Panax ginseng callus, suspension, and root cultures: extraction and qualitative analysis

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Abstract: Introduction. In recent years, scientists have been actively searching for medicinal plants containing biologically active substances with geroprotective properties to treat diseases of old age, in particular cancer, diabetes, cardiovascular diseases, and others. Ginseng (Panax ginseng L.) is a promising source of geroprotective compounds. We aimed to select optimal parameters for extracting organic compounds from ginseng callus, suspension, and root cultures and analyze their qualitative composition.

Study objects and methods. We studied ginseng callus, suspension, and root cultures, as well as their extracts. Biologically active substances were extracted with 30 to 70% ethanol. Organic compounds were determined by thin-layer chromatography. The results for each plant were archived and analyzed for the presence of quercetin, mangiferin, luteolin, rutin, quercetin-2-D-glucoside, malvidin, as well as caffeic, cinnamic, ferulic, and sinapinic acids.

Results and discussion. We developed a procedure for screening solvents and performed a fractional qualitative analysis of biologically active substances extracted from ginseng. As a result, we established the optimal parameters for extracting biologically active substances from the dried biomass of ginseng cultures. In all cases, temperature and the ratio of solvent to biomass were the same (50°C, 1:5). However, the extraction time and ethanol concentration differed, amounting to 60 min and 50% for callus cultures, 30 min and 60% for suspension cultures, and 60 min and 70% for root cultures. The qualitative analysis of organic compounds showed the presence of rutin (0.25), quercetin (0.75), and mangiferin (0.57), as well as caffeic and sinapinic acids in the extracts.

Conclusion. Our set of experiments to isolate biologically active substances from ginseng callus, suspension, and root cultures resulted in selecting the optimal extraction parameters and analyzing the extracts for the presence of organic compounds.

Keywords: Plant cultures, Panax ginseng, ginseng, plant extracts, geroprotective properties, gerontology

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INTRODUCTION

Modern medicine and biology are actively searching for new drugs with geroprotective effects [1–8]. Highly useful in this regard are extracts of medicinal plants [8, 9].

A common extraction method involves using a reflux condenser, a Soxhlet extractor, mechanical stirring, and ultrasound. Soxhlet extraction takes place at 80–90°C and lasts from 20 to 24 h. Such parameters make it possible to efficiently extract biologically active compounds, such as saponins [10–13].

Modern extraction methods include ultra-high pressure extraction (UHPE), ultrasonic extraction (UTE), pressured liquid extraction (PLE), microwave-assisted extraction (MAE), pressurized hot-water extraction (PHWE), and supercritical fluid extraction (SFE) [9–12, 14–17].

Compared to traditional techniques, modern methods use smaller amounts of solvents, are easily automated, and take little time. However, they are hardly more effective than, for example, Soxhlet extraction or...
mechanical mixing [13, 18]. Moreover, pressurized hot-water extraction and supercritical fluid extraction are technically quite difficult to perform [10, 14, 19, 20].

Among medicinal plants with geroprotective properties are *Schisandra chinensis* (L.), *Scutellaria baicalensis* (L.), *Rhodiola rosea* (L.), *Ginkgo biloba* (L.), and others [21–24]. The most highly valued geroprotective medicinal plants include *Panax ginseng* (L.), *Aralia mandshurica* (L.), and *Eleutherococcus senticosus* (L.) [25]. Since the 1980s, scientists have known of their antitumor effects [25–27].

Ginseng (*Panax ginseng*) is a slowly growing perennial plant that is often used as a functional component and a phytotherapeutic agent to prevent and treat various diseases, such as cancer, allergies, inflammatory diseases, and diabetes mellitus [26–31].

According to scientific literature, ginseng extract is used as an adaptogen to increase physical performance, vitality, immunity, as well as resistance to stress and aging [26, 32–34]. It also lowers total cholesterol and low-density lipoproteins, thereby improving a blood lipid profile [31, 32].

However, this plant is included in the Red Book of the Russian Federation and the collection of young roots is prohibited due to its depletion. In addition to low seed productivity and relatively slow growth, ginseng population is irreparably damaged by forest fires and human activities in its endemic areas [35, 36].

Therefore, a justified solution would be to use the plant’s cell and organ cultures as an alternative source of renewable medicinal material [30, 32, 35–37]. In our study, we used ginseng callus, suspension, and root cultures — obtained in the early stages of research — as a source of biologically active substances.

We aimed to select optimal extraction parameters and perform a qualitative analysis of organic compounds isolated from ginseng callus, suspension, and root cultures.

### STUDY OBJECTS AND METHODS

Our study objects included callus, suspension, and root cultures of ginseng (*Panax ginseng* L.) obtained in vitro, as well as their extracts.

To determine the optimal parameters for extracting biologically active substances from ginseng by reflux extraction, we analyzed several extraction systems for their effectiveness. A water-ethanol mixture was selected as an extractant due to its safety (GRAS), economic efficiency, and the ability to extract a wide range of biologically active substances from plant materials [38, 39]. We screened the solvents and performed a qualitative analysis of organic compounds (Fig. 1). The percentage of ethanol in the solvents is indicated in mass fractions. The yield of extracts (%) is expressed in terms of 100 g of dry raw material.

To extract biologically active substances from ginseng callus cultures, we placed 3 ± 0.001 g of dry powdered callus culture in a 50 mL plastic tube and added 40 mL of 30, 40, 50, 60, or 70% solvent according to the screening scheme (Fig. 1). The tube was connected to a reflux condenser. After 60 min of extraction, we separated the dry mass from the solution by filtration. To remove suspended particles, we centrifuged the filtrate at 3900 rpm. Ethanol was evaporated from a 100 mL pre-weighed flask under reduced pressure. After evaporation, we weighed the flask and measured the extract yield.

Then, we dissolved the residue in a minimum amount of the solvent and determined the qualitative composition of organic compounds in the extract by thin-layer chromatography.

The chromatograms for each plant were archived and analyzed for the presence of quercetin (Sigma-Aldrich, USA, ≥ 95%), mangiferin (Sigma-Aldrich, USA, ≥ 98%), luteolin (Sigma-Aldrich, USA, ≥ 98%), rutin (Sigma-Aldrich, USA, ≥ 94%), quercetin-2-D-glucoside (Sigma-Aldrich, USA, ≥ 95%), caffeic acid (Sigma-Aldrich, USA, ≥ 98%), cinnamic acid (Acros Organics, Belgium, USA, ≥ 98%), and aqueous solution of acetic acid.

![Flowchart of the extraction process](image)

**Figure 1** Solvents efficiency in extracting biologically active substances from ginseng

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To prepare ginseng suspension and root cultures for the experiment, they were pre-dried to constant weight. Then, 0.5–2.0 g samples of dried cultures were extracted with solvents for callus cultures.

Thin-layer chromatography was performed as described in Pharmacopeia Article 1.2.1.2.0003.15. After evaporation of the solvent from the total extract, we dissolved the dry residue in 1 ml of a suitable extractant (methanol, methylene chloride or acetone) and applied it to the plate with a glass capillary for thin-layer chromatography.

Then, we placed the plate in a chamber and added a suitable eluent. When we used silica gel without modification, chromatography was performed in the CH2Cl2:MeOH system with a 0–10% methanol gradient, in increments of 1%. For reversed-phase chromatography, we used the H2O:MeCN eluent system with a 0–20% acetonitrile gradient, in increments of 2%, and 0.1% trifluoroacetic acid as a modifier.

We separated the fractions with high-performance liquid chromatography (HPLC), using a Prominence LC-20 chromatograph with diode-array detection (Shimadzu, Japan) and a 250×4.6 mm Kromasil C18 chromatographic column with 5 μm sorbent particles. A mixture of water with orthophosphoric acid, pH = 4.6 (A) and acetonitrile (B) were used as a mobile phase. The gradient elution modes (% B) were 0–20 and 20–60 min with a gradient change of 10–20% and 20–50%, respectively. The eluent flow rate was 1.0 mL/min; the temperature of the column thermostat was 35°C. In the preparative accumulation mode, the eluent was used without the acid.

The instrument was calibrated with caffeine (Sigma-Aldrich, USA, ≥ 90%).

Nuclear magnetic resonance (NMR) spectra were recorded on a Varian NMR System 400 spectrometer with a silent Ceccato OFCS 5/8 SD compressor (Varian, USA), with DMSO-D6 used as a solvent and tetramethylsilane as the internal standard.

RESULTS AND DISCUSSION

To analyze the efficiency of various extraction systems, we obtained average yields of solids in total extracts. Total extract yields depending on the solvent’s concentration are presented in Fig. 2.

Based on the results, we selected 50% ethanol as a solvent to extract biologically active substances from the dried biomass of ginseng callus cultures by reflux extraction. Further selection parameters are shown in Tables 1–2.

According to Table 1, the maximum yield of biologically active substances extracted from dried ginseng callus cultures (5.88 ± 0.59%) at 45°C was provided by a 1:5 ratio of solvent to biomass and the

Table 1 Dry extract yield of biologically active substances from dried ginseng callus culture biomass depending on extraction time (at 45°C)

| Solvent:culture | 10 min | 30 min | 60 min | 120 min | 180 min | 360 min |
|-----------------|--------|--------|--------|---------|---------|---------|
| 1:1             | 0.50 ± 0.05 | 0.81 ± 0.08 | 1.22 ± 0.12 | 1.29 ± 0.13 | 1.38 ± 0.14 | 1.38 ± 0.14 |
| 1:2             | 0.80 ± 0.08 | 0.94 ± 0.09 | 1.35 ± 0.14 | 1.58 ± 0.16 | 1.67 ± 0.17 | 1.71 ± 0.17 |
| 1:5             | 1.20 ± 0.12 | 1.80 ± 0.18 | 2.78 ± 0.28 | 5.88 ± 0.59 | 5.95 ± 0.60 | 5.81 ± 0.58 |
| 1:10            | 1.40 ± 0.14 | 1.98 ± 0.20 | 2.98 ± 0.30 | 5.94 ± 0.59 | 5.97 ± 0.60 | 6.04 ± 0.60 |
| 1:20            | 1.40 ± 0.14 | 2.01 ± 0.20 | 3.01 ± 0.30 | 5.95 ± 0.60 | 6.01 ± 0.60 | 6.07 ± 0.61 |

Table 2 Temperature selection for extracting biologically active substances from ginseng callus cultures

| Temperature, °C | 10 min | 30 min | 60 min | 120 min | 180 min | 360 min |
|-----------------|--------|--------|--------|---------|---------|---------|
| 25              | 1.20 ± 0.12 | 1.80 ± 0.18 | 2.78 ± 0.28 | 5.88 ± 0.59 | 5.95 ± 0.60 | 5.81 ± 0.58 |
| 40              | 1.55 ± 0.16 | 1.98 ± 0.20 | 3.92 ± 0.39 | 6.21 ± 0.62 | 6.18 ± 0.62 | 6.24 ± 0.62 |
| 50              | 1.79 ± 0.18 | 2.35 ± 0.24 | 6.98 ± 0.70 | 7.05 ± 0.71 | 7.01 ± 0.70 | 7.12 ± 0.71 |
| 80              | 1.62 ± 0.16 | 2.14 ± 0.21 | 6.04 ± 0.60 | 6.12 ± 0.61 | 6.14 ± 0.61 | 6.17 ± 0.62 |
We found that the maximum yield of biologically active substances extracted from dried ginseng suspension cultures (8.78 ± 0.88%) at 45°C was provided by a 1:5 ratio of solvent to biomass and the extraction time of at least 120 minutes.

According to the results, the optimal parameters for extracting biologically active substances from ginseng with 60% ethanol (extract yield of 8.95 ± 0.90%) were 50°C, 30 min extraction, and a 1:5 solvent-to-biomass ratio.

At the next stage, we optimized the parameters for obtaining total extracts from in vitro ginseng root cultures. The total extract yield depending on the solvent is shown in Fig. 4.

According to Fig. 4, 70% ethanol produced the highest yield of biologically active substances from the dried biomass of ginseng root cultures. The total extract yield depending on the solvent was 8.21 ± 0.82.

According to the results, the duration of 30 to 180 min and the solvent-to-biomass ratio of 1:5 and 1:10 provided the maximum yield of biologically active substances from the dried biomass of ginseng root cultures. In particular, the yield of 11.98% was produced at a ratio of 1:10 at 45°C during 30–60 min.

**Figure 3** Solvents efficiency in extracting biologically active substances from ginseng suspension cultures

**Figure 4** Solvents efficiency in extracting biologically active substances from ginseng root cultures

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### Table 3

| Solvent:culture | Extract yield depending on duration, % |
|----------------|----------------------------------------|
|                | 10 min | 30 min | 60 min | 120 min | 180 min | 360 min |
| 1:1            | 2.50 ± 0.25 | 2.51 ± 0.25 | 2.62 ± 0.26 | 2.92 ± 0.29 | 2.98 ± 0.30 | 2.83 ± 0.28 |
| 1:2            | 2.80 ± 0.28 | 2.94 ± 0.29 | 2.75 ± 0.28 | 2.85 ± 0.29 | 2.76 ± 0.28 | 2.91 ± 0.29 |
| 1:5            | 2.93 ± 0.29 | 8.78 ± 0.88 | 8.80 ± 0.88 | 8.68 ± 0.87 | 8.95 ± 0.90 | 8.21 ± 0.82 |
| 1:10           | 5.40 ± 0.54 | 8.98 ± 0.90 | 8.98 ± 0.90 | 8.94 ± 0.89 | 8.97 ± 0.90 | 8.84 ± 0.88 |
| 1:20           | 6.34 ± 0.63 | 8.61 ± 0.86 | 8.51 ± 0.85 | 8.95 ± 0.90 | 8.71 ± 0.87 | 8.77 ± 0.88 |

**Table 4** Temperature selection for extracting biologically active substances from ginseng suspension cultures

| Temperature, °C | Extract yield depending on duration, % |
|-----------------|----------------------------------------|
|                 | 10 min | 30 min | 60 min | 120 min | 180 min | 360 min |
| 25              | 2.20 ± 0.22 | 1.80 ± 0.18 | 2.78 ± 0.28 | 5.88 ± 0.59 | 5.95 ± 0.60 | 5.81 ± 0.58 |
| 40              | 2.55 ± 0.26 | 1.98 ± 0.20 | 3.92 ± 0.39 | 6.21 ± 0.62 | 6.18 ± 0.62 | 6.24 ± 0.62 |
| 50              | 2.79 ± 0.28 | 8.95 ± 0.90 | 8.40 ± 0.84 | 8.75 ± 0.88 | 8.21 ± 0.82 | 8.32 ± 0.83 |
| 80              | 3.62 ± 0.36 | 7.56 ± 0.76 | 7.34 ± 0.73 | 7.12 ± 0.71 | 7.14 ± 0.71 | 7.17 ± 0.72 |
CONCLUSION

We developed a solvent screening procedure and performed a qualitative analysis of biologically active substances extracted from ginseng (Panax ginseng L.).

The optimal parameters for extracting biologically active substances (organic solvent, ratio of solvent to biomass, time, and temperature) were 50% ethanol, 1:5 ratio, 60 min, 50°C for ginseng callus cultures; 60% ethanol, 1:5 ratio, 30 min, 50°C for suspension cultures; and 70% ethanol, 1:5 ratio, 60 min, 50°C for root cultures, respectively.

Based on the results in Table 6, we selected the following parameters for extracting biologically active substances from the dried biomass of in vitro ginseng root cultures: extraction at 50°C during 30 min at a 1:5 ratio of solvent to dried biomass. These parameters produced a yield of 11.95 ± 1.20%. We recommend to use 70% ethanol as a solvent.

Thus, we determined the optimal parameters (time, temperature, organic solvent, ratio of solvent to biomass) for extracting biologically active substances from ginseng callus, suspension, and root cultures (Table 7).

The qualitative analysis of standard compounds and biologically active substances extracted from dried ginseng callus, suspension, and root cultures showed the presence of rutin, quercetin, quercetin-glycoside, mangiferin, luteolin, apigenin, and caffeic acid.

The fractions were separated by preparative HPLC (Fig. 5).

As a result, we isolated a basic substance with a retention time of 24 min, which was identified as mangiferin (Fig. 6).

Thus, rutin (0.25), quercetin (0.75), and mangiferin (0.57) were major biologically active substances found in the extracts of in vitro ginseng callus, suspension, and root cultures. We also identified caffeic and sinapinic acids in the extracts.
The qualitative analysis of the extracts of ginseng callus, suspension, and root cultures showed the presence of rutin (0.25), quercetin (0.75), and mangiferin (0.57) as predominant components. The extracts also contained caffeic and sinapinic acids.

Thus, the extracts obtained by water-ethanol extraction from ginseng callus, suspension, and root cultures can be used as biologically active ingredients in the production of functional geroprotective foods.

REFERENCES

1. Sameh S, Al-Sayed E, Labib RM, Singab AN. Genus spondias: a phytochemical and pharmacological review. Evidence-Based Complementary and Alternative Medicine. 2018. DOI: https://doi.org/10.1155/2018/5382904.

2. Mohamed MZ, Hafez HM, Hassan M, Ibrahim MA. PI3K/Akt and Nrf2/HO-1 pathways involved in the hepatoprotective effect of verapamil against thioacetamide toxicity in rats. Human and Experimental Toxicology. 2019;38(4):381–388. DOI: https://doi.org/10.1177/0960327118817099.

3. Abdel fattah-Hassan A, Shalaby SI, Khater SI, El-Shetry ES, Abd El Fadil H, Elsayed SA. *Panax ginseng* is superior to vitamin E as a hepatoprotector against cyclophosphamide-induced liver damage. Complementary Therapies in Medicine. 2019;46:95–102. DOI: https://doi.org/10.1016/j.ctim.2019.08.005.

4. Zaushintsena AV, Bruhachev EN, Belashova OV, Asyakina LK, Kurbanova MG, Vesnina AD, et al. Extracts of *Rhodiola rosea* L. and *Scutellaria galericulata* L. in functional dairy products. Foods and Raw Materials. 2020;8(1):163–170. DOI: http://doi.org/10.21603/2308-4057-2020-1-163-170.

5. Eremeeva NB, Makarova NV, Zhidkova EM, Maximova VP, Lesova EA. Ultrasonic and microwave activation of raspberry extract: antioxidant and anti-carcinogenic properties. Foods and Raw Materials. 2019;7(2):264–273. DOI: http://doi.org/10.21603/2308-4057-2019-2-264-273.

6. Zaushintsena AV, Milentyeva IS, Babich OO, Noskova SYu, Kiseleva TF, Popova DG, et al. Quantitative and qualitative profile of biologically active substances extracted from purple echinacea (*Echinacea Purpurea L*) growing in the Kemerovo region: functional foods application. Foods and Raw Materials. 2019;7(1):84–92. DOI: http://doi.org/10.21603/2308-4057-2019-1-84-92.

7. Sukhikh SA, Astakhova LA, Golubcova YuV, Lukin AA, Prosekova EA, Milent’eva IS, et al. Functional dairy products enriched with plant ingredients. Foods and Raw Materials. 2019;7(2):428–438. DOI: http://doi.org/10.21603/2308-4057-2019-2-428-438

8. Al-Turki AI, El-Ziney MG, Abdel-Salam AM. Chemical and anti-bacterial characterization of aqueous extracts of oregano, marjoram, sage and licorice and their application in milk and labneh. Journal of Food, Agriculture and Environment. 2008;6(1):39–44.

9. Babich O, Dyshlyuk L, Noskova S, Sukhikh S, Prosekov A, Ivanova S, et al. In vivo study of the potential of the carbohydrate-mineral complex from pine nut shells as an ingredient of functional food products. Bioactive Carbohydrates and Dietary Fibre. 2019;18. DOI: https://doi.org/10.1016/j.bcdf.2019.100185.

10. Qi L-W, Wang C-Z, Yuan C-S. Isolation and analysis of ginseng: advances and challenges. Natural Product Reports. 2011;28(3):467–495. DOI: https://doi.org/10.1039/c0np00057d.

11. Kim S-J, Murthy HN, Hahn E-J, Lee HL, Paek K-Y. Parameters affecting the extraction of ginsenosides from the adventitious roots of ginseng (*Panax ginseng* C.A. Meyer). Separation and Purification Technology. 2007;56(3):401–406. DOI: https://doi.org/10.1016/j.seppur.2007.06.014.

12. Wood JA, Bernards MA, Wan W-K, Charpentier PA. Extraction of ginsenosides from North American ginseng using modified supercritical carbon dioxide. The Journal of Supercritical Fluids. 2006;39(1):40–47. DOI: https://doi.org/10.1016/j.supflu.2006.01.016.

13. Ligor T, Ludwiczuk A, Wolski T, Buszewski B. Isolation and determination of ginsenosides in *American ginseng* leaves and root extracts by LC-MS. Analytical and Bioanalytical Chemistry. 2005;383(7–8):1098–1105. DOI: https://doi.org/10.1007/s00216-005-0120-8.

14. Sanchez-Camargo ADP, Ibanez E, Cifuentes A, Herrero M. Bioactives obtained from plants, seaweeds, microalgae and food by-products using pressurized liquid extraction and supercritical fluid extraction. Comprehensive Analytical Chemistry. 2017;76:27–51. DOI: https://doi.org/10.1016/bs.coac.2017.01.001.

15. Khaw K-Y, Parat M-O, Shaw PN, Falconer JR. Solvent supercritical fluid technologies to extract bioactive compounds from natural sources: A review. Molecules. 2017;22(7). DOI: https://doi.org/10.3390/molecules22071186.
16. Ciko A-M, Jokić S, Šubarić D, Jerković I. Overview on the application of modern methods for the extraction of bioactive compounds from marine macroalgae. Marine Drugs. 2018;16(10). DOI: https://doi.org/10.3390/md16100348.

17. Zhang L, Liu P, Li L, Huang Y, Pu Y, Hou X, et al. Identification and antioxidant activity of flavonoids extracted from xinjiang jujube (Ziziphus jujube Mill.) leaves with ultra-high pressure extraction technology. Molecules. 2018;24(1). DOI: https://doi.org/10.3390/molecules24010122.

18. Sun B-S, Gu L-J, Fang Z-M, Wang C-Y, Wang Z, Lee M-R, et al. Simultaneous quantification of 19 ginsenosides in black ginseng developed from Panax ginseng by HPLC-ELSD. Journal of Pharmaceutical and Biomedical Analysis. 2009;50(1):15–22. DOI: https://doi.org/10.1016/j.jpba.2009.03.025.

19. Wan J-B, Li S-P, Chen J-M, Wang Y-T. Chemical characteristics of three medicinal plants of the Panax genus determined by HPLC-ELSD. Journal of Separation Science. 2007;30(6):825–832. DOI: https://doi.org/10.1002/jssc.200600359.

20. Kwon J-H, Bélanger JMR, Paré JR. Optimization of microwave-assisted extraction (MAP) for ginseng components by response surface methodology. Journal of Agricultural and Food Chemistry. 2003;51(7):1807–1810. DOI: https://doi.org/10.1021/jf026068a.

21. Hong M, Zhang Y, Li S, Tan HY, Wang N, Mu S, et al. A network pharmacology-based study on the hepatoprotective effect of Fructus Schisandrae. Molecules. 2017;22(10). DOI: https://doi.org/10.3390/molecules22101617.

22. Wang Z-L, Wang S, Kuang Y, Hu Z-M, Qiao X, Ye M. A comprehensive review on phytochemistry, pharmacology, and flavonoid biosynthesis of Scutellaria baicalensis. Pharmaceutical Biology. 2018;56(1):465–484. DOI: https://doi.org/10.1080/13880209.2018.1492620.

23. Xu Y, Jiang H, Sun C, Adu-Frimpong M, Deng W, Yu J, et al. Antioxidant and hepatoprotective effects of purified Rhodiola rosea polysaccharides. International Journal of Biological Macromolecules. 2018;117:167–178. DOI: https://doi.org/10.1016/j.ijbiomac.2018.05.168.

24. Ali M, Khan T, Fatima K, Ali QUa, Ovais M, Khalil AT, et al. Selected hepatoprotective herbal medicines: Evidence from ethnomedicinal applications, animal models, and possible mechanism of actions. Phytotherapy Research. 2018;32(2):199–215. DOI: https://doi.org/10.1002/ptr.5957.

25. Huvaere K, Skibsted LH. Flavonoids protecting food and beverages against light. Journal of the Science of Food and Agriculture. 2015;95(1):20–35. DOI: https://doi.org/10.1002/jsfa.6796.

26. Irfan M, Kwak Y-S, Han C-K, Huyn SH, Rhee MH. Adaptogenic effects of Panax ginseng on modulation of cardiovascular functions. Journal of Ginseng Research. 2020. DOI: https://doi.org/10.1016/j.jgr.2020.03.001.

27. Jovanovski E, Lea-Duvnjak-Smircic, Komishon A, Au-Yeung F, Zurbau A, Jenkins AL, et al. Vascular effects of combined enriched Korean Red ginseng (Panax Ginseng) and American ginseng (Panax Quinquefolius) administration in individuals with hypertension and type 2 diabetes: A randomized controlled trial. Complementary Therapies in Medicine. 2020;49. DOI: https://doi.org/10.1016/j.ctim.2020.102338.

28. Zhang F, Tang S, Zhao L, Yang X, Yao Y, Hou Z, et al. Stem-leaves of Panax as a rich and sustainable source of less-polar ginsenosides: comparison of ginsenosides from Panax ginseng, American ginseng and Panax notoginseng prepared by heating and acid treatment. Journal of Ginseng Research. 2020. DOI: https://doi.org/10.1016/j.jgr.2020.01.003.

29. Zhao B, Lv C, Lu J. Natural occurring polysaccharides from Panax ginseng C.A. Meyer: A review of isolation, structures, and bioactivities. International Journal of Biological Macromolecules. 2019;133:324–336. DOI: https://doi.org/10.1016/j.ijbiomac.2019.04.004.

30. Dostalova L, Detvanova L, Kalhotka L. Antimicrobial activity of aqueous herbal extracts. MendelNet. 2014;6: 403–406.

31. Li F, Cao Y, Luo Y, Liu T, Yan G, Chen L, et al. Two new triterpenoid saponins derived from the leaves of Panax ginseng and their antiinflammatory activity. Journal of Ginseng Research. 2019;43(4):600–605. DOI; https://doi.org/10.1016/j.jgr.2018.09.004.

32. Zhao B, Lv C, Lu J. Natural occurring polysaccharides from Panax ginseng C.A. Meyer: A review of isolation, structures, and bioactivities. International Journal of Biological Macromolecules. 2019;133:324–336. DOI: https://doi.org/10.1016/j.ijbiomac.2019.03.229.

33. Zhao B, Wang X, Liu H, Lv C, Lu J. Structural characterization and antioxidant activity of oligosaccharides from Panax ginseng C.A. Meyer. International Journal of Biological Macromolecules. 2020;150:737–745. DOI: https://doi.org/10.1016/j.ijbiomac.2020.02.016.

34. Zheng X, Fu Z, Wang C, Zhang S, Dai M, Cai E, et al. Effect of Panax ginseng combined with Angelica sinensis on the dissolution of ginsenosides and in chemotherapy mice hematopoietic function. Bioorganic and Medicinal Chemistry. 2019;27(18):4211–4218. DOI: https://doi.org/10.1016/j.bmc.2019.07.054.
35. Poluchenie sukhikh ehkstraktov iz rasteniy i sozdanie na ikh osnove preparatov i biologicheski aktivnykh dobavok [Obtaining dry extracts from plants and creating preparations and biologically active additives]. [cited 2018 Dec 24]. Available from: http://medical-diss.com/docreader/481996/a#?page=2.

36. Risman M. Biologicheski aktivnye pishchevye dobavki. Neizvestnoe ob izvestnom [Biologically active food additives. The unknown about the known]. Moscow: Art-Business-Center; 1998. 496 p. (In Russ.).

37. Vitman MA, Pilipenko TV. Use of complex additives from plant raw material in development of products of healthy nutrition. Mezhdunarodnaya nauchno-prakticheskaya konferentsiya, posvyashchennaya pamyati Vasilya Matveevicha Gorbatova [International scientific and practical conference dedicated to the memory of V.M. Gorbatov]. 2016;(1): 74–75. (In Russ.).

38. Cox S, Noronha L, Herald T, Bean S, Lee S-H, Perumal R, et al. Evaluation of ethanol-based extraction conditions of sorghum bran bioactive compounds with downstream anti-proliferative properties in human cancer cells. Heliyon. 2019;5(5). DOI: https://doi.org/10.1016/j.heliyon.2019.e01589.

39. Chen X-X, Wu X-B, Chai W-M, Feng H-L, Shi Y, Zhou H-T, et al. Optimization of extraction of phenolics from leaves of Ficus virens. Journal of Zhejiang University: Science B. 2013;14(10):903–915. DOI: https://doi:10.1631/jzus.b1200365.

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