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Phytosterol Content in American Ginseng Seed Oil

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North American ginseng (*Panax quinquefolium* L.) oil was saponifed and the unsaponifiable matter trimethylsilylated. The phytosterol fraction of hexane-extracted, air-dried seed was quantified and identified by GC and GC-MS. Phytosterol contents (milligrams per 100 g of oil) were as follows: squalene (514−569), oxidosqualene (8.97−48.2), campesterol (9.96−12.4), stigmasterol (93.2−113), clerosterol (1.91−2.14), β-sitosterol (153−186), β-amyrin (11.7−19.5), Δ^5-avenasterol (12.4−20.5), $\Delta^{5,24(25)}$-stigmasterol (3.70−4.76), lupeol (14.4−15.2), Δ^7-sitosterol (12.5−14.6), Δ^7-avenasterol (4.11−8.09), 24-methylenecycloartanol (1.94−4.76), and citrostadienol (2.50−3.81). Seed stratification lowered the phytosterol levels. Oven-drying gave mixed results, and phytosterols varied slightly between the 1999 and 2000 harvests.

KEYWORDS: Phytosterol; triterpene alcohol; *Panax quinquefolium*; ginseng seed soil; fatty acid methyl ester

INTRODUCTION

American ginseng (*Panax quinquefolium* L.) is one of the most widely used medicinal herbs. It is native to North America and was used by native North Americans long before the arrival of Europeans in the New World (*1*). The general population is increasingly seeking alternative health remedies, resulting in an expanding global nutraceutical market. Phytosterols are among the most important compounds in the unsaponifiables of vegetable oils and are implicated in conferring biological activities to the oils. Recently their ability to reduce cholesterol in humans has been of particular interest (*2*).

Clinical studies have repeatedly shown that phytosterols taken as dietary supplements, or as supplemental ingredients in foods, reduced serum cholesterol and low-density lipid cholesterol levels in normal and mildly hypercholesteraemic subjects (*3*). The mechanism involved may relate to inhibition of dietary and biliary cholesterol absorption from the intestinal lumen (*4*). In addition to a cholesterol-lowering effect, phytosterols have been suggested to possess anti-inflammatory, antibacterial, antifungal, antiulcerative, and antitumor activities (*2*, *5*−*8*). They are also effective in the treatment of benign prostatic hyperplasia, hyperglycemia, and colon cancer (*9*, *10*). In addition to medicinal uses, the profile of phytosterols is characteristic of the botanical species from which the oil was obtained (*11*), which assists taxonomic classification and can be used to detect adulteration of commercial oil supplies. Phytosterols are useful as raw materials for the synthesis of hormones and related pharmaceuticals (*12*) and cosmetics (*13*) and as additives to thermoplastic resins used in the manufacture of rubber materials, including tires (*3*).

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Previous experiments have indicated that ginseng seeds are rich in oil (*14*) and that this oil may be useful as a specialty ingredient in functional foods or cosmetics because of its phytosterol content (*15*). This study details the quantities and identities of phytosterols found in American ginseng seed oil.

MATERIALS AND METHODS

Reagents. All solvents used were of reagent grade and were used without further purification. Hexane was a commercial mixture of glass-distilled hexanes (Caledon Laboratories, Georgetown, ON, Canada). Aluminum-backed, precoated silica gel 60F thin-layer chromatography (TLC) plates, 0.25 mm thickness, were obtained from Whatman Ltd. (Maidstone, Kent, U.K.). Reference phytosterols, betulin, 5α-cholestane (internal standard), lupeol, sitostanol, β-sitosterol, squalene, and uvaol were from Sigma-Aldrich Canada Ltd. (Oakville, ON, Canada), and β-amyrin and erythrodiol were from Extrasynthèse S.A. (Genay, France). Cholesterol was from BDH Inc. (Toronto, ON, Canada), and a plant sterol mixture containing cholesterol, brassicasterol, campesterol, stigmasterol, and β-sitosterol in chloroform was from Matreya Inc. (Pleasant Gap, PA). Tri-Sil reagent (Pierce Chemical Co., Rockford, IL) was used for the preparation of trimethylsilyl (TMS) ether derivatives.

Seeds and Oils. *P. quinquefolium* berries were collected in mid-September 1998 from Panax Q Farms Ltd., Vernon, BC, Canada, and in 1999 and 2000 from experimental plots of the Pacific Agri-Food Research Center in Summerland, BC, Canada. Seeds were removed from berries using a seed finisher (F. H. Langsenkamp Co. Inc., Indianapolis, IN) equipped with $^1/_8$ in. screens. A portion of the 1999-harvested seeds were stratified, defined as storage at 1 °C for 7 weeks, then at 15 °C for 15 weeks followed by 8 weeks at 1 °C (*16*). The remaining seeds were air-dried without stratification at ambient temperatures (~21 °C) or oven-dried at 35 °C in a Hotpack Environmental chamber (Hotpack Co., Philadelphia, PA) for 24 h. Dried seeds (80 g) were ground in a Thomas-Wiley model ED-5 mill (Arthur H.

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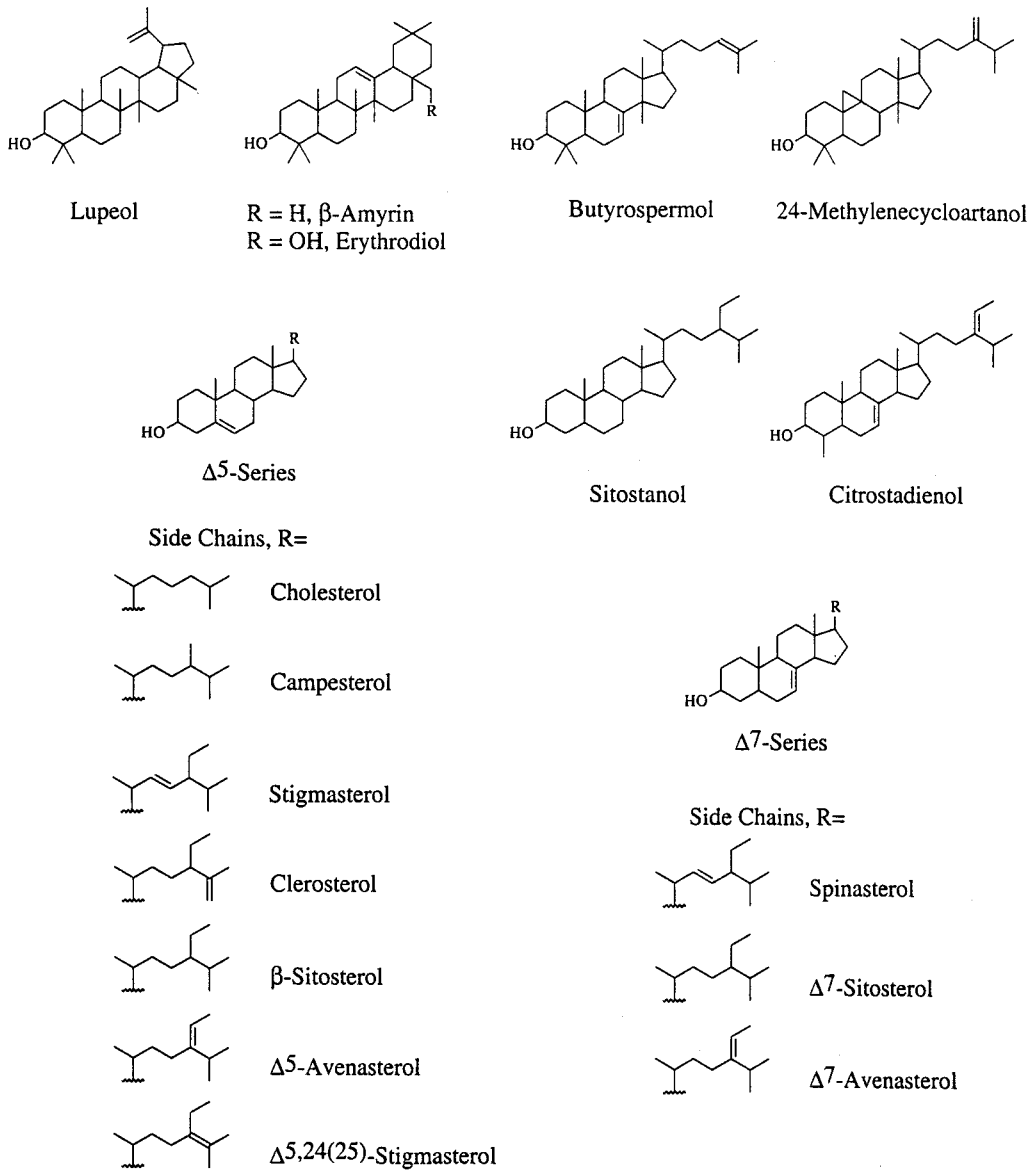

Figure 1. Structural formulas of phytosterols in American ginseng seed oil.

Thomas Co., Philadelphia, PA) with a 2 mm screen over 60 s and then reground through a 1 mm screen over 90 s.

Moisture content was determined (*17*) by drying duplicate subsamples of the 1 mm ground seeds at 105 °C in a forced-air oven (GCA/Scientific Inc., Chicago, IL) for 24 h. Oil was extracted from ground seed (60 g) by stirring for 2 h at ambient temperature in 180 mL of hexane or methylene chloride. Solvent was removed by suction filtration (Whatman glass fiber GF/A filter paper atop a Whatman No. 1 paper). The 2 h extraction was repeated and then followed by a final 1 h extraction. The pooled and filtered extracts were concentrated by rotary vacuum evaporation at 30 °C and ~584 Torr. The resulting oil was transferred to an amber bottle, and the last traces of solvent were removed with a nitrogen purge followed by continuous vacuum application overnight at ambient temperature.

Preparation of the Unsaponifiable Fraction. One milliliter of 0.1% (w/v) 5α-cholestane (internal standard) in *tert*-butyl methyl ether was added to 1 g of oil in a 100 mL stoppered flask. KOH (20 mL, 1 M) in methanol was added and stirred overnight (*18*). This solution was diluted with 40 mL of distilled water and extracted (three times) with 30 mL of *tert*-butyl methyl ether. The combined organic extract was washed with 15 mL of 0.5 M KOH in methanol, followed by repeated 30 mL distilled water washes until the pH was the same as that of the water, followed by one washing with 15 mL of saturated sodium chloride. The solvents were removed by rotary vacuum evaporation at 30 °C, and the residue was left under continuous vacuum overnight to remove solvent traces. Preparations were done in triplicate (duplicate for CH_2Cl_2 and stratified oils) and stored at −20 °C in the dark, until further analysis.

The saponification progress was monitored using TLC plates developed in hexane/ethyl ether/glacial acetic acid (80:20:1, v/v/v) (*19*). Plates were viewed under UV light (254 and 366 nm), then sprayed with 10% ethanolic phosphomolybdic acid, and charred (*20*).

Phytosterol Derivatization. TMS ether derivatives of the sterols were prepared by adding 100 μL of Tri-Sil reagent to 15−30 mg of the unsaponifiables in glass-stoppered tubes. After swirling to dissolve the sterols, the tubes were heated at 60 °C for 30−60 min (*21*, *22*). Excess reagent and solvent were removed under a nitrogen stream, and normally the residue was diluted to 2 mL with hexane for quantitation by gas chromatography (GC) with flame ionization detection (FID). For identification purposes residue dilution was to 0.1−0.3 mL followed by gas chromatography−mass spectrometry (GC-MS).

Phytosterol GC-FID and GC-MS Conditions. Analysis of the sterol TMS ether derivatives was performed using a DB-5 fused silica capillary column (60 m × 0.32 mm i.d., 0.25 μm film thickness; J&W Scientific, Folsom, CA) in an HP 5890 series II gas chromatograph (Hewlett-Packard, Avondale, PA) equipped with an FID detector. Samples (1 μL) were injected using an HP 7673 autosampler and a split−splitless injector with a split ratio of 1:15. The oven temperature was isothermal at 275 °C. The injector and detector temperatures

Table 1. Paired Comparisons of the Fatty Acid Methyl Ester Composition (Percent) of North American Ginseng Seed Oil[a]

	extraction solvent		seed stratification		stratified seed drying method	
fatty acid	hexane	CH_2Cl_2	without	with	air	oven
palmitic	2.25	2.26	2.17[b]	2	2	1.99
stearic	0.36	0.36	0.33	0.33	0.33	0.33
total saturated	2.61	2.62	2.50	2.33	2.33	2.32
oleic (mono-unsaturated)	87.0	86.8	87.5	87.7	87.7	87.7
linoleic (poly-unsaturated)	10.4	10.5	9.95	9.99	9.99	10

[a] Hexane was used throughout except where indicated as CH_2Cl_2. [b] Value in each column is significantly different ($p = 0.05$) from the value in the paired column according to the analysis of variance.

were 280 and 300 °C, respectively, and helium (carrier gas) was used at an inlet pressure of 175 kPa, giving a column flow of 1 mL/min. Peaks were recorded and peak areas computed using an HP3392A integrator.

All of the TMS ether derivative samples were run in triplicate. The level of each sterol was calculated as milligrams per 100 g of oil using the following formula (*23*): amount $= (PA_s \times m_{is} \times 100)/(PA_{is} \times m)$, where PA_s = sterol peak area, PA_{is} = internal standard peak area, m_{is} = weight (mg) of the internal standard, and m = weight (g) of oil taken for analysis. All data were subjected to analysis of variance using the SAS GLM procedures (*24*).

GC-MS analyses were performed using a Hewlett-Packard 5890A gas chromatograph equipped with a split−splitless injector, a Hewlett-Packard 5970 mass selective detector (MSD), and an HP 7673A autosampler. The split flow was 15 mL/min. The transfer line from GC to MSD was set at 300 °C. The injector, oven, column, carrier gas, column inlet pressure, and injection volume were as described for the GC-FID instrument above. MSD parameters were as follows: scan mode, 50−600 amu; threshold, 400; sample rate, 1.1 scans/s; ionizing voltage, 70 eV; and EM voltage, 2000 V. The GC and MSD were controlled, and MS data collected, by an HP Chemstation running G1034C software. Mass spectral identification was done using the Wiley MS database and comparing the spectra to the literature. Structures are shown in **Figure 1**.

Fatty Acid Methyl Ester Analysis. Fatty acids were esterified by boron trifluoride/methanol and analyzed by capillary GC with FID detection (*25*). The column was a 100 m SP-2560 fused silicon (Supelco, Oakville, ON, Canada) with 0.25 mm i.d. Column temperatures were programmed from 140 to 240 °C/min and injector temperatures were set at 260 °C. The carrier gas was helium, and analyses were performed in duplicate.

RESULTS AND DISCUSSION

Oil yields varied, based on seed source, drying method, and use or not of stratification, from 15.0 to 26.6%. Very limited information in the literature suggests that 20% yields using methylene chloride as extractant (*14*) are expected, and our data are consistent with this information.

Fatty Acid Methyl Ester Profile. Neither seed drying nor extraction solvent affected fatty acid methyl ester profiles (**Table 1**). However, seed stratification affected the contents of palmitic acid. The range of saturated (2.33−2.62%), monounsaturated (86.8−87.7%), and polyunsaturated (9.99−10.5%) fatty acids is consistent with values reported by Oomah et al. (*26*) for the neutral lipids of *P. quinquefolium*. Ginseng seed oil fatty acid composition is similar to olive oil as both have high levels of monounsaturated fatty acids.

Phytosterol Composition. Chromatographic analysis of the unsaponifiable fraction of ginseng oils showed *15* phytosterol peaks (**Figure 2**; **Table 2**). Identification of numbered peaks, other than peak 15, was possible using a combination of mass spectral evidence and relative retention times (RR_t). Five compounds were identified that have not been previously reported in North American ginseng seed oil. These include clerosterol (peak 5), spinasterol (peak 6, minor component), sitostanol (peak 7, minor component), Δ^7-sitosterol (peak 11), and erythrodiol (peak 14, minor component).

The identities of squalene, cholesterol, campesterol, stigmasterol, β-sitosterol, β-amyrin, sitostanol, lupeol, and erythrodiol were confirmed by comparing their RR_t values and their MS fragments with those of authentic samples. The sterol TMS ether derivatives of commercial olive (Filippo Berio Co. Ltd., Viareggio, Lucca, Italy), pumpkin (Omega Nutrition Inc., Vancouver, BC, Canada), safflower (Sunfresh Ltd., Toronto, ON, Canada), and sunflower (Hain Food Group Inc., Uniondale, NY) oils were prepared as described above. Comparing the results of the GC-MS and GC-FID analyses of the sterol TMS ether derivatives of these oils with literature values of composition (*27*−*31*) and MS data (*21*, *28*−*30*, *32*−*36*) allowed us to locate and identify spinasterol, Δ^5-avenasterol, Δ^7-sitosterol, and Δ^7-avenasterol. As shown by selected ion monitoring, peak 6 (**Figure 2**) contains a trace of spinasterol, peak 7 a trace of sitostanol, peak 8 a trace of butyrospermol, and peak 14 a trace of erythrodiol. A trace of cholesterol was observed in the samples at $RR_t = 0.67$, but it was too small to quantify.

Comparison of the MS fragmentation data and retention order of peak 2 with the data reported by Matsumoto et al. (*14*) confirmed the identity of this peak as oxidosqualene.

Peak 5 has the same RR_t as that reported for clerosterol in the ref *37* and has the same retention order relative to sitosterol as described for the acetate (*23*, *38*) and free sterol (*29*, *39*). Rahier and Benveniste (*36*) claim the allylic cleavage is weak in $\Delta^{5,25(27)}$ sterols and that a more prominent fragmentation results from allylic cleavage, followed by loss of C21 methyl to quench the primary carbocation at C23. This cleavage gives ions at *m*/*z* 386, due to allylic cleavage plus C21 methyl loss, and at *m*/*z* 296 due to loss of trimethylsilyl alcohol (TMSOH) from the *m*/*z* 386 ion. Both of these ions were seen in the MS of peak 5. On the basis of these data, the relative abundance of the other observed ions, and the RR_t information, the identity of the compound is assigned as clerosterol, a $\Delta^{5,25(27)}$ sterol.

The major 4-desmethyl sterols present in North American ginseng seed oil are reported to be stigmasterol and sitosterol (*14*). Examination of selected ion chromatograms for peak 6 (**Table 2**) showed the major component was β-sitosterol, but a trace of an uncharacteristic ion in the mass spectra at *m*/*z* 343 suggested the presence of a minor component with an RR_t of ~1.002. The component in this portion of peak 6 matched the RR_t and MS data of spinasterol present in the commercial pumpkin seed oil. The Δ^7 isomer of sitosterol was found to be present (peak 11; **Table 2**) in our samples. It is not surprising that the Δ^7 isomer of stigmasterol (spinasterol) is also present.

Using selected ion monitoring, peak 8 was shown to comprise Δ^5-avenasterol and a minor amount of butyrospermol. The identification of the minor component as butyrospermol is based on RR_t evidence of the acetate and TMS derivatives (*14*, *19*, *38*, *40*) and the mass spectral data of both the acetate (*40*−*43*) and free phytosterol (*43*, *44*). The fragmentation pattern observed is consistent with the $\Delta^{7,24}$ euphane structure of butyrospermol, and the total ion chromatogram of an isothermal run at 260 °C suggests this component might represent 10% of the area of peak 8.

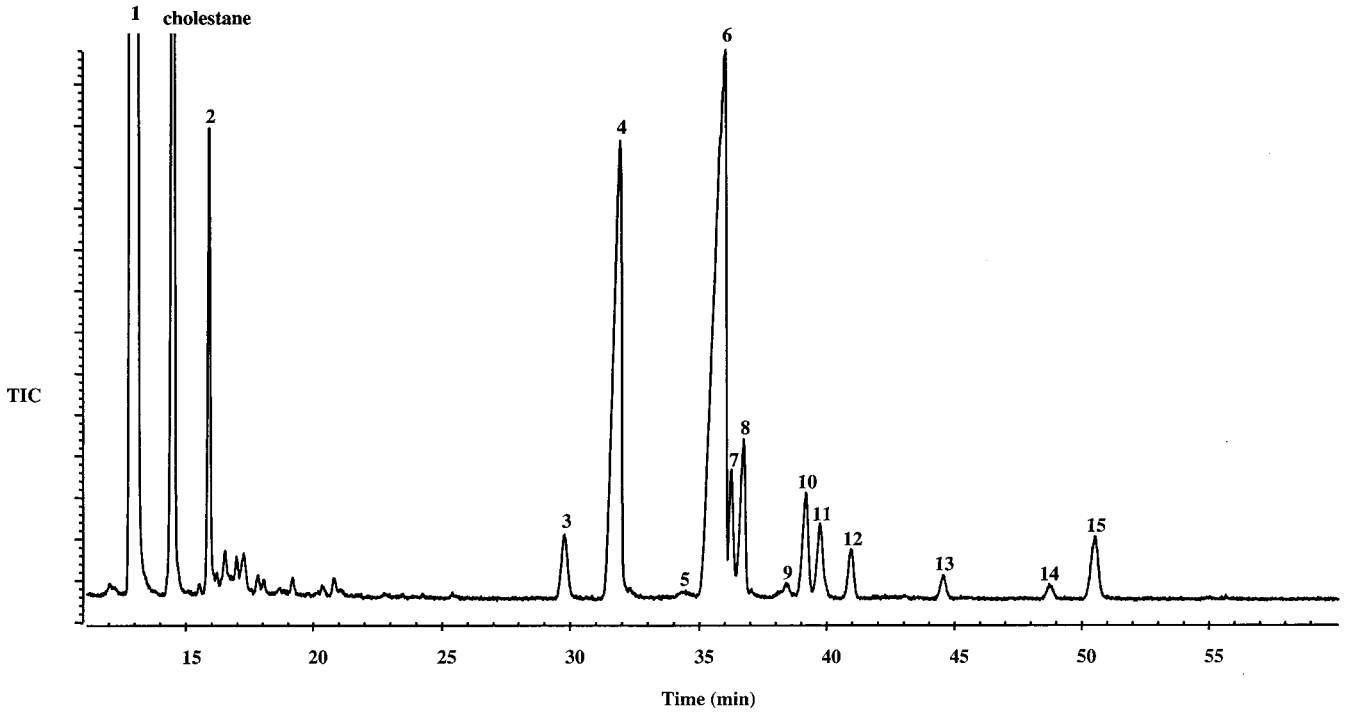

Figure 2. Gas chromatogram of the total ion count (TIC) of TMS derivatives of American ginseng seed oil unsaponifiables. Peaks are identified as in Table 2.

Table 2. Relative Retention Times and Fragmentation Ions Obtained in This Work and Used in the Identification of the Phytosterols of *P. quinquefolium*

compound	relative retention time (RR_t)[b]	peak	main fragmentation ions, *m/z* (RI)[a]					
			M^+	M – 15	M – 90	M – 105	M – 129	others
phytosterol precursors								
squalene	0.36	1	410 (1)					367 (1), 341 (1), 231 (1), 203 (1), 191 (1), 189 (1), 149 (6), 137 (7), 109 (8), 107 (8), 95 (16), 81 (51), 69[c]
oxidosqualene	0.45	2	426 (1)					383 (1), 357 (1), 231 (1), 203 (3), 191 (2), 189 (3), 149 (8), 109 (14), 107 (16), 95 (23), 81 (75), 69[c]
4-desmethyl sterols								
campesterol	0.84	3	472 (18)	457 (3)	382 (42)	367 (21)	343 (53)	315 (1), 255 (15), 213 (12), 129[c]
stigmasterol	0.89	4	484 (13)	469 (3)	394 (18)	379 (7)	355 (9)	343 (4), 255 (32), 213 (12), 129 (56), 83[c]
clerosterol	0.96	5	484 (18)	469 (1)	394 (15)	379 (9)	355 (15)	386 (2), 296 (4), 255 (15), 213 (16), 129 (63), 55[c]
β-sitosterol	1	6[d]	486 (15)	471 (5)	396 (41)	381 (20)	357 (50)	255 (17), 213 (12), 129[c]
Δ^5-avenasterol	1.03	8[d]	484 (4)	469 (3)	394 (1)	379 (4)	355 (8)	386 (66), 296 (60), 257 (26), 255 (16), 129 (87), 55[c]
$\Delta^{5,24(25)}$-stigmasterol	1.09	9	484 (8)	469 (4)	394 (5)	379 (9)	355 (4)	386 (28), 343 (19), 296 (26), 281 (18), 257 (10), 255 (11), 253 (10), 213 (12), 129 (42), 55[c]
Δ^7-sitosterol	1.12	11	486 (57)	471 (16)	396 (3)	381 (14)		345 (8), 343 (5), 303 (3), 255[c], 229 (30), 213 (49)
Δ^7-avenasterol	1.16	12	484 (1)	469 (5)	394 (1)	379 (4)		386 (43), 371 (7), 343[c], 296 (6), 281 (9), 253 (21)
4-monomethyl sterols								
citrostadienol	1.38	14[d]	498 (tr)	483 (5)	408 (1)	393 (6)		400 (53), 357[c], 267 (45)
4,4-dimethyl triterpene alcohols								
β-amyrin	1.02	7[d]	498 (1)	483 (tr)	408 (tr)	393 (1)		279 (3), 257 (2), 218[c], 203 (41), 190 (20), 189 (21)
lupeol	1.11	10	498 (9)	483 (2)	408 (3)	393 (6)		369 (13), 279 (12), 218 (27), 203 (44), 189 (85), 73[c]
24-methylenecycloartanol	1.26	13		497 (1)	422 (30)	407 (28)		379 (37), 353 (12), 300 (8), 73[c]
unknown A	1.43	15	586 (1)		496 (3)	481 (tr)		367 (4), 279 (6), 216 (13), 203 (16), 189 (40), 73[c]

[a] Intensity relative to base peak (percent); tr indicates trace. [b] Retention times relative to β-sitosterol TMS ether (35.9 min) using a DB-5 60 m column. The internal standard 5α-cholestane elutes with a relative retention time of 0.40. [c] Base peak (relative intensity = 100%). [d] Peak 6 contains spinasterol, peak 7, sitostanol, peak 8, butyrospermol, and peak 14, erythrodiol, as minor components (see text).

Peak 9 is tentatively assigned as $\Delta^{5,24(25)}$-stigmastadienol on the basis of the match of RR_t and MS fragmentation data with those reported by Kamal-Eldin et al. (*21*).

Peak 13 was identified as 24-methylenecycloartanol. The RR_t and MS data match Kamal-Eldin et al. (*34*), and matches were obtained for the 24-methylenecycloartanol known to be present in commercial olive, pumpkin, safflower, and sunflower oils (*45*−*48*). 24-Methylenecycloartanol is a major triterpene alcohol in all of these oils.

Using selected ion monitoring, peak 14 was shown to comprise citrostadienol and a trace of erythrodiol. Erythrodiol was identified by matching RR_t and MS data with that of an authentic sample. The MS of the main citrostadienol portion of the peak matches data provided by Kamal-Eldin et al. (*21*).

Table 3. Paired Comparisons of the Effects of Seed Oil Extraction, Stratification, Drying Method, and Production Year on the Levels of Phytosterol Contents in Ginseng Seed Oil (Milligrams per 100 g of Oil)[a]

	extraction solvent		seed stratification		stratified seed drying method		seed production year	
phytosterol component	hexane	CH_2Cl_2	without	with	air	oven	1999	2000
squalene	513.53	501.96	519.68[b]	488.05	488.05	485.82	519.68[b]	569.43
oxidosqualene	48.20[b]	59.14	8.97[b]	13.83	13.83	13.74	8.97[b]	10.49
campesterol	10.96	10.38	9.96	9.10	9.10	8.51	9.96[b]	12.38
stigmasterol	93.18	94.72	113.24	111.81	111.81[b]	102.98	113.24	110.45
clerosterol	2.14	2.08	2.12	1.54	1.54	1.27	2.12	1.91
β-sitosterol	176.92	164.23	152.59[b]	125.79	125.79[b]	116.59	152.59[b]	186.42
β-amyrin	11.74	14.63	19.50[b]	12.25	12.25	12.14	19.50[b]	12.56
Δ^5-avenasterol	20.54	22.97	15.77[b]	12.08	12.08	12.82	15.77[b]	12.42
$\Delta^{5,24(25)}$-stigmasterol	4.76	4.17	3.70	3.31	3.31[b]	2.85	3.70[b]	4.31
lupeol	15.17	15.68	14.48[b]	7.01	7.01[b]	8.10	14.48	14.41
Δ^7-sitosterol	13.30	15.02	12.46	12.86	12.86	13.11	12.46	14.62
Δ^7-avenasterol	8.09	8.44	4.53[b]	3.97	3.97	3.90	4.53	4.11
24-methylenecycloartanol	4.76	5.04	3.43[b]	2.16	2.16	2.36	3.43[b]	1.94
citrostadienol	3.81	4.19	3.73[b]	2.81	2.81	3.22	3.73[b]	2.50
unknown A	10.68[b]	19.54	16.30[b]	6.02	6.02[b]	11.24	16.30	15.70
total	937.78	942.19	900.47[b]	812.60	812.60	798.63	900.47[b]	973.64

[a] Hexane was used throughout except where indicated as CH_2Cl_2. [b] Value in each column is significantly different ($p = 0.05$) from the value in the parallel column according to the analysis of variance.

Additional evidence was available by matching RR_t and MS profiles with the same peak present in olive, sunflower, and safflower oils (*45*−*47*). Selected ion chromatograms of the base peaks (**Table 2**) suggest erythrodiol may comprise ∼23% of peak 14 area.

The identity of unknown A (peak 15) has not yet been assigned. The MS shows an ion at *m*/*z* 586, which is consistent with the molecular ion of a di-TMS ether derivative of a $C_{30}H_{50}O_2$ compound. A triterpene diol would be consistent with such a formula, but the peak was not due to uvaol or lup-3,28-diol (betulin) as shown by spiking experiments with authentic samples. This compound was not present in commercial olive, pumpkin, safflower, or sunflower oils.

Quantative estimation of the levels of phytosterols in ginseng (**Table 3**) showed squalene to be the major component followed by β-sitosterol and stigmasterol. Other components were minor compared to these three. Matsumoto et al. (*14*) indicated that the unsaponifiable matter in *P. quinquefolium* seeds contained 28% squalene. Our data (**Table 3**) suggest the amount of squalene would lie between 53 and 61%. The choice of solvent affected the levels of oxidosqualene and unknown A. Higher amounts were obtained from methylene chloride-extracted than with hexane-extracted oil. Interestingly, the sum of squalene and oxidosqualene for the hexane-extracted oil is 562 mg/100 g and is 561 mg/100 g for the methylene chloride-extracted oil, suggesting a relationship between these two components. Oxidation of squalene to oxidosqualene occurs in biological systems, and perhaps this difference reflects exposure to air as the hexane extractions were completed before the methylene chloride extractions, allowing an opportunity for increased oxidation to occur. Future studies should address this possibility by careful storage of samples frozen under an inert gas. Unknown A is thought to be a triterpene diol, and because methylene chloride is a more polar solvent than hexane, solubility differences may account for the observed increased extraction with methylene chloride.

Seed stratification (**Table 3**) results in losses of most phytosterols over the stratification period. Stigmasterol was the exceptional major component that did not change during stratification, and oxidosqualene actually increased during the procedure. The β-sitosterol/stigmasterol ratio decreased from 1.3 to 1.1 in contrast to the expected increase as suggested by Vlahakis and Hazebroek (*13*) indicating that continued β-sitosterol synthesis does not occur during cold storage.

The contents of the 4-desmethyl sterols stigmasterol, β-sitosterol, and $\Delta^{5,24(25)}$-stigmasterol are lower in oil extracted from oven-dried (35 °C) than in oil extracted from air-dried seeds. These differences may result from the higher drying temperature in the oven. However, unknown A and lupeol increased with thermal treatment.

Only the common vegetable oils corn, canola, and sesame have phytosterol levels comparable to those in ginseng (*12*, *27*, *45*, *49*, *50*). Phytosterols are thought to promote human health through cholesterol reduction (*3*, *4*, *8*) or as quenchers of singlet oxygen providing protection of skin from lipid peroxidation on exposure to UV and ionizing radiation (*51*). This latter observation is especially true of squalene. Commercial supplies of squalene are derived from fish liver oil, and these supplies are under pressure because of a decreased fishery and because of concerns relating to preservation of fisheries worldwide. A vegetable source of squalene would be desirable, and one source might be olive oil containing 0.3−0.7% squalene (*52*). Clearly ginseng oil containing 0.5−0.6% squalene would be another desirable source obtainable in cold or temperate climates.

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