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Comparison of Seed Oil Characteristics from Korean Ginseng, Chinese Ginseng (*Panax ginseng* C.A. Meyer) and American Ginseng (*Panax quinquefolium* L.)

Xue-Mei Zhu[1], Jiang-Ning Hu[2], Jung-Ah Shin[1], Jeung-Hee Lee[3], Soon-Teak Hong[1], and Ki-Teak Lee[1†]

[1]*Department of Food Science and Technology, Chungnam National University, Daejeon 305-764, Korea*
[2]*State Key Laboratory of Food Science and Technology, Nanchang University, Nanchang 330047, China*
[3]*Institute of Agricultural Science, Chungnam National University, Daejeon 305-764, Korea*

Abstract

The chemical characteristics of seed oils of Asian ginseng (*Panax ginseng* C.A. Meyer) at different ages grown in Korea (3, 4 and 5-year old) and China (5-year old), and American ginseng (*Panax quinquefoliu* L., 5-year old) grown in China were compared. Total fatty acid composition showed a significantly higher oleic acid content in American (87.50%) than in Korean (68.02～69.14%) and Chinese ginseng seed oils (61.19%). At the *sn*-2 position, the highest oleic acid (81.09%) and lowest linoleic acid (15.77%) were found in American ginseng seed oil. The main triacylglycerol species in ginseng seed oils were triolein (OOO) and 1,2-dioleoyl-3-linoleoyl-glycerol (LOO)/1,3-dioleoyl-2-linoleoyl-glycerol (OLO). In addition, the seed oils possessed an ideal oxidative stability showing 16.55～23.12 hr of induction time by Rancimat test. The results revealed that ginseng seed oil could be developed as a new healthy edible oil, and that the oil's chemical characteristics were strongly associated with the ginseng species and habitats.

Key words: ginseng seed oil, fatty acid composition, triacylglycerol, chemical characteristics, oxidative stability

INTRODUCTION

Ginseng is an important herb that has been used in many medical prescriptions for thousands years in Asia and eastern North America. The two most common varieties are Asian ginseng (*Panax ginseng* C. A. Meyer) (family: *Araliaceae*) and American ginseng (*Panax quinquefolium* L.) (family: *Araliaceae*). The physical shape of ginseng root somewhat resembles the human body. Modern pharmacological studies have revealed that ginseng root has many health benefits, including antiaging, antidiabetic, antitumor, analgesic, memory-enhancing, antistress, and antifatigue effects (1-7). Such pharmacological properties are generally attributed to ginsenosides (saponin compounds) as the major active ingredients, and, so far, more than 30 ginsenosides have been identified (8). In addition, non-saponin compounds are also known as important ingredients in ginseng root.

Ginseng seeds are rich in oil, ranging from 15 to 26 wt% (9,10). American ginseng seed oil has a fatty acid composition similar to olive oil, showing that both contain high levels of monounsaturated fatty acids (MUFAs), especially oleic acid (C18:1), which accounts for 87% of total fatty acids (11). According to the study of Beveridge et al. (9), American ginseng oil may be useful as a functional ingredient in food applications since it contains various kinds of phytosterols, including squalene, oxidosqualene, campesterol, stigmasterol, sitosterol and avenasterol, which are considered to promote human health by reducing cholesterol in humans. Considering the positional distribution of fatty acids, saturated fatty acids (SFAs) are generally located at *sn*-1,3 positions, while polyunsaturated fatty acids (PUFAs) tend to link at *sn*-2 position of the triacylglycerol (TAG) backbone. However, the positional distribution of fatty acids can be different in the tissues and species of material, i.e. Δ-5 olefinic acids in pine nut oil are naturally present at the *sn*-1,3 positions, while the palmitic acid is mainly located at *sn*-2 position in mature human milk fat (12,13).

To our knowledge, the distributions of fatty acids in TAG species of ginseng seed oils have not yet been reported. The positional composition of fatty acids in ginseng seed oil is important because the fatty acid located at *sn*-2 position of TAG is well absorbed in the human body after hydrolysis of TAG by pancreatic lipase system (14). Ginseng seeds originated from various species, age and habitats might have different positional fatty acid composition as well as oxidative stability. In the present study, the chemical characteristics of ginseng seed oils of Asian ginseng with different ages (3, 4 and 5-year old) grown in Korea and China, and American ginseng (5-year old) grown in China were compared.

†Corresponding author. E-mail: ktlee@cnu.ac.kr
Phone: +82-42-821-7873, Fax: +82-42-822-6729

After extraction of oils from the ginseng seeds, their total and positional fatty acid compositions, TAG species, and other chemical characteristics (e.g., saponification, iodine, peroxide, and acid values) were investigated. Oxidative stability of the extracted ginseng seed oil was also determined by Rancimat test.

MATERIALS AND METHODS

Ginseng seeds

After harvesting, mature berries of *Panax ginseng* C. A. Meryer with 3, 4, and 5 ages (*i.e.*, 3-, 4- and 5-year old Korean ginseng) were obtained from Experimental Station of Chungnam National University (Daejeon, Chungnam province, Korea) in 2008. The ginseng berries were soaked in water, and ginseng seeds were manually separated from berries, and then dried at 60°C in an air-circulated oven for 2 days. In addition, other ginseng seeds were obtained from 5-year old *Panax ginseng* (Chinese ginseng) and *Panax quinquefolium* L. (American ginseng) which were harvested in 2007 from Fusong County of Jilin province in China. The seeds were ground and preserved in hermetic bags at -20°C until analysis. Thus, in this study, the seeds of 5-year old Korean, Chinese and American ginseng (grown in China) were studied along with 3- and 4-year old Korean ginseng.

Materials

Pancreatic lipase, bile salt, $CaCl_2$, and BF_3-methanol (14% boron trifluoride-methanol solution) were purchased from Sigma Chemical Co. (St. Louis, MO, USA). HPLC grade of hexane, *iso*-octane, 2-propanol, diethyl ether, chloroform, and acetonitrile were obtained from Burdick & Jackson (Muskegon, MI, USA). Triolein (OOO), 1-dioleoyl-2, 3-linoleoyl-glycerol (LOO), 1,3-dioleoyl-2-linoleoyl-glycerol (OLO), and 2-oleoyl-glycerol (as a standard of *sn*-2-monoacylglycerol) were purchased from Sigma Chemical Co.

Oil extraction

Each extraction was carried out by a Soxhlet extractor from ground seed (5 g) with 300 mL of hexane at 70°C for 2 hr, and five extractions were repeated. The hexane was removed by rotary vacuum evaporator, and the extracted oils were stored at -20°C until analysis. The yield of oil (wt%) was determined on dry weight basis of ground seeds. Triplicate extraction was carried out.

Analysis of total and positional fatty acids composition

For total fatty acid composition analysis, oil samples (25 mg) were methylated with 0.5 M methanolic NaOH (1.5 mL) and BF_3-methanol (2 mL) at 95°C for total 8 min (13). After cooling to room temperature, *iso*-octane (2 mL) was added to extract fatty acid methyl esters for further analysis. Gas chromatography (GC, Agilent, HP 6890 Series, Avondale, PA, USA), accompanied with auto-injector and flame-ionization detector was used for fatty acid composition analysis. A fused-silica capillary column (SP-2560, 100 m × 0.25 mm × 0.2 μm, Supelco, PA, USA) was used for separation of fatty acid methyl esters. The column temperature was held at 100°C for 5 min and increased to 220°C at the rate 4°C/min, then held for another 20 min. The carrier gas was N_2, and the total gas flow rate in inlet was 52°C/min (constant flow rate) with split mode (50:1). The temperature of injector and detector were 250 and 260°C, respectively. For the analysis of positional fatty acid, each oil sample (7 mg) was taken in a test tube, and mixed with 7 mL of Tris-HCl buffer (pH 7.6), 0.05% bile salt (1.75 mL), 2.2% $CaCl_2$ (0.7 mL), and pancreatic lipase (7.0 mg). The tube was incubated in a water bath at 37°C for 3 min, and then vigorously agitated 3 times for 0.5 min each. The hydrolytic product was obtained by adding diethyl ether (4 mL), and dried through an anhydrous sodium sulfate column. The hydrolytic products were separated on silica gel 60 F_{254} plate by a developing solvent of hexane/diethyl ether/acetic acid (50/50/1, v/v/v). The band corresponding to *sn*-2-monoacylglycerol was scraped off for methylation and analyzed by GC. After that, the percentage of fatty acid at *sn*-1,3 position was calculated by the formula: *sn*-1,3 (%) = (3T – *sn*-2)/2, where T is the total fatty acid, and *sn*-2 is fatty acid at *sn*-2 position. All experiments were conducted in duplicate.

Analysis of triacylglycerol (TAG) species

Each oil sample (5 mg) was dissolved in 10 mL chloroform, and 20 μL of filtrated sample was injected into a reverse-phase high performance liquid chromatography (RP-HPLC) system (13). The RP-HPLC system was composed of Yonglin SP930D dual pump (Yonglin, Anyang, Korea) and a Sedex 75 evaporative light-scattering detector (ELSD, Sedere, Alfortvill, France). A Nova-Pak C18 (3.9 × 150 mm, Milford, MA, USA) column was used for the separation of TAG species. A binary solvent gradient of acetonitrile (A) and 2-propanol/hexane (B, 2:1, v/v) was used at a flow rate of 1 mL/min. The TAG separation was started with 20% B for 44 min, and the solvent ratio increased to 46% B for 10 min, and then jumped to 100% B for 7 min. The equivalent carbon number (ECN) was defined by the formula: ECN=CN (the total carbon number) − 2DB (the number of double bonds).

Analysis of chemical characteristics and oxidative stability

The saponification, peroxide, acid, and iodine values

of ginseng seed oils were determined according to the AOCS official methods (15). Oxidative stability was evaluated by measuring the induction time determined by a Rancimat 743 instrument (Metrohm, Switzerland) as described by Adhikari et al. (16). In the Rancimat test, ginseng seed oil (3 g each) was weighed into a glass vessel. The conductimetric cells were filled with 60 mL of distilled water. The temperature and air flow were set at 100°C and 20 L/hr. The induction time (hr) was defined as the time necessary to reach the inflection point of the conductivity curve. Duplicate analysis was performed.

Statistical analysis

Statistical computations were performed by Statistical Analysis System software (17). Duncan's multiple range tests were used to determine a significance of difference at $p<0.05$.

RESULTS AND DISCUSSION

Fatty acid composition

The total fatty acid compositions of Korean, Chinese and American ginseng seed oils are presented in Fig. 1 and Table 1. The ginseng seed oils contained mostly unsaturated fatty acids (UFA) up to 98%. The major fatty acid of Korean ginseng seed oils (3, 4 and 5-year old) were oleic (O, C18:1, n-9), linoleic (L, C18:2) and *cis*-vaccenic acid (V, C18:1, n-7), accounting for 68.02～69.14%, 16.13～17.01% and 10.83～11.64%, respectively. For the saturated fatty acids (SFA), palmitic (C16:0; 2.05～2.18%) and stearic acid (C18:0; 0.31～0.32%) were also found in a small amount. The fatty acid composition of Korean ginseng seed oils were not significantly affected by their ages (3, 4, and 5-year old) ($p>0.05$). However, the significant differences of total fatty acid compositions were observed among Korean, Chinese and American ginseng seed oils ($p<0.05$) (Table 1). When comparing to 5-year old seeds, oleic acid was at a significantly higher content in American ginseng seed oil (87.5%) than in Korean (69.14%) and Chinese ginseng (61.19%) ($p<0.05$). For mixtures of oleic acid (n-9) and its *cis* isomer-vaccenic acid (n-7), similar amounts can be found in Korean (80.63%) and Chinese ginseng seed oil (79.02%), while the content of oleic acid (n-9) and its isomer vaccenic acid (n-7) is lower than those in American ginseng seed oil (88.44%, data not shown).

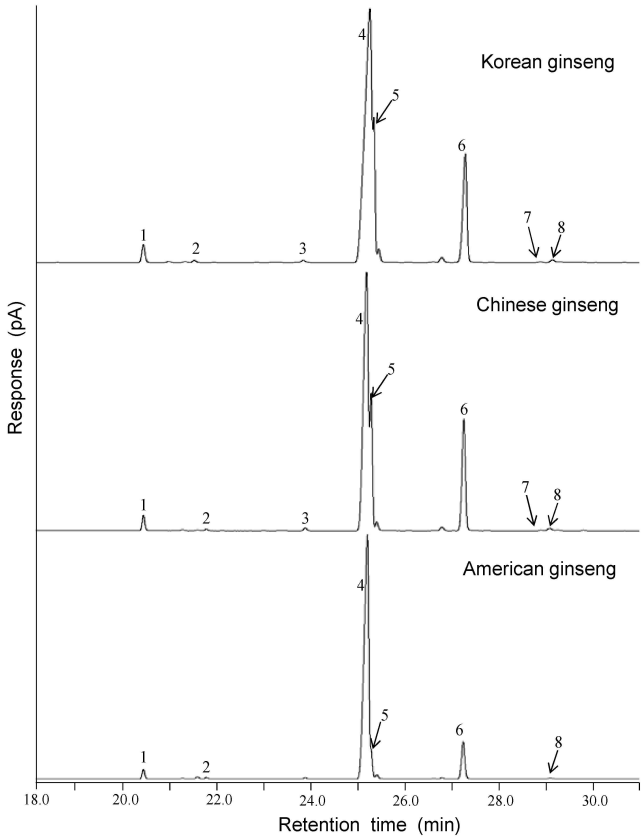

Fig. 1. GC chromatograph of fatty acids from 5-year old Korean, Chinese and American ginseng seed oils. Peak numbers: 1=C16:0; 2=C16:1; 3=C18:0; 4=C18:1 (n-9); 5=C18:1 (n-7); 6=C18:2; 7=C18:3 (n-6); and 8=C20:1.

Table 1. Total fatty acid compositions of Korean, Chinese, and American ginseng seed oils

Fatty acids	Korean ginseng			Chinese ginseng (5-year old)	American ginseng (5-year old)
	3-year old	4-year old	5-year old		
C16:0	2.18±0.00[a]	2.18±0.00[a]	2.05±0.00[b]	2.01±0.01[c]	1.85±0.01[d]
C16:1	0.28±0.00[c]	0.29±0.00[b]	0.29±0.00[b]	0.21±0.00[d]	0.30±0.00[a]
C18:0	0.32±0.00[b]	0.32±0.00[b]	0.31±0.01[c]	0.41±0.00[a]	0.28±0.00[d]
C18:1 n-9	68.02±0.59[b]	68.96±1.30[b]	69.14±1.09[b]	61.19±0.60[c]	87.50±0.03[a]
C18:1 n-7	11.64±0.60[b]	10.83±1.28[b]	11.49±1.11[b]	16.83±0.21[a]	0.91±0.00[c]
C18:2	17.01±0.01[b]	16.89±0.02[c]	16.13±0.02[d]	18.75±0.37[a]	9.12±0.02[e]
C18:3 n-6	0.11±0.00[b]	0.10±0.00[b]	0.15±0.00[a]	0.10±0.00[b]	−
C20:1 n-9	0.43±0.02[b]	0.46±0.01[b]	0.45±0.00[b]	0.50±0.00[a]	0.05±0.00[c]
ΣSFA	2.50±0.01[a]	2.50±0.00[a]	2.36±0.01[c]	2.43±0.01[b]	2.13±0.01[d]
ΣUFA	97.5±0.01[d]	97.50±0.00[d]	97.64±0.01[b]	97.58±0.10[c]	97.87±0.01[a]

All double bonds are in *cis* configuration. ΣSFA: total saturated fatty acid, ΣUFA: total unsaturated fatty acid. −: Not detected. Values with different superscripts in a row are significantly different ($p<0.05$).

A higher content of linoleic and vaccenic acid was found in Chinese ginseng oil (18.75 and 16.83%) than in either Korean (16.13 and 11.49%) or American ginseng seed oil (9.12 and 0.91%). *cis*-vaccenic acid (n-7) is generally considered a bacterial biomarker because of the abundant production in bacteria (18). *cis*-vaccenic acid was also observed in *Umbelliferae* and *Meliaceae* seed oil (19, 20). Differences in total fatty acid composition between American and Asian (Korean and Chinese) ginseng seed oils can be explained by the different ginseng species (genotypes). The significant difference observed between Korean and Chinese ginseng, which originated from the same ginseng species (*Panax ginseng* C.A. Meyer), is possibly due to their different habitats (growing environments).

The ginseng seed oils contained more than 98.22% of ΣUFAs at *sn*-2 position of TAG molecules (Table 2). Previous reports showed that a high level of PUFA at the *sn*-2 position is beneficial, since the *sn*-2 positional fatty acids are easily absorbed in the human body (14). With more than 95%, Korean, Chinese and American ginseng seed oils are rich in oleic and linoleic acids at the *sn*-2 position. More specifically, the content of oleic acid at *sn*-2 position in American ginseng seed oil was significantly higher than that in Korean and Chinese ginseng seed oils ($p<0.05$), representing 81.09%, 56.96～58.28%, and 65.91%, respectively. Therefore, ginseng seed oils could be desirable to health, possibly by allowing the prevention of distinct heart diseases (21). In comparison of fatty acids between at *sn*-2 and *sn*-1,3 positions, more oleic acid was found at *sn*-1,3 position in Korean and American ginseng seed oils, and more vaccenic acid was observed at *sn*-1,3 in Korean and Chinese ginseng (Tables 2 and 3). These results showed that the positional fatty acid compositions of ginseng seed oils were greatly affected by ginseng species and habitat. Much higher linoleic acid was contained at *sn*-2 position in all ginseng seed oils, with 15.77～39.09% at *sn*-2 and only 5.01～13.12% at *sn*-1,3 position, demonstrating that PUFAs tend to be located at the *sn*-2 position.

The American ginseng seed oil would be characterized as a high-oleic oil (87.50%), which is comparable to olive oil (80%), high-oleic canola oil (75%), high-oleic sunflower oil (>80%) and high-oleic safflower oil (77%) (22). Besides nutritional benefits, such high-oleic oils are more attractive in food applications since oleic acid

Table 2. *Sn*-2 positional fatty acid compositions of Korean, Chinese and American ginseng seed oils

Fatty acids	Korean ginseng			Chinese ginseng (5-year old)	American ginseng (5-year old)
	3-year old	4-year old	5-year old		
C16:0	0.54 ± 0.09^{c}	0.48 ± 0.02^{c}	0.49 ± 0.00^{c}	1.14 ± 0.02^{b}	1.78 ± 0.01^{a}
C16:1	0.45 ± 0.05^{b}	0.46 ± 0.01^{b}	0.51 ± 0.03^{a}	0.23 ± 0.00^{d}	0.36 ± 0.01^{c}
C18:0	−	−	0.05 ± 0.07^{b}	0.44 ± 0.01^{a}	−
C18:1 n-9	56.98 ± 1.10^{c}	58.28 ± 1.02^{c}	56.96 ± 0.17^{c}	65.91 ± 0.42^{b}	81.09 ± 0.40^{a}
C18:1 n-7	2.94 ± 0.62^{ab}	3.14 ± 0.10^{ab}	3.60 ± 0.93^{a}	2.05 ± 0.02^{bc}	1.0 ± 0.00^{c}
C18:2	39.09 ± 0.51^{a}	38.62 ± 0.92^{a}	38.37 ± 0.66^{a}	30.03 ± 0.30^{b}	15.77 ± 0.30^{c}
C18:3 n-6	−	−	−	0.09 ± 0.00	−
C20:1 n-9	−	−	−	0.14 ± 0.00	−
ΣSFA	0.54 ± 0.09^{c}	0.48 ± 0.02^{c}	0.54 ± 0.07^{c}	1.56 ± 0.01^{b}	1.78 ± 0.01^{a}
ΣUFA	99.46 ± 0.09^{a}	99.52 ± 0.02^{a}	99.46 ± 0.07^{a}	98.44 ± 0.10^{b}	98.22 ± 0.00^{c}

All double bonds are in *cis* configuration. ΣSFA: total saturated fatty acid, ΣUFA: total unsaturated fatty acid. −: Not detected. Values with different superscripts in a row are significantly different ($p<0.05$).

Table 3. *Sn*-1,3 positional fatty acid compositions of Korean, Chinese, and American ginseng seed oils

Fatty acids	Korean ginseng			Chinese ginseng (5-year old)	American ginseng (5-year old)
	3-year old	4-year old	5-year old		
C16:0	3.00 ± 0.05^{a}	3.02 ± 0.01^{a}	2.83 ± 0.00^{b}	2.46 ± 0.02^{c}	1.88 ± 0.02^{d}
C16:1	0.20 ± 0.03^{b}	0.20 ± 0.00^{b}	0.18 ± 0.01^{c}	0.19 ± 0.00^{b}	0.28 ± 0.00^{a}
C18:0	0.48 ± 0.00^{a}	0.48 ± 0.00^{a}	0.43 ± 0.04^{ab}	0.39 ± 0.01^{b}	0.42 ± 0.00^{b}
C18:1 n-9	73.55 ± 0.33^{b}	74.75 ± 1.44^{b}	75.23 ± 1.55^{b}	58.83 ± 0.36^{c}	90.70 ± 0.20^{a}
C18:1 n-7	15.99 ± 0.59^{b}	14.68 ± 1.87^{b}	15.42 ± 1.19^{b}	24.22 ± 0.03^{a}	0.86 ± 0.01^{c}
C18:2	5.98 ± 0.25^{b}	6.03 ± 0.43^{b}	5.01 ± 0.30^{c}	13.12 ± 0.20^{a}	5.79 ± 0.18^{b}
C18:3 n-6	0.16 ± 0.00^{b}	0.19 ± 0.00^{b}	0.22 ± 0.00^{a}	0.11 ± 0.01^{c}	−
C20:1 n-9	0.65 ± 0.03^{a}	0.68 ± 0.01^{a}	0.68 ± 0.00^{a}	−	0.08 ± 0.00^{b}
ΣSFA	3.48 ± 0.05^{a}	3.50 ± 0.01^{a}	3.26 ± 0.05^{b}	2.85 ± 0.01^{c}	2.30 ± 0.00^{d}
ΣUFA	96.52 ± 0.05^{d}	96.5 ± 0.01^{d}	96.74 ± 0.05^{c}	97.15 ± 0.07^{b}	97.70 ± 0.00^{a}

All double bonds are in *cis* configuration. ΣSFA: total saturated fatty acid, ΣUFA: total unsaturated fatty acid. −: Not detected. Values with different superscripts in a row are significantly different ($p<0.05$).

(MUFA) possesses ideal oxidative stability versus PUFA. While considering the high purity of oleic acid, the American ginseng seed oil may be applied to tailor-made lipids.

TAG composition and chemical properties

TAG is the main constituent of fats and oils. The chemical, physical and nutritional characteristics of lipids are largely dependent upon the TAG composition, as well as total fatty acid composition. Thus the analysis of TAG was considered important for use of the lipid for both dietary and industrial purposes. The TAG profiles of ginseng seed oils were analyzed by RP-HPLC, and presented in Fig. 2 and Table 4. The elution of TAG species was performed according to ECN. Predominant TAG species were LOO/OLO and OOO, and their contents were significantly different among Korean, Chinese and American ginseng seed oils ($p<0.05$). In other words, TAG amounts were strongly associated with the ginseng species and habitats. In detail, the highest OOO (75.31%) was observed in American ginseng seed oil while the lowest (52.02%) was found in Chinese ginseng seed oil, and *vice versa* for LOO/OLO concentrations. Korean ginseng seed oils consisted of 42.89～45.13% of LOO/OLO and 54.02～56.47% of OOO, in which the content of OOO was increased with ages from 3 to 5 years, while the content of LOO/OLO was decreased with age. Such relative simplicity of TAG profiles of these ginseng seed oils could be derived from the simple patterns of fatty acid compositions (Tables 1, 2 and 3).

Chemical characteristics of ginseng seeds oils are presented in Table 5. The oil content of ginseng seeds varied from 16.64 to 22.30 wt%, in which Chinese ginseng seed contained much lower oil content than Korean and American ginseng seeds. The oil content appeared to be affected by habitats and species. Our data were partly consistent with Beveridge et al. (9), and their study reported the oil contents in American ginseng seeds as 15～26 wt%.

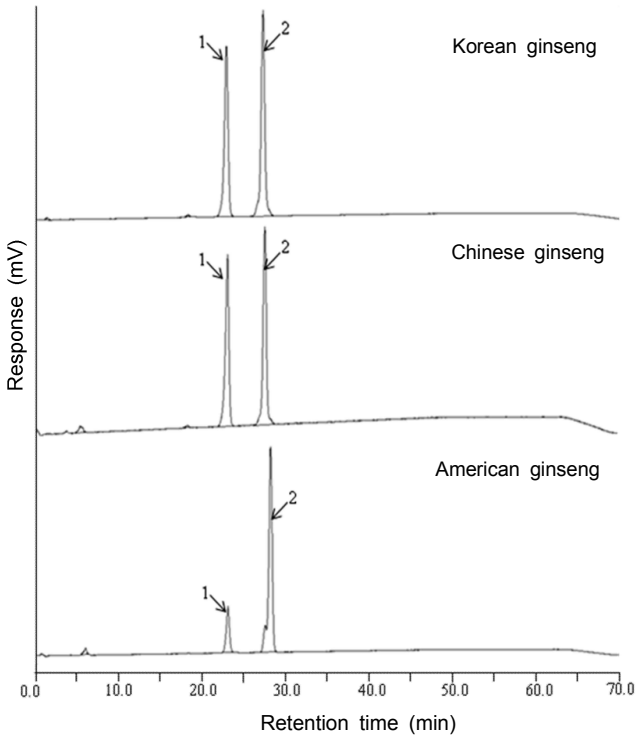

Fig. 2. HPLC separation of triacylglycerol species of 5-year old Korean, Chinese and American ginseng seed oils. Peak numbers: 1=LOO (1,2-dioleoyl-3-linoleoyl-glycerol)/OLO (1,3-dioleoyl-2-linoleoyl-glycerol) and 2=OOO (triolein), in which O=C18:1 and L=C18:2.

Table 4. The contents of triacylglycerols (area%) of Korean, Chinese and American ginseng seed oils

Triacylglycerols	Korean ginseng			Chinese ginseng (5-year old)	American ginseng (5-year old)
	3-year old	4-year old	5-year old		
LOO/OLO	45.13 ± 0.12^{b}	44.42 ± 0.10^{c}	42.89 ± 0.20^{d}	47.35 ± 0.39^{a}	16.58 ± 0.13^{e}
OOO	54.02 ± 0.08^{d}	54.82 ± 0.11^{c}	56.47 ± 0.26^{b}	52.02 ± 0.19^{e}	75.31 ± 0.43^{a}
Others	0.85 ± 0.03^{b}	0.76 ± 0.02^{bc}	0.64 ± 0.03^{c}	0.63 ± 0.01^{c}	8.11 ± 0.12^{a}

OLO: 1,3-dioleoyl-2-linoleoyl-glycerol; LOO: 1,2-dioleoyl-3-linoleoyl-glycerol; and OOO: triolein; in which O: oleic acid and L: linoleic acid.
Values with different superscripts in the same row are significantly different ($p<0.05$).

Table 5. Chemical characteristics of Korean, Chinese and American ginseng seed oils

Characteristics	Korean ginseng			Chinese ginseng (5-year old)	American ginseng (5-year old)
	3-year old	4-year old	5-year old		
Oil content (wt%)	20.02 ± 0.23^{b}	22.26 ± 0.25^{a}	22.24 ± 0.43^{a}	16.64 ± 0.31^{c}	22.30 ± 0.06^{a}
Peroxide value (meq/kg)	11.37 ± 0.38^{c}	24.82 ± 1.36^{a}	10.13 ± 0.69^{c}	12.23 ± 0.94^{c}	19.54 ± 1.86^{b}
Acids value (mg of KOH/g)	0.98 ± 0.14^{c}	2.98 ± 0.39^{b}	1.21 ± 0.26^{c}	12.59 ± 0.67^{a}	13.65 ± 0.96^{a}
Saponification value (mg of KOH/g)	189.93 ± 2.54^{a}	173.93 ± 1.58^{b}	178.72 ± 1.46^{b}	176.78 ± 3.42^{b}	181.27 ± 5.21^{b}
Iodine value (g of I_2/100 g)	95.23 ± 3.63^{ab}	94.81 ± 2.48^{ab}	90.78 ± 1.47^{b}	99.44 ± 3.58^{a}	89.05 ± 2.17^{b}

Values with different superscripts in the same row are significantly different ($p<0.05$).

Table 5 shows that the peroxide values of ginseng seed oils were 10.13～24.82 meq/kg. A wide range of acid values (0.98～13.65 mg of KOH/g) was observed in ginseng seed oils. The saponification values of ginseng seed oils were in the range of 173.93～189.93 mg of KOH/g. The iodine value was significantly higher in Chinese ginseng seed oil than Korean or American ginseng seed oils, and such results were closely related to their fatty acid composition, showing the highest linoleic acid in Chinese ginseng (Table 1). Thus, the iodine values of ginseng seed oils were influenced by ginseng species.

Oxidative stability

The oxidative stability is an important parameter in evaluating the quality of oils and fats. In the present study, the oxidative stability was determined with Rancimat test, and presented in Fig. 3. The ginseng seed oils showed induction times ranged from 16.55 to 23.12 hr. Such induction times seemed to be higher than other vegetable oils, suggesting higher oxidative stability. In the study of Gordon and Mursi (23), refined-olive, rapeseed, soybean, corn, safflower and sunflower oils showed 20.4, 14.4, 10.9, 12.8, 6.8 and 7.9 hr of induction times, respectively, at the same operation temperature (100°C) of Rancimat test as this present study. In Korean ginseng seed oils, the oxidative stability was not much influenced by the age of 3, 4 and 5 years. However, among the same age of ginseng seeds (5 years old) the oxidative stability was significantly different among the species and habitats ($p<0.05$). The highest oxidative stability (23.12 hr of induction time) was seen with American ginseng seed oil, and the lowest stability (16.55 hr) with Chinese ginseng seed oil. One of the most important factors for affecting oxidative stability in oils is fatty acid composition. Thus, the different oxidative stabilities could be explained by the differing contents of linoleic and oleic acid, such that American ginseng, which shows the highest stability, contained lower levels of linoleic acid and higher levels of oleic acid compared with Korean and Chinese ginseng seed oils (Table 1).

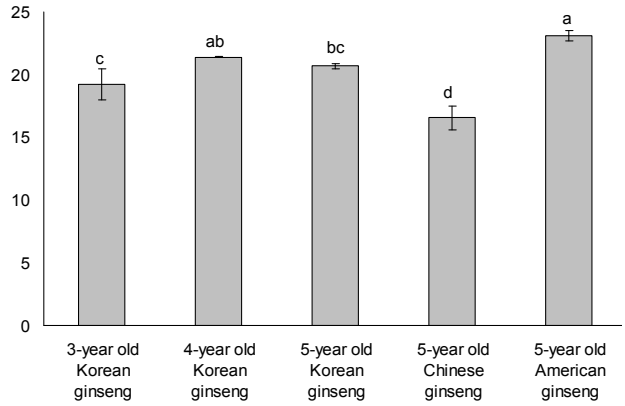

Fig. 3. Induction time (hr) of Korean, Chinese and American ginseng seed oils by Rancimat test. Values with different letters (a-d) are significantly different ($p<0.05$).

CONCLUSION

In this study, the characteristics of ginseng seed oil were investigated. The highest oleic acid concentration was found in American ginseng seed oil (87.50%), while the highest linoleic acid was found in Chinese ginseng seed oil (18.75%). For oleic acid, 56.96～81.09% existed at the *sn*-2 position, and 58.83～90.70% was located at the *sn*-1,3-positions of TAG molecules. Such a high level of oleic acid in the oils indicates a potential use for health benefits. The ginseng seed oils also have an ideal oxidative stability. These results suggest that ginseng seed oils deserve further consideration and investigation as new potential functional edible oils. With regard to fatty acid composition, TAG species, and evaluation of oxidative stability, the characteristics of ginseng seed oils were greatly affected by the species and habitats.

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