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REVIEW

Volatile compounds of ginseng (*Panax* sp.): a review

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Abstract The compositions of ginseng volatiles and their differences therein based on the species, cultivation age, and cultivation method are reviewed in this paper. Some sesquiterpene hydrocarbons (e.g., β-panasinsene, α-panasinsene, α-neoclovene, β-neoclovene, bicyclogermacrene, β-farnesene, aromadendrene, and (E)-caryophyllene) and sesquiterpene alcohols (e.g., (+)-spathulenol, ginsenol, panasinsenol A, and panasinsenol B) were reportedly the main volatile compounds of ginseng. The differences between ginseng species were mainly associated with sesquiterpene hydrocarbons and monoterpenes, such as α-selinene, α-terpinolene, β-bisabolene, β-phellandrene, β-sesquiphellandrene, zingiberene, germacrene D, limonene, α-gurjunene, (E)-caryophyllene, δ-cadinene, (E)-β-farnesene, α-humulene, bicyclogermacrene, longiborn-8-ene, β-neoclovene, and (+)-spathulenol. Also, the amounts of α-cadinol, α-bisabolol, thujopsene, and *n*-hexadecanoic acid significantly increased with the cultivation ages. Moreover, aromadendrene, calarene, β-panasinsene, (E)-caryophyllene, α-neoclovene, and α-farnensene contributed to the discrimination among ginsengs cultivated using different methods.

Keywords Differences in the volatiles · Ginseng · Metabolomics approach · Species · Volatile profiles

Introduction

Ginseng is one of the *Panax* genus of slow-growing perennial plants, belonging to the family *Araliaceae*. The English word 'ginseng' derives from the Chinese term 'rénshēn', which implies the meaning of person (rén) and plant root (shēn) (Oxford Dictionaries Online). The genus name *Panax* also means 'cure' (Pan = all + axos = medicine) in Greek (Court 2000). Almost ginseng species have been employed as a material of medicine (Cho 1995), in particular, the Asian populations have used it for more than 2,000 years in plant-based or herbal sources to deal with medical conditions (Park et al. 2006). The bioactive constituents of *P. ginseng* have been extensively studied, such as ginsenosides, polyacetylenes, acid polysaccharides, insulin-like acid peptides, and antioxidative aromatic compounds (Choi 2008), in particular, almost studies have focused on ginsenosides, which are a type of saponin exhibiting a lot of biological activities including anti-diabetic, anti-aging, anti-carcinogenic, anti-fatigue, anti-pyretic, anti-stress, and promotion of DNA, RNA, and protein synthesis activities (Han et al. 1984; Bhattacgarya and Mitra 1991; Kitts et al. 2000; Hu and Kitts 2001; Angelova et al. 2008; Woo et al. 2011). However, ginseng is also employed in diverse types of culinary dishes (e.g., salad, soup, stew, steamed dishes, tea, and other beverages) as well as processed food due to its distinct flavor characteristics. Thus, it is meaningful (1) to review the volatile profiles of ginseng as a source of food. Moreover, this study is (2) to compare the volatiles of ginseng according to different factors, such as species, cultivation ages, and cultivation methods, and (3) to understand their differences.

The volatile profiles of ginseng

There are specifically thirteen species in the *Panax* genus: *P. ginseng* C. A. Meyer (also known as Asian or Korean

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ginseng and cultivated in Korea, Japan, China, Russia, and Germany), *P. quinquefolius* L. (also known as American ginseng and grown in the United States of America and southern Canada), *P. japonicus* C. A. Meyer (also known as Japanese ginseng and cultivated in Japan), *P. notoginseng* (Burk.) F. H. Chen (also known as Sanchi ginseng and grown in Yunnan Province, China), *P. trifolius* L. (also known as Dwarf ginseng and cultivated from Nova Scotia to Wisconsin and further south), *P. major* Ting, *P. omeiensis* J. Wen, *P. pseudoginseng* Wallich (grown in Nepal), *P. sinensis* J. Wen, *P. stipuleanatus* H. Y. Tsai & K. M. Feng, *P. wangianus* Sun, *P. zingiberensis* C. Y. Wu & K. M. Feng, and *Panax vietanensis* Ha et Grushv (Nguyen et al. 1993; Yun 2001). One of the most commonly used and researched ginseng species is *P. ginseng* C. A. Meyer. The first studies of the aroma of ginseng investigated *P. ginseng* with Takahashi and Yoshikura isolating panaxynol from its ether extract (Takahashi and Yoshikura 1966). Yoshihara and Hirose (1975) also identified 15 sesquiterpene hydrocarbons extracted from *P. ginseng*, including α-panasinsene, β-panasinsene, α-neoclovene, and β-neoclovene. Another study found thirteen pyrazines in the basic fraction of *P. ginseng*, and that 3-sec-butyl-2-methoxy-5-methyl pyrazine was the main contributor to its characteristic aroma properties (Iwabuchi et al. 1984). More sesquiterpene hydrocarbons compounds (e.g., ginsenol, panasinsenol A, panasinsenol B, (+)-spathulenol, (−)-4β,10α-aromandendranediol, and (−)-neointermedeol) and sesquiterpenoids were additionally identified in the neutral fraction of *P. ginseng* (Iwabuchi et al. 1987, 1989, 1990). Figure 1 summarizes the representative sesquiterpene hydrocarbons and sesquiterpene alcohols of ginseng. Sesquiterpenes are a class of terpenes that consist of three isoprene units, with the molecular formula $C_{15}H_{24}$. In general, sesquiterpenes, together with monoterpenes ($C_{10}H_{16}$), are strongly associated with the aroma characteristics of plants (Reineccius 2007). In particular, various studies have indicated that most ginseng species exhibit large proportions of sesquiterpenes and smaller percentage of monoterpenes (Ko et al. 1996; Qiu et al. 2008; Lee et al. 2012; Cho et al. 2012). Ko et al. (1996) analyzed how the composition of volatiles varies with the ginseng species. As indicated in Table 1, a total of 55 volatile compounds comprising 29 terpene hydrocarbons, 11 alcohols, 7 acids and esters, 5 carbonyls, and 3 miscellaneous heterocyclic compounds were detected in *P. ginseng*, *P. notoginseng*,

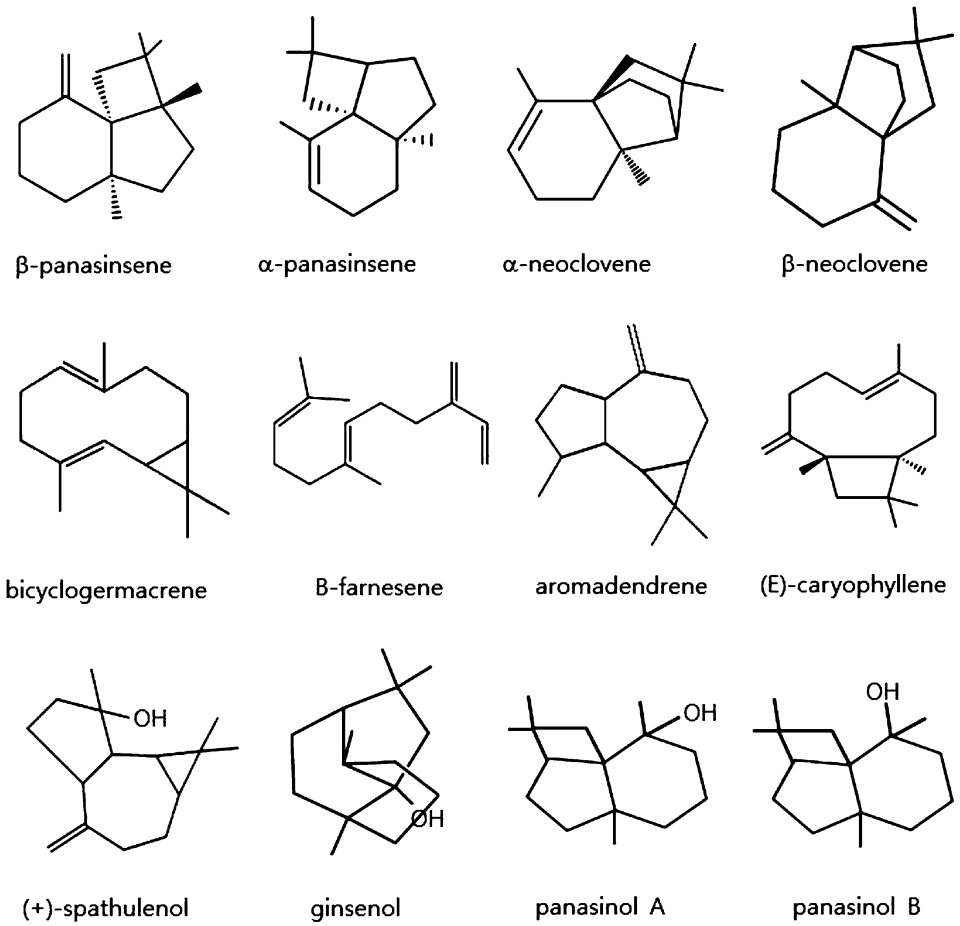

Fig. 1 Representative sesquiterpene hydrocarbons and sesquiterpene alcohols of ginseng

and *P. quinquefolium*. Sesquiterpene hydrocarbons and sesquiterpene alcohols were also found to be major volatile compounds of ginseng in that study, which is consistent with the founding of previous studies (Takahashi and Yoshikura 1966; Yoshihara and Hirose 1975; Iwabuchi et al. 1984, 1987, 1989, 1990; Qiu et al. 2008; Lee et al. 2012; Cho et al. 2012). Interestingly, the volatile profiles in *P. quinquefolium* and *P. notoginseng* differed somewhat from that of *P. ginseng*. Quantitatively, β-panasinsene, (+)-spatulenol, α-neoclovene, β-caryophyllene, and panasinesenol A were the primarily compounds in *P. ginseng*, while acids and esters were dominant in other ginseng species.

On the other hand, ginseng is normally employed in processed forms (white and red ginseng) with lower water content and longer shelf-life compared to fresh ginseng (Park et al. 2001). White ginseng is produced by drying fresh ginseng, while red ginseng is produced by multiple steps of steaming and then drying. Red ginseng exhibits greater bioactivities than white ginseng due to their much more ginsenoside contents (Kim et al. 2007; Wang et al. 2007) and is commonly used as herbal medicines in South Korea. Ko et al. (1996) profiled and compared the volatiles of white and red *P. ginseng*. The volatiles of red ginseng were primarily of the following compounds: β-caryophyllene, spathulenol, β-panasinsene, bicyclogermacrene, α-neoclovene, selina-4,11-diene, and α-panasinsene (Table 1). Sohn et al. (1997) focused on the ratios of β-panasinsene and γ-muurolene as contributors of the discrimination between Korean and Chinese white and red ginseng. More recently, Abod El-Aty et al. (2008) compared the volatile profiles from fresh, white, and red *P. ginseng*. They reported that fresh ginseng exhibits a high proportion of 3-actyl-1-(3,4-dimethoxyphenyl)-5-ethyl-4,5-dihydro-7,8-dimethoxy-4-methylene-3*H*-2,3-nzodiazepine and 23,24-dinor-3-oxolean-4,12-dien-28-oic acid, compared to white and red ginseng. In addition, 2-furanmethanol and 3-hydroxy-2-methyl-4*H*-pyran-4-one were main compounds of white ginseng, while the major compounds of red ginseng were 1,2-benzenedicarboxylic acid dibutyl ester and 2-furanmethanol. That study demonstrated that many characteristic volatile compounds of fresh ginseng might be disappeared while some compounds being newly produced through processing steps, which could result from chemical transformation of compositions during the heat treatment.

The differences in the compositions of ginseng volatiles using metabolomics-based analysis

In general, the qualities and chemical compositions of plants could be significantly influenced on the species, varieties, environmental factors, and methods of cultivation, harvesting, and storage, and/or processing conditions (Baldwin et al. 2000; Fellman et al. 2000), and this is especially true for ginseng due to its unique growth characteristics. In addition, some species are frequently substituted with other species because the demand and consumption of ginseng have been increased and they have different market values according to the species. However, it is difficult to identify the origin of ginseng species because some are morphologically very similar, especially *P. ginseng* versus *P. notoginseng* species, and many ginsengs are consumed in the form of powder or slices. Thus, it is required to study and determine the differences in the chemical compositions, qualities, and biological effects among ginseng based on objective factors. Metabolomics is one of the systematic study approaches in order to do it. (Okada et al. 2010). In recent, it has been used in various plant research applications (Roessner et al. 2001; Ward et al. 2003; Kim et al. 2004; Garratt et al. 2005; Baker et al. 2006; Beckmann et al. 2007; Deborde et al. 2009; Kim et al. 2009; Lee et al. 2009; Ren et al. 2009; Lebot et al. 2011). This approach has been also applied in ginseng studies to determine the age of ginseng roots, to identify ginseng according to the cultivation area or origin, to investigate biomarkers between ginseng varieties, and to compare chemical compounds in ginseng roots (Qiu et al. 2008; Lu et al. 2008; Zhang et al. 2010; Cho et al. 2012; Li et al. 2012; Lee et al. 2012; Kwon et al. 2014). In particular, the differences in the volatile compositions of ginseng based on the species, cultivation age, and cultivation method have been reviewed herein (Qui et al. 2008; Cho et al. 2012; Lee et al. 2012).

Qiu et al. (2008) identified 369 volatile compounds in ginseng species, and then applied principal component analysis (PCA) to GC–MS datasets of volatiles to determine differences between ginseng volatiles with age. The PCA scores were clearly clustered in three groups according to the ages. This indicates that the volatile compositions of ginseng are different according to the cultivation ages. Twenty variables, α-cadinol, (E,Z)-farnesol, hydroxy neoisolongifolane, isoaromadendrene epoxide, 1,4-dimethyl-7-(1-methylethly)-azulene, 1,2,3,4,5,6-hexahydro-1,1,5,5-tetramethyl-2(s-cis)-2,4a-methanonaphthalene-7(4aH)-one, 4,4-dimethyl-3-(3-methylbut-3-enylidene)-2-methylenebicyclo[4,1,0]heptane, 8,9-dehydroneoisolongifolen, *n*-hexanoic acid, *n*-hexadecanoic acid, 9,17-octadecadienal, calarene epoxide, 8,14-cedranoxide, veridiflorol, α-vatirenene, ledene oxide-(2), neoclovene oxide, thujopsene, longipinocarvone, α-bisabolol, and aromadendrene oxide-(2), were the main contributors to the discrimination. In particular, this study reported that α-cadinol, α-bisabolol, thujopsene, and n-hexadecanoic acid significantly increased with the cultivation age (Fig. 2). In addition, the difference in the compositions of ginseng volatiles according to the species was studied (Cho et al. 2012). As shown in Fig. 3, *P. ginseng* and *P. notoginseng*

Table 1 Volatile compositions of white and red ginseng

No.	Compounds	Relative GC peak area (%)			
		White ginseng			Red ginseng
		P. ginseng	*P. quinquefolium*	*P. notoginseng*	*P. ginseng*
	Carbonyls				
1	*n*-Pentanal	0.32	0.04	nd	0.04
2	*n*-Hexanal	2.24	1.14	0.73	0.11
3	*n*-Octanal	1.41	1.58	3.97	0.48
4	*n*-Nananal	0.14	0.57	0.94	0.22
5	Selina-4,11-diene	1.25	3.77	2.00	3.69
	Alcohols				
6	*n*-Hexanol	0.14	0.13	nd	0.22
7	*trans*-2-hexen-1-ol	0.89	0.30	nd	0.50
8	2,4-Decadienol	0.76	0.25	1.69	nd
9	Maltol	nd	nd	nd	0.61
10	Panasinsenol A	4.67	0.45	nd	0.50
11	Panasinsenol B	2.27	nd	nd	0.68
12	Ledol	2.59	0.41	0.42	0.90
13	Spathulenol	9.58	0.90	20.84	5.07
14	Neointernedeol	2.05	nd	nd	1.37
15	Ginsenol	2.02	0.56	nd	1.22
16	Cedrol	0.39	nd	nd	0.24
17	Farnesol	0.40	2.01	nd	0.39
	Sesquiterpenes				
18	α-Pinene	0.15	t	nd	nd
19	Camphene	1.08	0.05	nd	0.05
20	β-Pinene	1.08	nd	nd	nd
21	Myrcene	0.60	t	0.68	0.22
22	α-Phellandrene	0.35	0.97	1.03	0.21
23	Limonene	0.11	nd	nd	nd
24	γ-Terpinene	0.05	0.11	nd	0.10
25	ρ-Cymene	0.27	0.33	nd	nd
26	δ-Elemene	0.46	nd	nd	0.21
27	α-Cubebene	0.17	0.64	2.18	1.62
28	Amorphene	0.42	nd	2.51	0.28
29	α-Copaene	0.32	0.22	nd	0.31
30	α-Bourbonene	0.53	nd	3.66	0.37
31	β-Panasinsene	9.95	0.37	nd	4.68
32	Longipinene	0.40	0.49	1.98	0.52
33	α-Gurjunene	0.45	nd	nd	0.19
34	α-Bergamotene	0.11	0.23	nd	0.28
35	β-Caryophyllene	7.07	0.92	nd	5.59
36	Guaiene	0.27	nd	1.68	0.42
37	α-Panasinsene	1.73	nd	5.04	3.36
38	α-Neoclovene	7.61	nd	nd	4.38
39	γ-Elemene	1.36	t	1.52	1.04
40	α-Humulene	0.38	nd	nd	2.58
41	β-Neoclovene	2.22	nd	nd	1.05
42	β-Selinene	1.00	0.22	nd	1.01
43	γ-Cadinene	0.38	nd	nd	0.83

Table 1 continued

No.	Compounds	Relative GC peak area (%)			
		White ginseng			Red ginseng
		P. ginseng	*P. quinquefolium*	*P. notoginseng*	*P. ginseng*
44	α-Cadinene	t	0.18	nd	1.30
45	Bicyclogermacrene	t	2.30	3.67	4.60
46	β-Bisabolene	0.28	0.72	nd	2.54
	Acids and esters				
47	*n*-Hexanoic acid	t	16.36	nd	nd
48	*n*-Heptanoic acid	0.10	0.62	nd	nd
49	*n*-Octanoic acid	nd	3.69	nd	nd
50	Methyl palmitate	t	3.35	nd	1.34
51	Ethyl palmitate	1.64	nd	5.97	1.22
52	Methyl linoleate	0.25	1.67	1.87	0.23
53	Ethyl linoleate	0.15	2.39	0.39	nd
	Miscellaneous				
54	2-Acetyl pyrrole	nd	nd	1.51	0.83
55	2-Pentylfuran	nd	0.88	0.59	nd
56	2,3-Dimethyl pyrazine	0.06	0.12	nd	nd
57	2,3,5-Trimethyl pyrazine	nd	nd	nd	0.23

From Ko et al. (1996)

nd not detected, *t* trace (peak area percent less than 0.05)

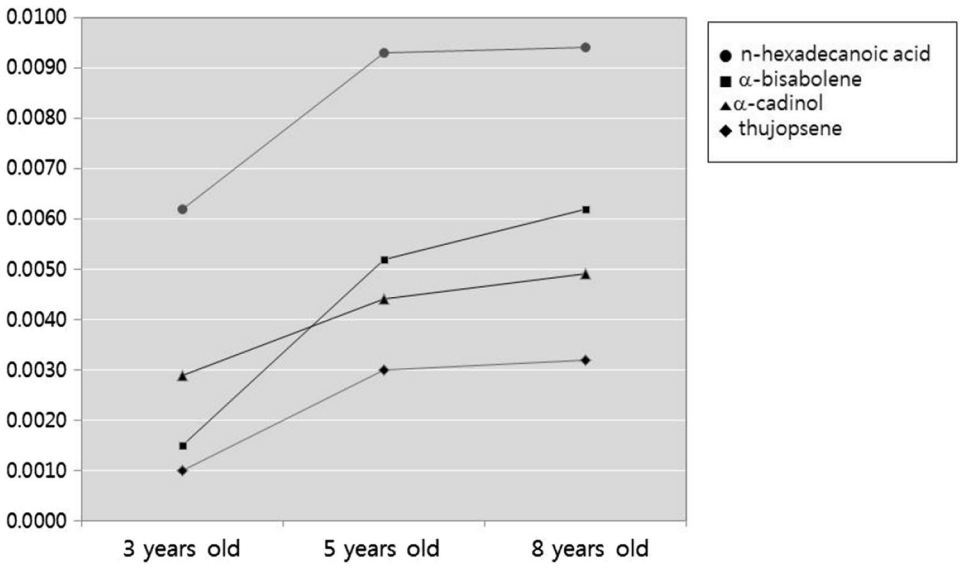

Fig. 2 Relative abundances of main volatiles contributors with cultivation age (Qiu et al. 2008). They were calculated by averaging their relative peak volumes (vol%) in three samples, respectively

were grouped from *P. quinquefolius* mainly by PC 1, and then *P. ginseng* and *P. notoginseng* species were discriminated from each other by PC 2. The levels of α-selinene, α-terpinolene, β-bisabolene, β-phellandrene, β-sesquiphellandrene, zingiberene, germacrene D, limonene, α-gurjunene, (E)-caryophyllene, δ-cadinene, (E)-β-farnesene, α-humulene, bicyclogermacrene, longiborn-8-ene, β-neoclovene, and (+) spathulenol, which are known as major volatile compounds of ginseng, mainly affect the separation between *P. ginseng* and *P. notoginseng* versus P. quinquefolius (Table 2). In particular, *P. ginseng* and *P. notoginseng* have larger amounts of α-gurjunene, (E)-caryophyllene, α-humulene, bicyclogermacrene, longiborn-8-ene, β-neoclovene, and (+) spathulenol, whereas *P. quinquefolius* contained higher portions of α-selinene, α-terpinolene, β-bisabolene, β-phellandrene, β-sesquiphellandrene, zingiberene, germacrene D, limonene, δ-cadinene, and (E)-β-farnesene. On the other hand, the

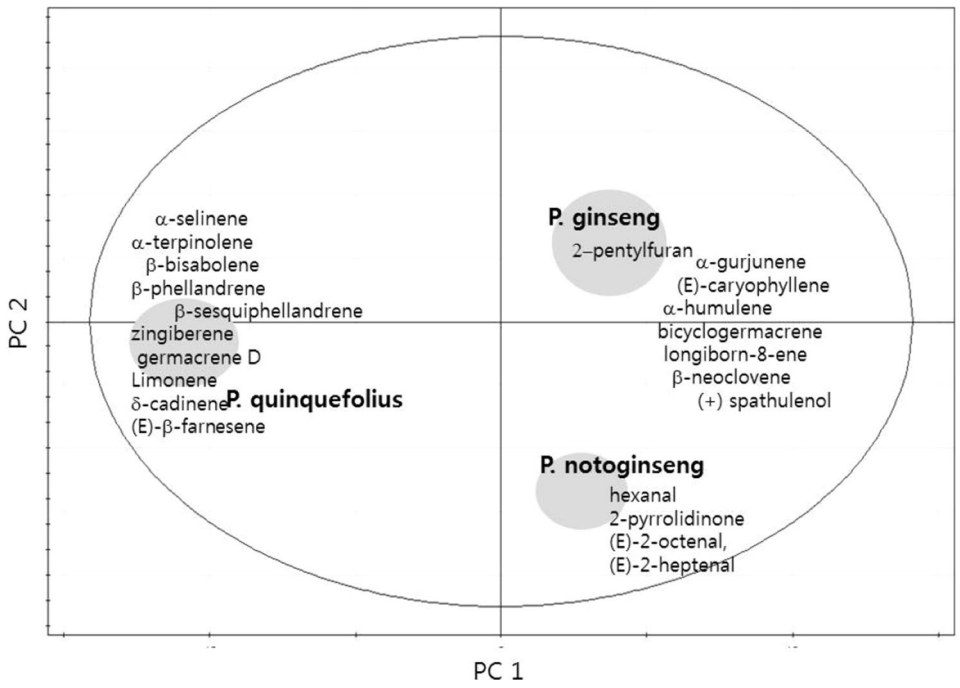

Fig. 3 PCA score plot and scatter plots for ginsengs with different species generated by a combination of PC 1 and PC 2, accounting for 74.0 % of the total variance (Cho et al. 2012). This plot shows main sources of variability between the species distinction and between the volatile compounds

Table 2 The contribution of volatile variances in ginseng according to the species

No.	PC 1	PC 2	No.	PC 1	PC 2	No.	PC 1	PC 2
15	−0.994	−0.060	35	0.862	0.476	31	0.408	−0.842
50	−0.994	−0.024	5	−0.857	−0.406	16	0.519	−0.836
48	−0.994	−0.024	6	−0.844	−0.298	8	0.535	−0.820
53	−0.994	−0.024	41	0.833	−0.455	12	0.430	0.817
49	−0.994	−0.024	23	0.810	−0.055	28	−0.349	−0.802
19	−0.994	−0.024	37	0.759	0.275	56	0.336	−0.788
46	−0.993	−0.024	24	0.744	−0.636	30	0.336	−0.787
14	−0.993	−0.041	26	0.736	−0.517	11	0.363	−0.780
39	0.971	−0.144	17	−0.732	−0.230	9	0.483	−0.773
40	0.961	−0.016	29	−0.690	−0.403	33	−0.160	−0.689
52	−0.960	0.049	2	−0.672	−0.247	44	0.399	0.658
42	−0.960	−0.140	13	−0.654	−0.445	22	0.154	0.646
43	0.925	0.316	1	0.281	−0.955	4	0.107	−0.065
51	0.910	−0.030	20	0.036	−0.939	25	0.192	0.481
34	0.907	0.369	18	0.309	−0.908	27	0.239	0.489
45	0.903	0.210	7	0.326	−0.908	21	0.592	−0.134
55	0.901	−0.086	10	0.110	−0.906	38	0.129	−0.542
36	0.885	0.456	3	−0.134	−0.897	54	−0.460	0.201
47	0.868	0.459	57	0.254	−0.811	32	0.435	−0.269

From Cho et al. (2012)

Numbers correspond to following compounds; *1* hexanal, *2* 2-heptanal, *3* heptanal, *4* dihydro-2(3H)-furanone, *5* α-pinene, *6* camphene, *7* (E)-2-heptenal, *8* benzaldehyde, *9* β-pinene, *10* β-myrcene, *11* hexanoic acid, *12* 2-pentylfuran, *13* octanal, *14* limonene, *15* β-phellandrene, *16* 3-octen-2-one, *17* 5-ethyldihydro-2(3H)-furanone, *18* (E)-2-octenal, *19* α-terpinolene, *20* 2-pyrrolidinone, *21* heptanoic acid, *22* teramethyl-pyrazine, *23* 2-methoxy-3-(1-methylethyl)-pyrazine, *24* nonanal, *25* 3-hydroxy-2-methyl-pyran-4-one, *26* 2,5-pyrrolidinedione, *27* 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one, *28* (E)-2-octenal, *29* octanoic acid, *30* 1-isopropyl-2-methoxy-4-methyl-benzene, *31* (E,E)-2,4-decadienal, *32* bicycloelemene, *33* 5-penyl-2(5H)-furanone, *34* longiborn-8-one, *35* longigolen-v2, *36* β-panasinsene, *37* β-elemene, *38* 4-hydroxy-3-methoxy-benaldehyde, *39* α-gurjunene, *40* (E)-caryophyllene, *41* calarene, *42* (E)- β-farnesene, *43* α-humulene, *44* neoclovene, *45* β-neoclovene, *46* germacrene D, *47* β-selinene, *48* zingiberene, *49* α-selinene, *50* β-bisabolene, *51* bicyclogermacrene, *52* δ-cadinene, *53* β-sesquiphellandrene, *54* nerolidol, *55* (+)-spathulenol, *56* veridiflorol, and *57* isospathulenol

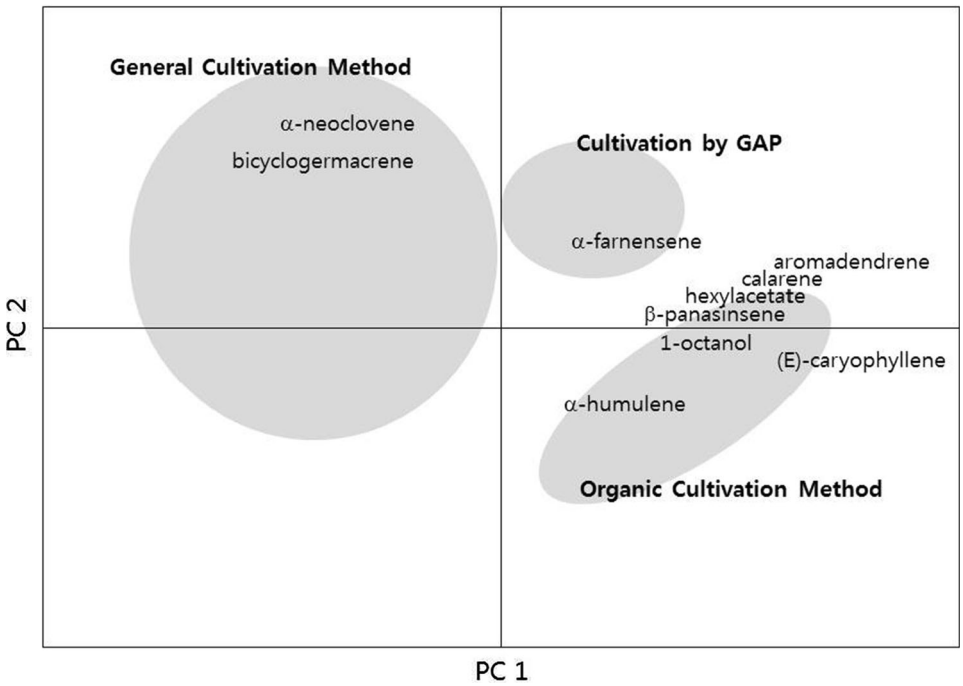

Fig. 4 PCA score and scatter plots of ginsengs with different cultivation methods (Lee et al. 2012) generated using a combination of PC 1 and PC 2, accounting for 76.6 % of the total variance. This plot shows main sources of variability between the cultivation methods distinction and between the volatile compounds

differences between *P. ginseng* and *P. notoginseng* species were influenced by the levels of some carbonyls, such as hexanal, 2-pyrrolidinone, (E)-2-heptenal, (E)-2-octenal, heptanal, isospathulenol, (E,E)-2,4-decadienal, 3-octen-2-one, benzaldehyde, 2-pentylfuran, and (E)-2-nonenal, which were quantitatively minor volatiles of ginseng. The amounts of hexanal, 2-pyrrolidinone, (E)-2-octenal, (E)-2-heptenal, heptanal, (E,E)-2,4-decadienal, 3-octen-2-one, benzaldehyde, isospathulenol, and (E)-2-nonenal were larger in *P. notoginseng*, whereas *P. ginseng* contained more 2-pentylfuran. In recent, good agricultural practice (GAP) manuals have been applied for the quality assurance of ginseng due to its unique cultivation conditions (Lewington 1993). Lee et al. (2012) reported their correlations between the cultivation methods, e.g., cultivated by GAP, organic cultivation method, and general cultivation method, and the compositions of ginseng volatiles (Fig. 4). In the correlation between them, aromadendrene, calarene, β-panasinsene, (E)-caryophyllene, α-neoclovene, and α-farnensene were mainly associated with the differences among ginsengs cultivated using different methods (Fig. 4). In particular, the level of α-farnensene, aromadendrene, calarene, β-panasinsene, and hexylacetate in ginseng cultivated by GAP and a part of ginseng cultivated by organic cultivation method were higher than those in ginseng cultivated by general cultivation method. On the other hand, α-neoclovene and bicyclogermacrene were present in a relatively higher concentration in ginseng cultivated by general cultivation method.

Conclusion

In this study, many volatiles in ginseng have been summarized with sesquiterpene hydrocarbons and sesquiterpene alcohols as its main volatile compounds. In particular, β-panasinsene, α-panasinsene, α-neoclovene, β-neoclovene, bicyclogermacrene, β-farnesene, aromadendrene, (E)-caryophyllene, (+)-spathulenol, ginsenol, panasinsenol A, and panasinsenol B were representative volatile compounds of ginseng. They have been also compared based on different cultivation ages, species, and cultivation methods using metabolomics approaches. Metabolomics analysis allows the determination of the differences and/or similarities in the compositions of volatiles of ginseng according to objective factors. However, there was no study to investigate the aroma-active compounds of ginseng. Further study on the aroma-active compounds would be suggested thoroughly to understand the flavor characteristics of ginseng.

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