plants. The improvement in the extraction process on using ultrasound is related to the destruction of the cellular walls, reduction of the particle size, and enhancement of the mass-transfer through the cell wall due to the collapse of bubbles produced by cavitations (Maclas-Sanchez et al., 2009).

In this paper, the essential oil from page mandarin flower obtained by UAE method has been compared with those obtained by conventional hydrodistillation.

MATERIALS AND METHODS

Rootstock

In 1989, Page mandarin trees, grafted on Yuzu, were planted at 8 × 4 m^2 with three replication at Ramsar research station [latitude 36° 54' N, Longitude 50° 40' E; Caspian Sea climate, average rainfall 970 mm per year and average temperature 16.25°C; soil was classified as loam-clay, pH range (6.9 to 7)].

Preparation of flower sample

In the early week of June 2007, for each rootstock about 300 g flower were collected from many parts of the same trees, located in Ramsar research station, early in the morning (6 to 8 a.m.) and only by dry weather.

Ultrasound-assisted extraction technique

The methodology, used in this study, was described by Allissandrakis et al. (2003). In order to obtain the volatile compounds from the flowers, 50 g of fresh flowers were placed in a 2000-ml spherical flask, along with 300 ml of n-pentane:diethylether (1:2). The flask was covered and then placed in an ultrasound (US) water bath apparatus for 20 min. Ultrasonic extractions were performed with an ultrasound cleaning bath-Fisatom Scientific-FS14H (Frequency of 40 KHz, nominal power 90 W and 24 × 14 × 10 cm internal dimensions water bath). The temperature of the US water bath was held constant at 25°C. The extract was subsequently filtered through MgSeO4 monohydrate. The extract was finally concentrated with a gentle stream of nitrogen to 1 ml, placed in a vial and sealed. It was kept in the freezer at −4°C until the GC-MS analysis. Three replicates were used for the quantitative and qualitative analysis (n = 3).

Hydrodistillation extraction technique

In order to obtain the volatile compounds from the flower, 250 g of fresh flowers were subjected to hydrodistillation for 3 h using a Clevenger-type apparatus. N-Hexane was used to isolate the oil layer from the aqueous phase. The hexane layer was dried over anhydrous sodium sulphate and stored at −4°C until used. Three replicates were used for the quantitative and qualitative analysis (n = 3).

GC and GC-MS

An Agilent 6890 N gas chromatograph equipped with a DB-5 (30 m ×0.25 mm i.d; film thickness = 0.25 µm) fused silica capillary column (J&W Scientific) and a flame ionization detector (FID) was used. The column temperature was programmed from 50°C (2 min) to 188°C (20 min) at a rate of 3°C/min. The injector and detector temperatures were 220°C and helium was used as the carrier gas at a flow rate of 0.8 ml/min and a linear velocity of 22 cm/s. The linear retention indices (LRIs) were calculated for all volatile components using a homologous series of n-alkanes (C9 to C16) under the same GC conditions. The weight percent of each peak was calculated according to the response factor to the FID. Some standards such as decanal, β-sinensal, α-sinensal, linalool, terpinene-4-ol, α-terpineol, (E) nerolidol, cis-jasmone, sabinene and limonene were acquired from the Sigma-Aldrich. Gas chromatography- mass spectrometry was used to identify the volatile components. The analysis was carried out with a Varian Saturn 2000R. 3800 GC linked with a Varian Saturn 2000R MS. The oven condition, injector and detector temperatures, and column (DB-5) were the same as those given earlier for the Agilent 6890 N GC. Helium was the carrier gas at a flow rate of 1.1 ml/min and a linear velocity of 38.7 cm/s. Injection volume was 1 µl.

Identification of components

Components were identified by comparing their LRIs and matching their mass spectra with those of reference compounds in the data system of the Wiley library and NIST Mass Spectral Search program (Chem. SW. Inc; NIST 98 version database) connected to a Varian Saturn 2000 R MS. Identifications were also determined by comparing the retention time of each compound with that of known compounds (Adams, 2001; McLafferty and Stauffer, 1989).

RESULTS

Flavors compounds of the page mandarin flower obtained by ultrasound-assisted extraction (UAE)

GC-MS analyze of the flavor compounds extracted from page mandarin flower by using ultrasound water bath allowed identification of thirty-eight volatile components (Table 1, Figure 1): 17 oxygenated terpenes (3 aldehydes, 13 alcohols, 1 ketones), 14 non oxygenated terpenes (9 monoterpenes hydrocarbons, 5 sesquiterpenes hydrocarbons) and 7 other components.

Table 1. Chemical composition of essential oils of the flowers of page mandarin obtained by UAE method.

Component	KI
α-Pinene	939
Sabinene	975
β-pinene	979
β-myrcene	991
δ-3-carene	1031
Limonene	1029
(E)-β-ocimene	1050
(E)sabinene hydrate	1070
α-terpinolene	1089
Linalool	1097
Phenyl ethyl alcohol	1107
Terpinene-4-ol	1177
α-terpineol	1189
Decanal	1202
Lilace alcohol B*	1217
Lilace alcohol D*	1233
Indol	1291
δ-elemene	1338
(Z)-2,6-dimethyl-2,7-octadien-1,6-diol*	1366
Cis-jasmone	1391
(Z)-β-caryophyllene	1409
(Z)-β-farnesene	1443
E,E, α-farnesene	1506
β-sesquiephellandrene	1523
(E)-nerolidol	1563
Germacrene D – 4 – ol	1576
Spathulenol	1578
Hexadecane	1600
α-Cadinol	1654
8-Heptadecene *	1676
Heptadecane	1700
β-Sinensal	1700
E,E-cis-farnesol	1725
α-sinensal	1757
Unknown	1832
Nonadecane	1900
Eicosane	2000
Heneicosane	2100

*The identification was based on the NBS72K mass spectra library and on published MS or MS and NMR data of Alistair et al. (1993) and Alissandrakis et al. (2003).

Flavor compounds of the page mandarin flower obtained by hydrodistillation (HD)

GC-MS analysis of the flavor compounds extracted from page mandarin flower by using hydrodistillation allowed identification of twenty-nine volatile components (Table 2): 10 oxygenated terpenes (2 aldehydes, 7 alcohols, 1 ketone), 17 non oxygenated terpenes (13 monoterpenes hydrocarbons, 4 sesquiterpenes hydrocarbons), and 2 other components.

Aldehydes

Three aldehyde components identified by two methods

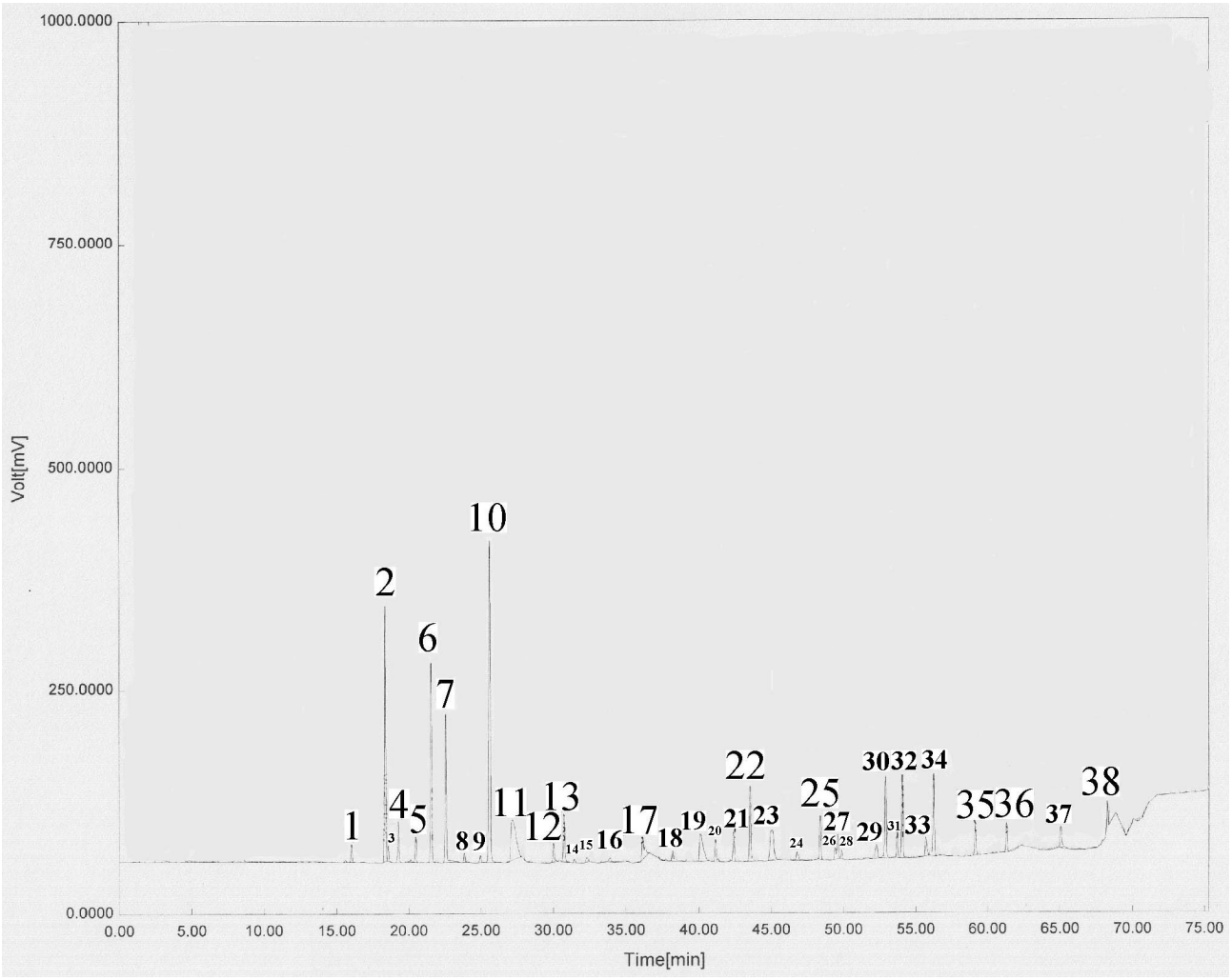

Figure 1. HRGC chromatogram of page mandarin flower oil obtained by ultrasound-assisted extraction (USE).

were: decanal, β-sinensal and α-sinensal (Table 3). Which they were quantified (from 5.16 to 7.16%) in the HD and UAE method, respectively. β-sinensal and α-sinensal were the most abundant in two methods. These findings were similar to the previous study undertaken by Salem (2003), Kharebava and Tsertsvadze (1986). β-sinensal has a green-sweaty aroma (Buettner et al., 2003), and is considered as one of the major contributors to mandarin flavor (Salem, 2003). Flower aldehyds obtained by UAE were also compared to those obtained by HD in this study. Decanal was identified in UAE, while it was not detected in HD. The content of flower aldehyds obtained by UAE were higher than those obtained by HD (Table 3). Compared with HD, the UAE method improved and increased aldehyds in page mandarin flower oil. Since the aldehyde content of citrus oil is considered as one of the more important indicators of high quality, method apparently has a profound influence on Page mandarin oil quality. Among the two method examined, UAE showed the highest content of aldehydes (Table 3).

Alcohols

Thirteen alcohol components identified by two methods were: linalool, Phenyl ethyl alcohol, terpinene-4-ol, α-terpineol, lilace alcohol B, lilace alcohol D, indol, (E)-2,6-dimethyl-2,7-octadien-1,6-diol, (E) nerolidol, Germacrene D – 4 – ol, spathulenol, α-cadinol and E,E-cis-farnesol (Table 3). The total amount of alcohols range (from 22.52 to 39.27%) in the HD and UAE method, respectively. Linalool was the most abundant in two methods. It was the main component in the essential oil isolated from page mandarin flowers and its relative amount was different for the two isolation methods. It was (from 12.6 to 16.82%) in the HD and UAE method, respectively. Linalool has a flowery (rose-like) aroma (Buettner et al., 2003) and its level in citrus flower, is important to flavor character (Alissandrakis et al., 2003). Flower alcohols obtained by UAE were also compared to those obtained by HD in this study. Phenyl ethyl alcohol, lilace alcohol B, lilace alcohol D, indol, (E)-2,6-dimethyl-2,7-octadien-1,6-

Table 2. Chemical composition of essential oils of the flowers of page mandarin obtained by hydrodistillation method.

Component	KI
α-Thujene	930
α-Pinene	939
Sabinene	975
β-Pinene	979
β-Myrcene	991
α-Phellandrene	1003
δ-3–carene	1031
α-Terpinene	1017
Limonene	1029
(E)-β-Ocimene	1050
γ-Terpinene	1060
(z) linalool oxide	1073
α-Terpinolene	1089
Linalool	1097
Terpinene-4-ol	1177
α-Terpineol	1189
Cis-Jasmone	1391
(Z)-β-Caryophyllene	1409
(Z)-β-Farnesene	1443
Bicyclogermacrene	1500
E,E, α-Farnesene	1506
(E)–nerolidol	1563
Spathulenol	1578
α-Cadinol	1654
8-Heptadecene	1676
β-Sinensal	1700
E,E-Cis-farnesol	1725
α-Sinensal	1757
Nonadecane	1900

diol and Germacrene D – 4 – ol were identified in flower oil obtained by UAE, while they were not detected in flower oil obtained by HD. Lilace alcohol B, lilace alcohol D, Germacrene D – 4 – ol were present in a weak rate in the essential oil obtained by UAE. The content of flower alcohol compounds obtained by UAE were nearly 2 times than those obtained by HD. Among the two methods examined, UAE showed the highest content of alcohols (Table 3).

Ketone

The only ketone compound identified by two methods was cis-jasmone (Salem, 2003; Kharebava and Tsertsvadze, 1986; Yoshikawa et al., 1996). The amount of cis-jasmone range from 0.63 to 0.79% in the HD and UAE method, respectively. Among the two methods examined, UAE showed the highest content of ketone (Table 3).

Monoterpenes hydrocarbons

The total amount of monoterpene hydrocarbons range from 31.58 to 64.80% in the UAE and HD method, respectively. Sabinene was the major component among the monoterpene hydrocarbons of page mandarin flower oil obtained by two methods. Limonene was the second component among the monoterpene hydrocarbons of page mandarin flower oil obtained by two methods. Limonene has a weak citrus-like aroma (Buettner et al., 2003) and is considered as one of the major contributors to mandarin flavor (Babazadeh, 2009). Among the two methods examined, HD had the highest monoterpenes content (Table 3).

Sesquiterpenes hydrocarbons

The total amount of sesquiterpene hydrocarbons range from 2.19 to 9.28% in the HD and UAE method, respectively.

(Z)-β-Farnesene and E,E-α-farnesene were the major components among the sesquiterpene hydrocarbons of page mandarin flower oil obtained by UAE method while (Z)-β-caryophyllene was the major component among the sesquiterpene hydrocarbons of method. Among the two methods examined, UAE had the highest sesquiterpenes content (Table 3).

Result of correlation

Simple intercorrellations between 10 components are presented in a correlation matrix (Table 4). The highest positive values or r(correlation coefficient) were between [limonene and terpinene-4-ol(99%)];[(Z)-β-farnesene and E,E-α-farnesene (99%)]; [sabinene and limonene(97%)]; [limonene and ocimene (97%)]; [ocimene and terpinene-4-ol (97%)]; [E,E-α-farnesene and α-sinensal (97%)]. The highest significant negative correlations were between [limonene and (Z)-β-farnesene (99%)]; [limonene and E,E-α-farnesene (99%)]; [terpinene-4-ol and (Z)-β-farnesene (99%)]. When 10 components were cluster analyzed, there was clustering of only 4 components into 2 two-compound factors above the 98% level of function. These 2 factors resulted from the clustering of highly positively interrelated compounds such as [limonene and terpinene-4-ol (99%)]; [(Z)-β-farnesene and E,E-α-farnesene (99%)] (Table 4).

Statical analyses

The Duncan's multiple range test was used to separate the significant methods. Of the 10 individual oil

Table 3. Statistical analysis of variation in oil components of page mandarin flower obtained by UAE and HD methods (materials and methods). Mean is average composition (%) in two different methods used with three replicates. St. err. = standard error. F value is accompanied by its significance, indicated by: NS = not significant, * = significant at P = 0.05, ** = significant at P = 0.01.

Compounds	Ultrasound-assisted extraction (%)		Hydrodistillation (%)		
	Mean	St.err	Mean	St.err	F value
Oxygenated compounds					
a) Aldehyds					
1) decanal	0.16	0.04	0.00	0.00	
2) β-sinensal	3.20	0.28	3.13	0.25	NS
3) α-sinensal	3.80	0.30	2.03	0.11	F**
Total	7.16	0.62	5.16	0.36	
b) Alcohols					
1) linalool	16.82	0.61	12.60	1.47	F*
2) phenyl ethyl alcohol	8.16	0.96	0.00	0.00	
3) terpinene-4-ol	0.60	0.05	4.60	0.70	F**
4) α- terpineol	2.19	0.16	1.20	0.26	
5) lilace alcohol B	0.38	0.03	0.00	0.00	
6)lilace alcohol D	0.43	0.12	0.00	0.00	
7) indol	1.81	0.16	0.00	0.00	
8) (E)-2,6-dimethyl-2,7-octadiene-1,6-diol	3.42	0.55	0.00	0.00	
9) (E) nerolidol	2.00	0.30	2.06	0.37	
10) Germacrene D – 4 – ol	0.49	0.05	0.00	0.00	
11) spathulenol	1.39	0.27	1.60	0.11	
12) α-cadinol	0.79	0.29	0.20	0.00	
13) E,E-cis-farnesol	0.79	0.29	0.26	0.05	
Total	39.27	3.84	22.52	2.96	
c) ketone					
1) cis-jasmone	0.79	0.29	0.63	0.11	
Total oxygenated compounds	47.22	4.75	28.31	3.43	
Monoterpenes					
1) α-thujene	0.00	0.00	0.60	0.10	
2) α-pinene	0.60	0.05	2.49	0.40	
3) sabinene	11.81	0.97	20.10	2.20	F**
4) β-pinene)	0.60	0.05	0.80	0.00	
5) β-myrcene	1.58	0.22	3.03	0.81	F*
6) α -phellandrene	0.00	0.00	0.20	0.00	
7) δ -3-carene	0.79	0.31	2.30	0.11	
8) α-terpinene	0.00	0.00	1.43	0.20	
9) limonene	9.01	0.45	18.03	0.89	F**
10) (E)- β - ocimene	6.38	0.40	11.76	0.32	F**
11) γ -terpinene	0.00	0.00	2.73	0.85	
12) (z)-sabinene hydrate	0.41	0.03	0.00	0.00	
!3) (z)-linalool oxide	0.00	0.00	0.50	0.00	
14) α terpinolene	0.40	0.003	0.83	0.15	
Total	31.57	2.48	64.80	6.03	
Sesquiterpenes					
1) δ- elemene	0.55	0.02	0.00	0.00	
2) (Z)- β -caryophyllene	1.20	0.11	0.70	0.10	
3) (Z)- β - farnesene	3.39	0.06	0.63	0.15	F**
4) bicyclogermacrene	0.00	0.00	0.66	0.11	
5) E,E-α-farnesene	3.58	0.33	0.20	0.00	F**
6) β-sesquiphellandrene	0.56	0.04	0.00	0.00	

Table 3 Contnd.

Total	9.28	0.56	2.19	0.36
Other compounds				
1) hexadecane	0.38	0.03	0.00	0.00
2) 8-heptadecene	4.00	0.03	0.66	0.15
3) heptadecane	0.98	0.27	0.00	0.00
4) neophytadiene	1.20	0.11	0.00	0.00
5) nonadecane	1.20	0.11	0.30	0.10
6) Eicosane	0.44	0.03	0.00	0.00
7) heneicosane	1.20	0.11	0.00	0.00
total	9.40	0.69	0.96	0.25
Total	97.48	8.48	96.26	10.07

Table 4. Correlation matrix (numbers in this table correspond with main components mentioned in Table 3).

	Sabinene	**β-Myrcene**	**Limonene**	**Ocimene**	**Linalool**	**Terpinene-4-ol**	**z-β-Farnesene**	**E,E-α-Farnesene**	**β-Sinensal**
β-Myrcenee	0.76								
Limonene	0.97**	0.78							
Ocimene	0.91*	0.82*	0.97**						
Linalool	-0.94**	-0.61	-0.94**	-0.90*					
Terpinene-4-ol	0.95**	0.71	0.99**	0.97**	-0.96**				
z-β-Farnesene	-0.95**	-0.79	-0.99**	-0.98**	0.93**	-0.99**			
E,E-α-Farnesene	-0.95**	-0.81*	-0.99**	-0.97**	0.91*	-0.97**	0.99**		
β-Sinensal	-0.03	-0.17	-0.1	-0.18	0.1	-0.09	0.11	0.18	
α-Sinensal	-0.92**	-0.85*	-0.96**	-0.97**	0.90*	-0.94**	0.96**	0.97**	0.32

* = significant at 0.05, ** = significant at 0.01.

components analyzed, 9 showed statistically significant differences due to the influence of different methods and even here differences were small. These differences on the 1% level occurred in sabinene, limonene, ocimene, terpinene-4-ol, (Z)-β-farnesene, E,E-α- farnesene and α-sinensal (Table 3). These differences on the 5% level occurred in β-myrcene and linalool. The non affected oil component was β-sinensal and it is provided only for convenience of the reader (Table 3).

DISCUSSION

Our observation that changing method has an effect on some of the components of oil is accord with other observations (Porto and Decort, 2009; Kimbaris et al., 2006; Bendahou et al., 2008; Presti et al., 2005). The compositions of page mandarin flower by HD and UAE method were very similar. However, relative concentration of compounds differed according to the extraction method. The higher abundance of aldehyd components in UAE method than in HD is related to the low heating and the smaller amount of water used which prevented the decomposition of principal aldehyd constituents by thermal and hydrolytic reactions. It may be concluded that the effect of heat on this particular molecules is strongly destructive, causing those to degrade to other volatiles.

The effect of heat appears to be the crucial factor for the differentiation of the volatile fraction constituents, mainly through degradation reactions (Kimbaris et al., 2006). Compared with HD, the UAE method improved and increased alcohol components about 2 times for page mandarin flowers. The amount of alcohol

components obtained by HD was low because of the application of heating for long time resulting in thermal degradation of labile compounds.

The lower proportion of the detected alcohol components in HD method was probably due to the use a large quantity of water (Porto and Decorti, 2009). The pronounced enhancement in the amount of oxygenated compounds, when UAE was used as the method, showed that either the synthesis of geranyl pyrophosphate (GPP) is enhanced or activities of both enzymes (isopentenyl pyrophosphate isomerase and geranyl pyrophosphate synthase) increased (Hay and Waterman, 1995). High positive correlations between two terpens such as [limonene and terpinene-4-ol(99%)]; [(Z)-β-farnesene and E,E-α-farnesene (99%)]; [sabinene and Limonene (97%)]; [limonene and ocimene (97%)]; [ocimene and terpinene-4-ol (97%)]; [E,E-α-farnesene and α-sinensal (97%)] suggest a genetic control (Scora et al., 1976). Whether such dependence between two terpenes is due to their derivation of one from another is not known. Similarly, high negative correlations observed between [limonene and (Z)-β-farnesene (99%)]; [limonene and E,E-α- farnesene (99%)]; [terpinene-4-ol and (Z)-β-farnesene (99%)] suggest that one of the two compounds is being synthesized at the expense of the other or of its precursor. Non-significant negative and positive correlations can imply genetic and /or biosynthetic independence. However, without a thorough knowledge of the Biosynthetic pathway leading to each terpenoid compound, the true significance of these observed correlations is not clear. The highest positive value (correlation) were between [limonene and terpinene-4-ol (99%)]; [(Z)-β-farnesene and E,E-α-farnesene (99%)]. This result indicated which these compounds were under the control of a single dominant. (Scora et al., 1976) gene (Table 4).

Conclusion

The percent of flavor compounds recovery depends on method. The essential oil obtained by UAE method contained more oxygenated compounds and fewer monoterpene components than those isolated by the HD method. It is easy to observe the significant variations among the HD and UAE method, mainly in terms of the quantities of oxygenated compounds. The application of UAE method for the extraction of the essential oil is considered to cause a lesser damage of thermal-sensitive molecules, thus, providing a better approach of the compounds primarily responsible for the characteristic odor and taste of freshly mandarin flower.

The effect of heat appears to be the crucial factor for the differentiation of the volatile fraction constituents, mainly through degradation reactions. The application of UAE method can be a promising technique to recovery aroma compounds from plants to use as natural flavoring in food, hygienic and aromatherapy products. It can be also utilized in pharmacy, cosmetics and other areas. The UAE procedure diminishes the danger of thermal degradation of sensitive aroma compounds from mandarin flower. Moreover, the method is easy to carry out and could be applicable for large scale industrial use. The mechanical effect of ultrasound is able to accelerate the extraction of organic compounds, contained within the body of plants, due to disruption of the cell walls and enhanced mass transfer of cell contents. Further research on the relationship between method and essential oil (oxygenated terpenes) is necessary.

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