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Investigation of Phenolic, Flavonoid, and Vitamin Contents in Different Parts of Korean Ginseng (*Panax ginseng* C.A. Meyer)

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ABSTRACT: This study investigated the phenolic, flavonoid, and vitamin constituents in the main root, root hair, and leaf of ginseng. The total individual phenolic and flavonoid contents were the highest in the leaf, followed by the main root and root hair. Ferulic acid and *m*-coumaric acid were found to be the major phenolics in the main root and root hair, while *p*-coumaric acid and *m*-coumaric acid were the major phenolics in the leaf. Catechin was the major flavonoid component in the main root and root hair, while catechin and kaempferol were the major flavonoid components in the leaf. Pantothenic acid was detected in the highest quantity in the non-leaf parts of ginseng, followed by thiamine and cobalamin. Linolenic acid and menadione were the major components in all parts of ginseng.

Keywords: ginseng, phenolics, flavonoid, vitamins

INTRODUCTION

Ginseng is a slow-growing perennial plant of the *Panax* genus that has been used as a medicinal plant and a functional food for more than 2,000 years (1). Biochemical and pharmacological studies on *Panax ginseng* C.A. Meyer have mainly concentrated on ginseng saponins (ginsenosides) as the effective components. More than 30 different kinds of ginsenosides have so far been isolated and their chemical structures elucidated. Ginseng products are standardized according to these compounds. Other chemical constituents present in ginseng include polyacetylenes, phenolic compounds (flavonoids and phenolic acids), essential oils, polysaccharides, microelements, and vitamins (2). These constituents are also responsible for the complex pharmacological activities of ginseng (3). However, non-saponin components have recently received much attention for their antioxidant, anticancer, antidiabetic, and immunomodulating activities. One of the non-saponin components of ginseng are phenolic acids. It has been reported that ginseng extract has strong antioxidant activity on metal-induced lipid peroxidation and human low-density lipoprotein oxidation, and inhibitory activity on the scission of supercoiled deoxyribonucleic acid strands induced by peroxyl radicals (4,5). In addition, many flavonoids and their related compounds are known to possess strong antioxidative characteristics (6) and have been widely investigated as new sources of bioactive ingredients that can be incorporated into foods for the development of functional foods.

Since most studies have focused on ginseng roots, comparatively little research has been conducted on ginseng leaves. However, several groups have reported that ginseng leaves are rich in polysaccharides, phenolics, flavonoids, and ginsenosides (7,8). Polyphenols such as ferulic, cinnamic, and syringic acid are found in ginseng, irrespective of species and cultivation conditions (9). Vitamins are biologically active organic compounds that are essential micronutrients involved in metabolic and physiological functions in the human body. There are 13 vitamins, which are classified according to their solubility into fat-soluble vitamins and water-soluble vitamins (10). These compounds differ greatly in their chemical compositions, physiological actions, and nutritional importance in the human diet, even within the same group (11). However, the phenolic compound content (total amount as well as individual flavonoids and phenolic acids) and vitamin content (water and fat-soluble vitamins) of the different parts of ginseng are unknown. Therefore, the objective of the present study was to measure the contents of individual flavonoids, phenolic acids, and water and fat-soluble vitamins in the main root, root hair, and leaf of ginseng.

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MATERIALS AND METHODS

Chemicals and reagents

Gallic acid, *p*-hydroxybenzoic acid, chlorogenic acid, catechin, caffeic acid, epicatechin, epigallocatechin gallate, *p*-coumaric acid, ferulic acid, *m*-coumaric acid, *o*-coumaric acid, quercitrin, myricetin, resveratrol, morin, quercetin, naringenin, apigenin, vanillic acid, kaempferol, formic acid, thiamin (B_1), riboflavin (B_2), niacin (B_3), pantothenic acid (B_5), pyridoxine (B_6), biotin (B_7), folic acid (B_9), cobalamin (B_{12}), ascorbic acid, linolenic acid (F), tocopherol (E), menadione (K_3), menaquinone (K_2), phylloquinone (K_1), cholecalciferol (D_3), retinol (A), retinoic acid, and butylated hydroxytoluene were purchased from Sigma Chemical Co. (St. Louis, MO, USA). Acetonitrile, methanol, tetrahydrofuran, and high-performance liquid chromatography (HPLC)-grade water were purchased from J.T. Baker (Phillipsburg, NJ, USA). All other chemicals and solvents were of analytical reagent grade.

Plant material

Six-year-old ginseng plants (Chunpoong cultivar) were obtained from the Gaeseong Ginseng Cooperative Association in Gyeonggi, Korea in late September 2012. The average temperature and precipitation of the area in Gyeonggi throughout the year was 10.5°C and 1,300 mL, respectively. The ginseng was divided into main root, root hair, and leaf, which were freeze-dried and stored at −70°C.

Extraction of phenolic compounds

The method described by the international organization for standardization (ISO) 14502-1 was used (12). Briefly, 0.200±0.001 g of each sample was weighed in an extraction tube, and 5.0 mL of 70% methanol at 70°C was added. The extract was mixed and heated at 70°C for 10 min. After cooling to room temperature, the extract was centrifuged at 7,840 *g* for 10 min. The supernatant was decanted into a graduated conical tube. The extraction step was repeated 3 times. The extracts were pooled and the volume adjusted to 10 mL with cold 70% methanol. A 1.0 mL aliquot of the extract was diluted with water to 5.0 mL.

Determination of total phenolic content

The total phenolic content was determined spectrophotometrically using gallic acid as a standard, according to the method described by ISO 14502-1 (12). Briefly, 1.0 mL aliquots of the diluted sample extract were transferred to separate tubes containing 5.0 mL of a 1/10 dilution of Folin-Ciocalteu's reagent in water. Then, 4.0 mL of a sodium carbonate solution (7.5%, w/v) was added. The tubes were then allowed to stand at room temperature for 60 min before the absorbance at 765 nm was measured against water. All values are expressed as mg gallic acid equivalents (GAE) per 100 g dry matter of the ginseng sample.

Determination of total flavonoid content

Total flavonoid content was determined using a colorimetric method as previously described (13). Ginseng powder (0.2 g) was added to 20 mL of 80% methanol, extracted for 2 h at room temperature, and centrifuged at 18,000 *g* for 15 min. The volume of the extract was made up to 100 mL with 80% methanol. A 0.5 mL portion was taken, and 0.5 mL of a 2% ethanolic solution of $AlCl_3$ was added. After 1 h at room temperature, the absorbance was measured at 420 nm. All values are expressed as mg quercetin equivalents (QE) per 100 g dry matter of the ginseng sample.

Analysis of individual phenolics

Individual (free+bound) phenolics were determined by the method reported by Mattila and Kumpulainen (14) with slight modifications. Ginseng powder (3.0 g) was weighed into a 200 mL glass tube, 35 mL of a mixture of methanol (containing 2.0 g/L of butylated hydroxyanisole) and 10% acetic acid at a ratio of 85:15 was added, and the mixture was homogenized. After addition of 15 mL deionized water, the sample extract was ultrasonicated for 30 min. The sample was then subjected to alkaline hydrolysis by the addition of 60 mL of deionized water containing 22 mM ethylenediaminetetraacetic acid, 2% ascorbic acid, and 25 mL of 10 M NaOH. This mixture was incubated at 30°C for 30 min. The solution was then adjusted to pH 2 with 4 M HCl, and the phenolic acids were extracted 3 times with 15 mL ethyl acetate. The combined extracts were filtered through anhydrous sodium sulfate, evaporated to dryness, and dissolved in 2.0 mL methanol. Finally, the sample was filtered and injected into the HPLC. The measurements were performed using an Agilent 1260 infinity quaternary liquid chromatograph (Hewlett Packard, Wilmington, NC, USA) with a multiple wavelength detector (MWD) operating at 280 nm. Chromatographic separations were performed on an Agilent zorbax rapid resolution high-definition SB-C18 column (2.1 mm i.d.×100 mm, 1.8 μm particle size, Agilent Technologies, Santa Clara, CA, USA). The column temperature was 30°C, and the flow rate was 0.3 mL/min. Eluents A and B were used for gradient elution. Solution A was water with 0.1% formic acid and solution B was acetonitrile with 0.1% formic acid. The following gradient was used: 0% B (0 min), 5% (0～3.5 min), 15% (3.5～7.1 min), 40% (7.1～25 min), 40% (25～26 min), 100% (26～27 min), 100% (27～29 min), and 0% (29～35 min). Data analysis was performed using the Chemstation software (Hewlett Packard). The standards used were *p*-hydroxybenzoic acid, gallic acid, chloro-

genic acid, caffeic acid, *p*-coumaric acid, ferulic acid, *m*-coumaric acid, *o*-coumaric acid, and vanillic acid.

Analysis of individual flavonoids

Extracts were prepared according to the method reported by Hertog et al. (15) with slight modifications. Briefly, 15 mL of 62.5% aqueous methanol containing 2.0 g/L *tert*-butylhydroquinone were added to 3.0 g of ginseng powder. Then, 15 mL of 6 M HCl was added, and the mixture was refluxed at 90°C for 1 h. The extract was allowed to cool, and the extract was then sonicated for 10 min. The flavonoids were then extracted 3 times with 15 mL ethyl acetate. The combined extracts were filtered through anhydrous sodium sulfate, evaporated to dryness, and the residue redissolved in 2.0 mL of methanol. The measurements were performed using an Agilent 1260 infinity quaternary liquid chromatograph (Hewlett Packard) fitted with a MWD. Chromatographic separations were performed on an Agilent zorbax rapid resolution high-definition SB-C18 column (2.1 mm i.d.×100 mm, 1.8 μm particle size, Agilent Technologies). The column temperature was 30°C, and the flow rate was 0.3 mL /min. Eluents A and B were used for gradient elution. Solution A consisted of water with 0.1% formic acid and solution B consisted of acetonitrile with 0.1% formic acid. The following gradient was used: 0% B (0 min), 5% (0～3.5 min), 15% (3.5～7.1 min), 40% (7.1～25 min), 40% (25～26 min), 100% (26～27 min), 100% (27～29 min), and 0% (29～35 min). Detection was performed at a wavelength of 280 nm. Data analysis was performed using the Chemstation software (Hewlett Packard). The standards used were catechin, epicatechin, epigallocatechin gallate, quercitrin, myricetin, resveratrol, morin, quercetin, naringenin, apigenin, and kaempferol.

Determination of water-soluble vitamins

Ginseng consists of many components that can cause chromatographic interference with vitamins. For this reason, the sample treatment proposed consisted of solid-phase extraction (SPE) using Sep-Pak C_{18} (500 mg) cartridges that enable separation of water-soluble vitamins and remove most of the interfering components. Deionized water (20 mL) was added to ginseng powder (3.0 g), and the mixture was homogenized using a homogenizer at medium speed for 1.0 min. The homogenized samples were then centrifuged at 3,136 *g* for 10 min. The SPE method reported by Cho et al. (16) was used for the extraction of water-soluble vitamins. The SPE cartridge was flushed with 10 mL methanol and 10 mL water adjusted to pH 4.2 to activate the stationary phase. The homogenized and centrifuged samples (10 mL) were then loaded onto the cartridge. Acidified water was prepared by adding a 5 mM HCl solution dropwise to deionized water by stirring until the pH reached a predetermined value. The sample was eluted with 5.0 mL water (pH 4.2) and then 10 mL methanol. The measurements were performed using an Agilent 1260 infinity quaternary liquid chromatograph (Hewlett Packard) fitted with a MWD operating at 220 nm. Separation was carried out with an Agilent poroshell 120 EC-C18 column (4.6 mm i.d.×50 mm, 2.7 μm particle size, Agilent Technologies). A linear gradient elution employing 25 mM sodium phosphate at pH 2.5 (solvent A) and MeOH (solvent B) was performed. The gradient applied was 1% B (0 min), 12% (0～0.5 min), 30% (0.5～0.52 min), 30% (0.52～3.5 min), and 1% (3.5～4.5 min) at a flow rate of 0.8 mL/min. The column temperature was 35°C and 5.0 μL of sample was injected into the HPLC system. The column was equilibrated for 5 min under the initial conditions prior to injection of the next sample. Data analysis was performed using the Chemstation software (Hewlett Packard).

Determination of fat-soluble vitamins

Ginseng powder (2.0 g) was placed into a 100 mL glass tube, and 20 mL of ethanol containing 0.025% of butylated hydroxytoluene (to protect the vitamins against oxidation) was added. The mixture was treated for 2 min in an ultrasonic bath to disrupt the fat globule membranes (proteins and phospholipids) that encapsulate the fat-soluble vitamins. The solution was then transferred to a separating funnel, and 15 mL of hexane was added, followed by vortex mixing for 5 min. The organic layer was transferred and the extraction process was repeated with another 15 mL of hexane. The two organic layers were combined, transferred into another separating funnel, and washed twice with 5.0 mL methanol-water (9:1). The upper organic layer was separated and passed through a 0.45 μm filter. This was then evaporated until dryness, and the residue was reconstituted in 3.0 mL methanol. The measurements were performed using an Agilent 1260 infinity quaternary liquid chromatograph (Hewlett Packard) fitted with a MWD. Separation was carried out with an Agilent poroshell 120 EC-C18 column (4.6 mm i.d.×50 mm, 2.7 μm particle size, Agilent Technologies). A linear gradient profile using water/tetrahydrofuran with 0.05% acetic acid (95:5, v/v) (solvent A) and acetonitrile/methanol/tetrahydrofuran with 0.035% acetic acid (75:25:5, v/v) (solvent B) was applied at a flow rate of 0.9 mL/min. The gradient program was as follows: 30% B (0 min), 75% (0～3 min), 100% (3～8 min), 100% (8～15 min), and 30% (15～15.1 min). The column temperature was 45°C and 5.0 μL of sample was injected into the HPLC system. The column was equilibrated for 5 min under the initial conditions prior to injection of the next sample. Individual stock standard solutions of each vitamin were prepared in ethanol containing 0.025% BHT at a concentration of 1.0 mg/mL for all fat-soluble vitamins and provitamins. Individual working standard sol-

utions were prepared by appropriate dilution of the stock standard solution, and filtered through a 0.22 μm membrane before being injected into the system. By mixing suitable volumes of each stock solution the working solutions were prepared to give concentrations ranging from 0.1 to 0.5 mg/mL for linolenic acid, tocopherol, menadione, vitamin K_2, vitamin K_1, cholecalciferol, retinol, and retinoic acid. The wavelength of the detector was set at 216 nm for linolenic acid and tocopherol; 246 nm for menadione, vitamin K_2, and vitamin K_1; 266 nm for cholecalciferol; 326 nm for retinol; 356 nm for retinoic acid. Data analysis was performed using the Chemstation software (Hewlett Packard).

Statistical analysis

Each experiment was performed in triplicate. The data are reported as the mean±standard deviation and were analyzed by SPSS (version 17.0, IBM Inc., New York, NY, USA). An analysis of variance (ANOVA) and Duncan's multiple range test were used to determine the significance of differences among the means, and $P<0.05$ was considered significant.

RESULTS AND DISCUSSION

Total phenolic and total flavonoid contents in the main root, root hair, and leaf of ginseng

Phenolic compounds are known to have antioxidant properties, and it is likely that the medicinal activity of ginseng extracts is due to these compounds (17). The redox properties of phenolics play an important role in adsorbing and neutralizing free radicals, quenching singlet and triplet oxygen, and decomposing peroxides (18). Flavonoids are complex phenolic molecules and have many functions in plants, particularly as a defense against insects and a range of pathogens (19). However, although most antioxidant properties of plant extracts are due to phenolic compounds (20), these effects do not always correlate with the presence of large quantities of phenolics. Therefore, both the total phenolic and total flavonoid contents of plant extracts must be investigated in order to understand these effects.

The total phenolic and flavonoid contents of the main root, root hair, and leaf of ginseng are shown in Fig. 1 and 2. The total phenolic content in different parts of ginseng, expressed as GAE/100 g of dry matter, ranged between 10.46 and 95.98 mg GAE/100 g. The ginseng leaf extract had the highest phenolic content (95.98 mg GAE/100 g) followed by the main root (12.10 mg GAE/100 g) and root hair (10.46 mg GAE/100 g) extracts. The difference in the total phenolic content of the main root and root hair was not significant.

The total flavonoid content in different parts of ginseng was determined using a spectrophotometric method with aluminum chloride. The flavonoid content is expressed in terms of QE/100 g of dry matter. The total flavonoid content in different parts of ginseng ranged from 59.74 to 137.30 mg QE/100 g. The leaf of ginseng showed a higher flavonoid content (137.30 mg QE/100 g) than the other parts examined.

The results show that the total phenolic and flavonoid contents of the leaves are higher than those of the main root, followed by those of the root hair. Plant materials may contain phenolics varying from those with simple structures (e.g., phenolics and anthocyanins) to highly polymerized substances (e.g., tannins) in different quantities. Also, phenolics may be associated with other plant components, such as carbohydrates and proteins. Furthermore, these forms may occur at different levels in different parts of ginseng, depending on the types of phenolic compounds therein.

Individual phenolic acid contents in the main root, root hair, and leaf of ginseng

More than 8,000 different phenolic compounds are found in nature. Some phenolics have been reported to be secondary plant metabolites for protecting plants against

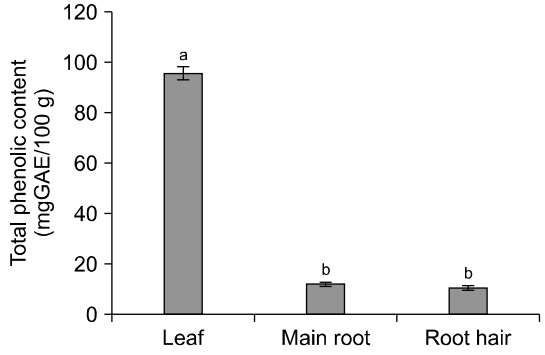

Fig. 1. The total phenolic content of the main root, root hair, and leaf of ginseng. Different letters (a,b) above the bars are significantly different at $P<0.05$, as analyzed by Duncan's multiple range test. GAE, gallic acid equivalent.

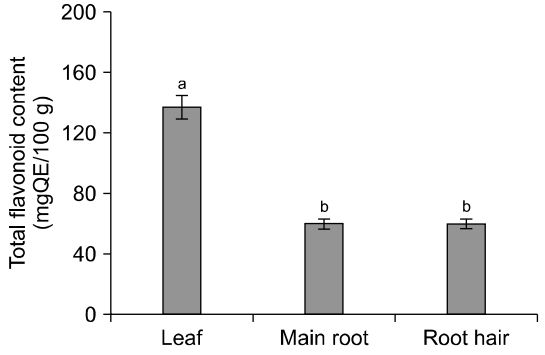

Fig. 2. The total flavonoid content of the main root, root hair, and leaf of ginseng. Different letters (a,b) above the bars are significantly different at $P<0.05$, as analyzed by Duncan's multiple range test. QE, quercetin equivalent.

threats such as pathogens and herbivores, while many are thought to be bioactive compounds that may have many health benefits to humans (21). In addition, the library of the analytical characteristics of phenolics profile established by Rauter et al. (22) and Lin et al. (23) provides important reference data, such as retention time, UV and visible λ_{max}, and spectra shapes, for these compounds.

The individual phenolic constituents of the main root, root hair, and leaf of ginseng as quantified by HPLC using 9 standard phenolics are shown in Table 1. The average total individual phenolic contents were 3.24±0.01, 9.94±0.01, and 62.56±0.42 mg/100 g for the main root, root hair, and leaf, respectively. The total individual phenolic content of the leaf was significantly higher than that of the other samples ($P<0.05$). Moreover, hydroxycinnamic acid derivatives were found to be the major phenolics in ginseng. The sum of the 6 hydroxycinnamic acids was the highest in the leaf (60.29 mg/100 g of dry matter). In addition, ferulic acid and *m*-coumaric acid were found to be the major phenolics in the main root and root hair, while *p*-coumaric acid and *m*-coumaric acid were found to be the major phenolics in the leaf. Gallic acid and chlorogenic acid were detected only in the leaf. Juliani and Simon (24) suggested that the antioxidant activity of basil is largely due to the presence of phenolic components. The same relationship was observed between phenolics and antioxidant activity in rosehip extracts (25). There are also several reports on the antioxidant activity of phenolics present in ginseng. Han et al. (26) isolated and identified salicylic acid, vanillic acid, and *p*-coumaric acid as the principal antioxidant components in Korean ginseng roots. Four other phenolics (gentisic, caffeic, *p*-hydroxybenzoic, and 1H-indole-2-carboxylic) were identified by Wee et al. (27) in the antioxidant fractions of *Panax ginseng*. Moreover, Choi et al. (28) reported that hydroponically cultivated ginseng leaves contained significantly higher amounts of *p*-coumaric acid. The results above indicate that each phenolic constituent is distributed in different amounts in different parts of ginseng.

Table 1. The individual phenolic constituents in the main root, root hair, and leaf of ginseng (unit: mg/100 g of dry matter)

	Main root	Root hair	Leaf
HBA			
p-Hydroxybenzoic acid	0.29±0.004^{NS}	0.29±0.02	0.30±0.01
Gallic acid	–	–	1.86±0.21
Vanillic acid	0.17±0.01^{a}	–	0.11±0.01^{b}
HCA			
Chlorogenic acid	–	–	1.49±0.16
Caffeic acid	–	0.24±0.004^{b}	0.15±0.01^{a}
p-Coumaric acid	–	0.64±0.001^{b}	25.30±0.37^{a}
Ferulic acid	1.40±0.01^{c}	2.42±0.01^{b}	8.00±0.07^{a}
m-Coumaric acid	1.38±0.02^{c}	6.09±0.02^{b}	24.88±0.36^{a}
o-Coumaric acid	–	0.26±0.01^{b}	0.47±0.06^{a}
Total HBA	0.46±0.01^{b}	0.29±0.02^{c}	2.27±0.66^{a}
Total HCA	2.78±0.02^{c}	9.65±0.01^{b}	60.29±0.17^{a}
Total phenolic acids	3.24±0.01^{c}	9.94±0.01^{b}	62.56±0.42^{a}

Value are mean±SD (n=5).
Different letters (a-c) within same row are significantly different ($P<0.05$) according to Duncan's multiple range test.
HBA, hydroxybenzoic acid derivatives; HCA, hydroxycinnamic acid derivatives.
NS: not significant.

Individual flavonoid contents in the main root, root hair, and leaf of ginseng

Flavonoids are one of the most powerful antioxidants found in plants. Typically, they possess one or more of the following structural elements that are considered important to their antioxidant activities: An *o*-diphenol group in ring B; a 2–3-double bond conjugated with the 4-oxo function; and hydroxyl groups at positions 3 and 5 (29). The individual flavonoid constituents in the main root, root hair, and leaf of ginseng as quantified by HPLC using 11 standard flavonoids are shown in Table 2. Previous experiments (30,31) showed the presence of rutin, kaempferol, and quercetin, as well as protocatechuic, gentisic, *p*-coumaric, caffeic, and ferulic acids in roots. Hyperoside, quercitrin, and isoramnetin-3-rutinoside, as well as protocatechuic, gentisic, *p*-coumaric, caffeic, salicylic, and *p*-hydroxybenzoic acids, were detected in ginseng leaves. In our experiments, as shown in Table 2, the total individual flavonoid content in the root hair was significantly higher than that in the main root and leaf. Among the 4 major subgroups of flavonoids in ginseng, the flavanol content was the highest, except in the leaf. Flavonols were found at the highest concentration in the leaf. Catechin was the major component in the main root and root hair, while catechin and kaempferol were the main components in the leaf. The catechin content in the main root and root hair was 3 times higher than that in the leaf. Particularly, the kaempferol content was higher in the leaf (49.61±1.92 mg/100 g) than in the main root (1.47±0.01 mg/100 g) and root hair (2.78±0.02 mg/100 g). Naringenin was not detected in the leaf. The ratios of the concentrations of catechin and kaempferol for the main root, root hair, and leaf were 92.12, 49.83, and 1.08, respectively, and may be used as a convenient parameter for differentiating different parts of ginseng.

Vitamin contents in the main root, root hair, and leaf of ginseng

Vitamins are biologically active organic compounds that are essential micronutrients involved in metabolic and physiological functions in the human body. Thirteen vitamins have been identified and classified into fat-soluble vitamins (A, D, E, and K) and water-soluble vitamins (B-group vitamins and vitamin C). In the present study, we used HPLC to determine the amounts of water- and

Table 2. The individual flavonoid constituents in the main root, root hair, and leaf of ginseng (unit: mg/100 g of dry matter)

	Main root	Root hair	Leaf
Flavanols			
Catechin	135.41±10.98[a]	138.53±1.98[a]	46.03±3.16[b]
Epicatechin	1.94±0.04[a]	0.32±0.06[c]	0.72±0.01[b]
Epigallocatechin gallate	1.15±0.02[c]	1.73±0.15[b]	3.79±0.26[a]
Flavones			
Quercitrin	0.30±0.02[c]	2.76±0.10[b]	9.67±0.60[a]
Apigenin	0.15±0.02[b]	0.14±0.01[b]	0.25±0.02[a]
Flavonols			
Myricetin	1.86±0.06[a]	1.14±0.07[b]	0.62±0.09[c]
Resveratrol	0.12±0.001[b]	0.12±0.001[b]	0.47±0.01[a]
Morin	0.53±0.01[b]	0.11±0.01[c]	2.89±0.37[a]
Quercetin	1.09±0.01[c]	2.21±0.07[a]	1.67±0.10[b]
Kaempferol	1.47±0.01[b]	2.78±0.02[b]	49.61±1.92[a]
Flavanones			
Naringenin	1.34±0.07[b]	1.51±0.02[a]	–
Total flavanols	138.50±3.68[a]	140.58±0.73[a]	50.54±1.14[b]
Total flavones	0.45±0.02[c]	2.90±0.06[b]	9.92±0.31[a]
Total flavonols	5.07±0.02[c]	6.36±0.03[b]	55.26±0.50[a]
Total flavanones	1.34±0.07[b]	1.51±0.02[a]	–
Total flavonoids	145.36±0.95[b]	151.35±0.21[a]	115.72±0.65[c]

Value are mean±SD (n=5).
Different letters (a-c) within same row are significantly different (P<0.05) according to Duncan's multiple range test.

Table 3. The water-soluble vitamin contents in the main root, root hair, and leaf of ginseng (unit: mg/100 g of dry matter)

	Main root	Root hair	Leaf
Thiamine (B_1)	153.57±0.34[c]	316.70±0.63[a]	176.12±2.20[b]
Riboflavin (B_2)	2.58±0.36[a]	0.33±0.05[b]	–
Niacin (B_3)	8.30±0.11[b]	10.72±0.30[a]	4.56±0.17[c]
Pantothenic acid (B_5)	316.94±8.46[a]	324.28±10.27[a]	191.74±17.94[b]
Pyridoxine (B_6)	14.09±0.96[b]	18.10±1.10[a]	7.17±0.19[c]
Biotin (B_7)	7.51±0.60[c]	14.00±1.26[b]	42.91±6.34[a]
Cobalamin (B_{12})	53.32±0.45[a]	39.11±0.33[b]	28.58±0.08[c]
Ascorbic acid (C)	25.81±0.21[b]	32.41±2.89[a]	5.23±0.20[c]
Total vitamin content	582.12±1.44[b]	755.65±2.10[a]	456.31±3.87[c]

Value are mean±SD (n=5).
Different letters (a-c) within same row are significantly different (P<0.05) according to Duncan's multiple range test.

fat-soluble vitamins in the main root, root hair, and leaf of ginseng. The results are shown in Table 3 and 4. The average total water-soluble vitamin contents were 582.12 ±1.44, 755.65±2.10, and 456.31±3.87 mg/100 g for the main root, root hair, and leaf, respectively. The total water-soluble vitamin content of the root hair was significantly higher than those of the other samples (P<0.05). Pantothenic acid was detected in the highest quantity in the non-leaf parts of ginseng, followed by thiamine and cobalamin. Pantothenic acid and thiamine contents were the main components in the root hair, while biotin and cobalamin were the main components in the leaf and main root, respectively. Riboflavin was not detected in the leaf.

Fat-soluble vitamins are classified into 4 groups of compounds, and are involved in important biological functions, namely, vision (vitamin A), calcium absorption (vi-

Table 4. The fat-soluble vitamin contents in the main root, root hair, and leaf of ginseng (unit: mg/100 g of dry matter)

	Main root	Root hair	Leaf
Linolenic acid (F)	2.54±0.05[b]	2.42±0.09[c]	2.73±0.01[a]
Tocopherol (E)	–	–	–
Phylloquinone (K_1)	–	–	–
Menaquinone (K_2)	–	–	–
Menadione (K_3)	2.67±0.32[a]	2.41±0.26[a]	1.74±0.04[b]
Cholecalciferol (D_3)	–	–	–
Retinol (A)	–	–	0.34±0.02
Retinoic acid	0.12±0.01[a]	0.10±0.01[b]	–
Total vitamin content	5.33±0.13[a]	4.93±0.12[b]	5.01±0.02[b]

Value are mean±SD (n=5).
Different letters (a-c) within same row are significantly different (P<0.05) according to Duncan's multiple range test.

tamin D), antioxidative protection of cell membranes (vitamin E), and blood coagulation (vitamin K) (32). The total fat-soluble vitamins contents were 5.33±0.13, 4.93 ±0.12, and 5.01±0.02 mg/100 g for the main root, root hair, and leaf, respectively. The total fat-soluble vitamin contents were much lower than those of the water-soluble vitamins. Linolenic acid and menadione were the major components in all parts of ginseng.

In conclusion, this study has provided information on the phenolic acid, flavonoid, and vitamin constituents in the main root, root hair, and leaf of ginseng. The results of the present investigation showed the variation in the quantities of phenolic acids, flavonoids, and vitamins in each part of ginseng. The total phenolic and flavonoid contents in the leaf were higher than in the main root, followed by the contents in the root hair. Moreover, hydroxycinnamic acid derivatives were found to be the major phenolic acids in ginseng. The summed content of the 6 hydroxycinnamic acids was the highest in the leaf. Ferulic acid and *m*-coumaric acid were found to be the major phenolic acids in the main root and root hair, while *p*-coumaric acid and *m*-coumaric acid were found to be the major phenolic acids in the leaf. Among the 4 major subgroups of flavonoids in ginseng, the flavanol content was found to be the highest, except in the leaf. Flavonols were found at the highest concentration in the leaf. Catechin was the major component in the main root and root hair, while catechin and kaempferol were the major components in the leaf. The catechin contents in the main root and root hair were 3 times higher than that in the leaf. Pantothenic acid was detected in the highest quantity in the non-leaf parts of ginseng, followed by thiamine and cobalamin. The average total fat-soluble vitamin contents were much lower compared with the water-soluble vitamin contents. Linolenic acid and menadione were the major components in all parts of ginseng.

This work demonstrates that comparative analysis of different plant parts can be helpful when estimating the beneficial properties of valuable medicinal raw plant materials used as natural antioxidants in phytopharmacy.

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AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

REFERENCES

1. Kang KS, Yokozawa T, Kim HY, Park JH. 2006. Study on the nitric oxide scavenging effects of ginseng and its compounds. *J Agric Food Chem* 54: 2558-2562.
2. Jung MY, Jeon BS, Bock JY. 2002. Free, esterified, and insoluble-bound phenolic acids in white and red Korean ginsengs (*Panax ginseng* C.A. Meyer). *Food Chem* 79: 105-111.
3. Attele AS, Wu JA, Yuan CS. 1999. Ginseng pharmacology: multiple constituents and multiple actions. *Biochem Pharmacol* 58: 1685-1693.
4. Hu C, Kitts DD. 2001. Free radical scavenging capacity as related to antioxidant activity and ginsenoside composition of Asian and North American ginseng extracts. *J Am Oil Chem Soc* 78: 249-255.
5. Kitts DD, Wijewickreme AN, Hu C. 2000. Antioxidant properties of a North American ginseng extract. *Mol Cell Biochem* 203: 1-10.
6. Dziedzic SZ, Hudson BJF. 1983. Hydroxy isoflavones as antioxidants for edible oils. *Food Chem* 11: 161-166.
7. Park HS, Kwak TH, Bae JH, Moon DG, Kim JJ, Cheon J. 2004. Development of the novel anti-cancer immunotherapy for human prostate cancer: *in vivo* characterization of an immunotropic and anti-cancer activities of the new polysaccharide from the leaves of *Panax ginseng* C.A. Meyer. *Eur Urol Suppl* 3: 365-366.
8. Xie JT, Mehendale SR, Wang A, Han AH, Wu JA, Osinski J, Yuan CS. 2004. American ginseng leaf: ginsenoside analysis and hypoglycemic activity. *Pharmacol Res* 49: 113-117.
9. Fishbein AB, Wang CZ, Li XL, Mehendale SR, Sun S, Aung HH, Yuan CS. 2009. Asian ginseng enhances the anti-proliferative effect of 5-fluorouracil on human colorectal cancer: comparison between white and red ginseng. *Arch Pharm Res* 32: 505-513.
10. Ball GMF. 2006. *Vitamins in foods: analysis, bioavailability, and stability*. CRC Press, Boca Raton, FL, USA. p 3.
11. Finglas PM, Faure U, Wagstaffe PJ. 1993. Improvements in the determination of vitamins in food through intercomparisons and preparation of RMs for vitamin analysis within the BCR1 programme. *Fresenius J Anal Chem* 345: 180-184.
12. ISO. 2005. Determination of substances characteristic of green and black tea − Part 1: Content of total polyphenols in tea − Colorimetric method using Folin-Ciocalteu reagent. International Organization for Standardization, Geneva, Switzerland. ISO 14502-1:2005.
13. Woisky RG, Salatino A. 1998. Analysis of propolis: some parameters and procedures for chemical quality control. *J Apic Res* 37: 99-105.
14. Mattila P, Kumpulainen J. 2002. Determination of free and total phenolic acids in plant-derived foods by HPLC with diode-array detection. *J Agric Food Chem* 50: 3660-3667.
15. Hertog MGL, Hollman PCH, Venema DP. 1992. Optimization of a quantitative HPLC determination of potentially anticarcinogenic flavonoids in vegetables and fruits. *J Agric Food Chem* 40: 1591-1598.
16. Cho CM, Ko JH, Cheong WJ. 2000. Simultaneous determination of water-soluble vitamins excreted in human urine after eating an overdose of vitamin pills by a HPLC method coupled with a solid phase extraction. *Talanta* 51: 799-806.
17. Djeridane A, Yousfi M, Nadjemi B, Boutassouna D, Stocker P, Vidal N. 2006. Antioxidant activity of some algerian medicinal plants extracts containing phenolic compounds. *Food Chem* 97: 654-660.
18. Pan Y, Liang Y, Wang H, Liang M. 2004. Antioxidant activities of several Chinese medicine herbs. *Food Chem* 88: 347-350.
19. Franco D, Sineiro J, Pinelo M, Núñez MJ. 2007. Ethanolic

extraction of *Rosa rubiginosa* soluble substances: oil solubility equilibria and kinetic studies. *J Food Eng* 79: 150-157.
20. John JA, Shahidi F. 2010. Phenolic compounds and antioxidant activity of Brazil nut (*Bertholletia excelsa*). *J Funct Foods* 2: 196-209.
21. Sakakibara H, Honda Y, Nakagawa S, Ashida H, Kanazawa K. 2003. Simultaneous determination of all polyphenols in vegetables, fruits, and teas. *J Agric Food Chem* 51: 571-581.
22. Rauter AP, Dias C, Martins A, Branco I, Neng NR, Nogueira JM, Goulart M, Silva FVM, Justino J, Trevitt C, Waltho JP. 2012. Non-toxic *Salvia sclareoides* Brot. extracts as a source of functional food ingredients: Phenolic profile, antioxidant activity and prion binding properties. *Food Chem* 132: 1930-1935.
23. Lin L, Lei F, Sun DW, Dong Y, Yang B, Zhao M. 2012. Thermal inactivation kinetics of *Rabdosia serra* (Maxim.) Hara leaf peroxidase and polyphenol oxidase and comparative evaluation of drying methods on leaf phenolic profile and bioactivities. *Food Chem* 134: 2021-2029.
24. Juliani HR, Simon JE. 2002. Antioxidant activity of basil. In *Trends in New Crops and New Uses*. Janick J, Whipkey A, eds. ASHS Press, Alexandria, VA, USA. p 575-579.
25. Gao X, Björk L, Trajkovski V, Uggla M. 2000. Evaluation of antioxidant activities of rosehip ethanol extracts in different test systems. *J Sci Food Agric* 80: 2021-2027.
26. Han BH, Park MH, Han YN. 1985. Studies on the antioxidant components of Korean ginseng (V): the mechanism of antioxidant activity of maltol and phenolic acids. *Korean Biochem J* 18: 337-340.
27. Wee JJ, Hoe JN, Kim MW. 1996. Analysis of phenolic components in Korean red ginseng by GS/MS. *Korean J Ginseng Res* 20: 284-290.
28. Choi SY, Cho CW, Lee Y, Kim SS, Lee SH, Kim KT. 2012. Comparison of ginsenoside and phenolic ingredient contents in hydroponically-cultivated ginseng leaves, fruits, and roots. *J Ginseng Res* 36: 425-429.
29. Rice-Evans CA, Miller NJ, Paganga G. 1996. Structure-antioxidant activity relationships of flavonoids and phenolic acids. *Free Radic Biol Med* 20: 933-956.
30. Ludwiczuk A, Wolski T, Hołderna-Kędzia E. 2006. Estimation of the chemical composition and antimicrobial and antioxidant activity of extracts received from leaves and roots of American ginseng (*Panax quinquefolium* L.). *Herba Pol* 52: 79-90.
31. Jung CH, Seog HM, Choi IW, Park MW, Cho HY. 2006. Antioxidant properties of various solvent extracts from wild ginseng leaves. *LWT-Food Sci Tehnol* 39: 266-274.
32. Pawliszyn J. 2012. *Comprehensive sampling and sample preparation*. Academic Press, San Diego, CA, USA. p 3.