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Short communication

The phenolic compound content in plants of the family Ericaceae under cryolithozone conditions

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Abstract. The content of phenolic compounds in the fruits of various plant species of the family Ericaceae, collected on the territory of the Republic of Sakha (Yakutia) during the fruiting period in July–August, was studied. The study confirms that plants growing in permafrost conditions accumulate large amounts of phenolic compounds. As a result of phytochemical analysis, it was found that the most valuable plant raw material in terms of content of phenolic compounds is *Vaccinium uliginosum*.

Keywords: *Vaccinium vitis-idaea, Vaccinium uliginosum, Arctostaphylos uva-ursi*, arbutin, extractives, flavonoids, tannins, Yakutia

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Краткое сообщение

Содержание фенольных соединений в растениях семейства Ericaceae в условиях криолитозоны

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Аннотация. Изучено содержание фенольных соединений в плодах различных видов растений семейства Ericaceae, собранных на территории Республики Саха (Якутия) в период плодоношения в июле – августе. Исследование подтверждает, что растения, произрастающие в условиях криолитозоны, накапливают большое количество фенольных соединений. В результате фитохимического анализа установлено, что наиболее ценным растительным сырьем по содержанию фенольных соединений является *Vaccinium uliginosum*.

Ключевые слова: *Vaccinium vitis-idaea, Vaccinium uliginosum, Arctostaphylos uva-ursi*, арбутин, экстрактивные вещества, флавоноиды, дубильные вещества, Якутия

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Introduction

Representatives of the family Ericaceae and their processed products are successfully used as functional foods and nutraceuticals. To a certain extent, many of the medicinal properties of fruit and berry plants are due to the accumulation of phenolic compounds (Ershova, 2016). It is known that local climate and seasonal changes, as well as other external factors, affect the chemical composition of plants used in medicine (Borisov and Nogovitsyn, 2019), and the adaptation of plants to changing environmental environmental conditions leads to an increase in the accumulation of biologically active substances with antioxidant properties in their tissues (Popova et al., 2008). The use of plant resources as raw materials and the study of mechanisms of adaptation and use of phenolic compounds for medicinal purposes are of great interest due to the unique flora of Yakutia and its great introduction potential.

Common lingonberry (*Vaccinium vitis-idaea* L.) grows in all floristic regions of Yakutia in light-coniferous or mixed forests and woodlands, dwarf birch thickets, and mountain tundra (Afanasieva, 2020).

Lingonberries contain polyphenols such as flavonoids, polyphenolic acids, organic acids, vitamins (A, B_1, B_2, B_3 and C), potassium, calcium, magnesium and phosphorus (Dróżdż et al., 2018; Ek, 2006; Kowalska et al., 2019). Derivatives of ferulic and coumaric acids and caffeoylquinine from the group of phenolic acids were found in lingonberry fruits (Ek, 2006; Kowalska et al., 2019). In addition, flavonoids such as quercetin and its glycosylated derivatives, as well as two flavonols identified as catechin and epicatechin, were found in the berries (Kowalska et al., 2019).

Lingonberries are widely used in folk medicine as a diuretic, for scurvy, to strengthen the body during colds, gout, rheumatism, and gastritis, as well as to improve immunity in general. In official medicine, various forms of lingonberries are currently used: tinctures, syrups, extracts and powders, as well as dietary supplements (Lyutikova, 2013).

Common blueberry (*Vaccinium uliginosum* L.) is widely distributed throughout the Republic of Sakha. It is found in swampy coniferous forests and woodlands, in thickets of bushes, mountain and lowland tundra, on the outskirts of swamps, and ice glades (Afanasieva, 2020).

Blueberries contain benzoic, malic, citric, oxalic, tartaric, ascorbic, salicylic acids, tannins, and glycosides: malvidin, delphinidin, cyanidin. The composition of blueberry fruits is characterized by a high level of vitamins C, K, E (Kurlovich, 2014). Berries contain a large amount of water, carbohydrates (glucose, fructose, sucrose), proteins, fiber, pectin, organic acids and a significant amount of macro- and microelements (Cherkasov et al., 1999).

Blueberry fruits have antidiabetic, anti-inflammatory, antitumor, antiscorbutic, diuretic, choleretic, cardiotonic, antifungal and anthelmintic effects. Berries normalize metabolism, reduce blood sugar levels, strengthen the walls of blood capillaries, and normalize the functioning of the intestines and pancreas (Dikorastushchie..., 2001).

The common bearberry (*Arctostaphylos uva-ursi* L.) is found in all floristic regions of Yakutia, except for the Arctic and Kolyma. *A. uva-ursi* is a light-loving plant. It is found at the edges of dry pine, less often larch, forests (Afanasieva, 2020).

Bearberry contains tannins of the pyrogall group – ellagitannins and gallotannins, in particular the biologically active ellagitannin corilagin (Kurkin et al., 2015). The main active ingredients of bearberry are phenolic glycosides: arbutin, methylarbutin, pyrozide, caffeoylarbutin. In addition, the chemical profile of bearberry is characterized by the presence of ursolic, tannic, gallic, paracoumaric and syringic acids and galloylarbutin (Olennikov and Chekhirova, 2013; Ștefănescu et al., 2019).

Arctostaphylos uva-ursi has a strong astringent effect, mainly due to the presence of glycosides. Bearberry is widely used in the treatment of kidney, bladder and urinary tract diseases (Radulovic, 2010).

The purpose of the work is to study the quantitative composition of phenolic compounds in the fruits of plants of the family Ericaceae growing in Yakutia.

Materials and methods

The objects of the study are the fruits of *Vaccinium vitis-idaea*, *Vaccinium uliginosum*, and *Arctostaphylos uva-ursi*. Samples of plant materials were collected in July–August in Central Yakutia: lingonberry and bearberry fruits – in the vicinity of the city of Yakutsk (N 62°3'40" E 129°31'20"), blueberries – in the vicinity of the village of Magaras, Mountain region (N 62°8'52" E 128°3'41") during fruiting. Permafrost rocks are developed on the territory of Yakutia. The place where plant samples were collected is characterized by a strongly continental climate with large seasonal temperature fluctuations. According to long-term data, the average annual air temperature in Yakutsk is −10.2 °C. The average temperature in January is −42.7 °C, in July – +18.7 °C. The absolute minimum in the Mountainous

Region is −65 °C, and the maximum is +37 °C. Mean January temperature: −36... −40 °C, July: +16... +17 °C (Prisyazhnyi, 2003).

Collection, drying and storage of plant materials were carried out in accordance with pharmacopoeial requirements (Gosuderstvennaya Farmakopeya RF, 2015).

Metabolomic analysis was carried out using spectrophotometric, titrimetric and gravimetric methods. Determination of the quantitative content of the total phenolic compounds in the studied objects was carried out using the Folin-Ciocalteu reagent (Singleton et al., 1999). The quantitative content of flavonoids was assessed in terms of the concentration of rutin in the fruits of the studied plants. The content of extractives and tannins was carried out according to standard methods (Gosuderstvennaya Farmakopeya RF, 2015).

Results and discussion

The indicator "content of extractive substances" characterizes the content of the entire amount of biologically active substances in medicinal plant raw materials. The fruits of *Vaccinium vitis-idaea* contain a high level of water-soluble extractives. Most likely, this is due to the content of water-soluble components in fruits (monosaccharides, soluble polysaccharides) (Yudina and Maksimova, 1993). The fruits of *Arctostaphylos uva-ursi* and *Vaccinium uliginosum*, on the contrary, are rich in lipophilic biologically active substances (fat-soluble vitamins, waxes, phospholipids) (Tarantul and Eliseeva, 2020), which leads to a decrease in the yield of extractives (Table 1).

The fruits of *Vaccinium vitis-idaea* and *Vaccinium uliginosum* have the highest content of phenolic compounds; their content in the fruits of *Arctostaphylos uva-ursi* is significantly lower (Table 1). This is presumably because lingonberries and blueberries have a much greater diversity of phenolic compounds than bearberries (Ek, 2006; Lin and Harnly, 2007). According to a study of the fruits of *Vaccinium vitis-idaea* and *Vaccinium uliginosum* growing on the territory of Yugra, the content of phenolic compounds is 16.3 ± 1.7 and 25.5 ± 0.9 mg/g, respectively (Belova et al., 2020), which is lower than our results.

The highest content of flavonoids was recorded in the berries of *Vaccinium uliginosum*, and the lowest in the fruits of *Arctostaphylos uva-ursi* (Table 1). According to phytochemical studies of the berries of plants growing in Nizhny Novgorod, the fruits of *Vaccinium uliginosum* accumulate less flavonoids – about 1.34 mg/g (Pavlova et al., 2012).\

Blueberry and lingonberry fruits release more tannins than bearberry (Table 2).

The arbutin content increases in the order *Arctostaphylos uva-ursi* – *Vaccinium vitis-idaea* – *Vaccinium uliginosum*. High levels of arbutin in plants may be associated with adaptation to stressful conditions, such as Arctic low temperatures or drought stress (Panusa et al., 2015).

Thus, the study demonstrates that the fruits of plants from the family Ericaceae growing in Yakutia have a significant amount of phenolic compounds with antioxidant properties. Presumably this can be explained by the activation of oxidative stress under the influence of low temperatures.

Table 1. Extractivity and quantitative content of organic compounds in the studied plants (for absolutely dry raw materials).

Plant species	Content of extractive substances, %	Content of phenolic compounds, mg/g	Flavonoid content, mg/g
Vaccinium vitis-idaea	94.51 ± 2.78	73.14 ± 0.41	0.91 ± 0.08
Vaccinium uliginosum	50.13 ± 0.87	62.38 ± 0.17	6.85 ± 0.19
Arctostaphylos uva-ursi	44.00 ± 0.86	20.34 ± 0.28	0.32 ± 0.07

Table 2. Quantitative content of tannins and arbutin in the studied plants (for absolutely dry raw materials).

Plant species	Tannins content, %	Arbutin content, mg/g
Vaccinium vitis-idaea	8.31 ± 0.34	24.22 ± 0.18
Vaccinium uliginosum	8.87 ± 0.22	58.51 ± 0.31
Arctostaphylos uva-ursi	3.33 ± 0.18	9.24 ± 0.08

Conclusions

The content of phenolic compounds in the fruits of various plant species of the family Ericaceae growing on the territory of the Republic of Sakha (Yakutia) was studied.

The extractivity in the aqueous extract of the studied plants varied from 44.00 ± 0.86% in the fruits of *Arctostaphylos uva-ursi* to 94.51 ± 2.78% in *Vaccinium vitis-idaea*.

The highest content of phenolic compounds in aqueous extracts was observed in the fruits of *Vaccinium vitis-idaea* (73.14 ± 0.41 mg/g), the highest content of flavonoids (6.85 ± 0.19 mg/g) and tannins (8.87 ± 0.22%) was found in the berries of *Vaccinium uliginosum*. The quantitative content of arbutin in aqueous extracts of representatives of the family Ericaceae increases in the order *Arctostaphylos uva-ursi* (9.24 ± 0.08 mg/g) – *Vaccinium vitis-idaea* (24.22 ± 0.18 mg/g) – *Vaccinium uliginosum* (58.51 ± 0.31 mg/g). Thus, *Vaccinium uliginosum* can be considered the most valuable local plant raw material in terms of its content of phenolic compounds.

References

Afanasiyeva, E.A., 2020. Opredelitel' vysshikh rasteniy Yakutii [Key to higher plants of Yakutia]. KMK Scientific Press Ltd, Moscow, Russia, 896 p. (In Russian).

Belova, E.A., Krivykh, E.A., Kavushevskaya, N.S., Bystrevskaya, L.K., Zhautikova, S.B., 2020. Tsitoprotektornyi potentsial polifenol'nykh ekstraktov plodov roda *Vaccinium*, proizrastaiushchikh na territorii Iugry, v usloviiakh *in vitro* [Cytoprotective potential of polyphenolic extracts of fruits of the genus *Vaccinium* growing on the territory of Ugra under *in vitro* conditions]. *Vestnik SurGU. Meditsina [Bulletin of Surgut State University. Medicine]* **1** (43), 86–93. (In Russian).

Borisov, V.E., Nogovitsyn, R.R., 2019. Osobennosti prirodno-klimaticheskikh faktorov dlya sozdaniya novykh biotekhnologicheskikh proizvodstv v respublike Sakha (Yakutiya) [Features of natural and climatic factors for the creation of new biotechnological production in the Republic of Sakha (Yakutia)]. *Materialy Mezhdunarodnoi nauchno-prakticheskoi konferentsii "Resursnaia ekonomika v kontekste sovremennykh tendentsii globalizatsii" [Proceedings of the International Scientific and Practical Conference "Resursnaya ekonomika v kontekste sovremennykh tendentsiy globalizatsii"], Yakutsk, 22–23.03.2019.* Yakutsk, Russia, 67–73. (In Russian).

Cherkasov, A.F., Gorbunov, A.B., Tyak, G.V., Makeyev, V.A., Levgerova, N.S., 1999. Klyukva, brusnika i golubika [Cranberries, lingonberries and blueberries]. In: Sedov, E.N. and Ogoltsova, T.P. (eds.), *Programma i metodika sortoizucheniya plodovykh, yagodnykh i orekhoplodnykh kul'tur [Program and methodology for studying varieties of fruit, berry and nut crops].* All-Russian Research Institute for Breeding Fruit Crops, Orel, Russia, 481–492 (In Russian).

Dikorastushchiye poleznyye rasteniya Rossii [Wild useful plants of Russia], 2001. Budantsev, A.L. and Lesiovskaya, E.E. (eds.). Saint Petersburg State Chemical and Pharmaceutical University, St. Petersburg, Russia, 663 p. (In Russian).

Dróżdż, P., Šėžienė, V., Wójcik, J., Pyrzyńska, K., 2018. Evaluation of bioactive compounds, minerals and antioxidant activity of lingonberry (*Vaccinium vitis-idaea* L.) fruits. *Molecules* **23** (1), 53. https://doi.org/10.3390/molecules23010053

Ek, S., 2006. Characterization of phenolic compounds from lingonberry (*Vaccinium vitis-idaea*). *Journal of Agricultural and Food Chemistry* **54** (26), 9834–9842.

Ershova, I.V., 2016. Soderzhaniye biologicheski aktivnykh fenol'nykh soyedineniy v sibirskikh plodakh i yagodakh [Content of biologically active phenolic compounds in Siberian fruits and berries]. *Dostizheniya nauki i tekhniki APK [Achievements of Science and Technology of the Agro-Industrial Complex]* **30** (9), 44–47. (In Russian).

Gosudarstvennaya farmakopeya Rossiyskoy Federatsii. XIII izdanie [State Pharmacopoeia of the Russian Federation. XIII edition], 2015. Ministry of Health of the Russian Federation, Moscow, Russia, 1470 p. (In Russian).

Kowalska, K., Olejnik, A., Zielińska-Wasielica, J., Olkowicz, M., 2019. Inhibitory effects of lingonberry (*Vaccinium vitis-idaea* L.) fruit extract on obesity-induced inflammation in 3T3-L1 adipocytes and RAW 264.7 macrophages. *Journal of Functional Foods* **54**, 371–380. https://doi.org/10.1016/j.jff.2019.01.040

Kurkin, V.A., Ryazanova, T.K., Platonov, I.A., Pavlova, L.V., 2015. Kolichestvennoye opredeleniye arbutina v list'yakh toloknyanki obyknovennoy [Quantitative determination of arbutin in bearberry leaves]. *Khimiya rastitel'nogo syr'ya [Chemistry of Plant Materials]* **1**, 95–100. (In Russian).

Kurlovich, T.V., 2014. Golubika vysokoroslaya: biologicheskiye osobennosti i lekarstvennyye svoystva [Highbush blueberry: biological features and medicinal properties]. *Materialy III Mezhdunarodnoi nauchno-prakticheskoi konferentsii "Lekarstvennoe rastenievodstvo: ot opyta proshlogo do sovremennykh tekhnologii" [Materials of the III International Scientific and Practical Conference "Lekarstvennoye rasteniyevodstvo: ot opyta proshlogo do sovremennykh tekhnologiy"]. Poltava, 15–16.05.2014*, Poltava, Ukraine, 122–125. (In Russian).

Lin, L.-Z., Harnly, J.M., 2007. A screening method for the identification of glycosylated flavonoids and other phenolic compounds using a standard analytical approach for all plant materials. *Journal of Agricultural and Food Chemistry* **55** (4), 1084–1096. https://doi.org/10.1021/jf062431s

Lyutikova, M.N., 2013. Study of the composition of biologically active components of wild berries *Vaccinium vitis-idaea* and *Oxycoccus palustris* depending on their degree of maturity and storage conditions [Izucheniye sostava biologicheski aktivnykh komponentov dikorastushchikh yagod *Vaccinium vitis-idaea* i *Oxycoccus palustris* v zavisimosti ot stepeni ikh zrelosti i usloviy khraneniya]. *PhD in Chemistry thesis.* Surgut, Russia, 124 p. (In Russian).

Olennikov, D.N., Chekhirova, G.V., 2013. 6″-Galloylpicein and other phenolic compounds from *Arctostaphylos uva-ursi*. *Chemistry of Natural Compounds* **49** (1), 1–7. https://doi.org/10.1007/s10600-013-0491-6

Panusa, A., Petrucci, R., Marrosu, G., Multari, G., Gallo, F.R., 2015. UHPLC-PDA-ESI-TOF/MS metabolic profiling of *Arctostaphylos pungens* and *Arctostaphylos uva-ursi*. A comparative study of phenolic compounds from leaf methanolic extracts. *Phytochemistry* **115**, 79–88. https://doi.org/10.1016/j.phytochem.2015.01.002

Pavlova, E.E., Berezina, E.V., Mishukova, I.V., Brilkina, A.A., 2012. Analiz soderzhaniia fenol'nykh soedinenii i askorbinovoi kisloty u razlichnykh vidov golubiki (*Vaccinium* L.) v periody tsveteniia i plodonosheniia [Analysis of the content of phenolic compounds and ascorbic acid in various blueberry species (*Vaccinium* L.) during flowering and fruiting]. *Vestnik Nizhegorodskogo universiteta im. N.I. Lobachevskogo [Bulletin of Nizhny Novgorod University named after N.I. Lobachevsky]* **2** (3), 222–229. (In Russian).

Popova, A.S., Mironova, G.E., Argunov, V.A., 2008. Antioksidantnyye sistemy zashchity organizmov i biotekhnologicheskiye puti korrektsii ikh narusheniy v usloviyakh severa [Antioxidant systems for protecting organisms and biotechnological ways to correct their violations in northern conditions]. Publishing House of the Yakut Scientific Centre of the Siberian Branch RAS, Yakutsk, Russia, 128 p. (In Russian).

Prisyazhnyy, M.Yu., 2003. Geograficheskiye osnovaniya razvitiya otdel'nykh chastey Yakutii v kratkikh opisaniyakh ulusov, naslegov i naselennykh mest respubliki [Geographical basis for the development of individual parts of Yakutia in brief descriptions of uluses, naslegs and populated areas of the republic]. Sakhapoligrafizdat, Yakutsk, Russia, 696 p. (In Russian).

Radulovic, N., 2010. Comparative study of the leaf volatiles of *Arctostaphylos uva-ursi* (L.) Spreng. and *Vaccinium vitis-idaea* L. (Ericaceae). *Molecules* **15** (9), 6168–6185. https://doi.org/10.3390/molecules15096168

Singleton, V.L., Orthofer, R., Lamuela-Raventós, R.M., 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods in Enzymology* **299**, 152–178. https://doi.org/10.1016/S0076-6879(99)99017-1

Ștefănescu, B.E., Szabo, K., Mocan, A., Crişan, G., 2019. Phenolic compounds from five Ericaceae species leaves and their related bioavailability and health benefits. *Molecules* **24** (11), 2046. https://doi.org/10.3390/molecules24112046

Tarantul, A., Eliseeva, T., 2020. Golubika (lat. *Vaccinium uliginosum*) [Blueberry (lat. *Vaccinium uliginosum*)]. *Zhurnal zdorovogo pitaniia i dietologii [Journal of Healthy Eating and Dietetics]* **13**, 14–25. (In Russian). https://doi.org/10.59316/.vi13.80

Yudina, V.F., Maksimova, T.A., 1993. Sezonnoye razvitiye rasteniy bolot [Seasonal development of swamp plants]. Karelian Research Center RAS, Petrozavodsk, Russia, 168 p. (In Russian).

Список литературы

Афанасьева, Е.А., 2020. Определитель высших растений Якутии. Товарищество научных изданий КМК, Москва, Россия, 896 с.

Белова, Е.А., Кривых, Е.А., Кавушевская, Н.С., Быстревская, Л.К., Жаутикова, С.Б., 2020. Цитопротекторный потенциал полифенольных экстрактов плодов рода *Vaccinium*, произрастающих на территории Югры, в условиях *in vitro*. *Вестник СурГУ. Медицина* **1** (43), 86–93.

Борисов, В.Е., Ноговицын, Р.Р., 2019. Особенности природно-климатических факторов для создания новых биотехнологических производств в Республике Саха (Якутия). *Материалы Международной научно-практической конференции «Ресурсная экономика в контексте современных тенденций глобализации», Якутск, 22–23.03.2019.* Якутск, Россия, 67–73.

Государственная фармакопея Российской Федерации. XIII издание, 2015. Минздрав России, Москва, Россия, 1470 с.

Дикорастущие полезные растения России, 2001. Буданцев, А.Л. и Лесиовская, Е.Е. (ред.). СПХФА, Санкт-Петербург, Россия, 663 р.

Ершова, И.В., 2016. Содержание биологически активных фенольных соединений в сибирских плодах и ягодах. *Достижения науки и техники АПК* **30** (9), 44–47.

Куркин, В.А., Рязанова, Т.К., Платонов, И.А., Павлова, Л.В., 2015. Количественное определение арбутина в листьях толокнянки обыкновенной. *Химия растительного сырья* **1**, 95–100.

Курлович, Т.В., 2014. Голубика высокорослая: биологические особенности и лекарственные свойства. *Материалы III Международной научно-практической конференции «Лекарственное растениеводство: от опыта прошлого до современных технологий», Полтава, 15–16.05.2014.* Полтава, Украина, 122–126.

Лютикова, М.Н., 2013. Изучение состава биологически активных компонентов дикорастущих ягод *Vaccinium vitis-idaea* и *Oxycoccus palustris* в зависимости от степени их зрелости и условий хранения. *Диссертация на соискание ученой степени кандидата химических наук.* Сургут, Россия, 124 с.

Павлова, Е.Е., Березина, Е.В., Мишукова, И.В., Брилкина, А.А., 2012. Анализ содержания фенольных соединений и аскорбиновой кислоты у различных видов голубики (*Vaccinium* L.) в периоды цветения и плодоношения. *Вестник Нижегородского университета им. Н.И. Лобачевского* **2** (3), 222–229.

Попова, А.С., Миронова, Г.Е., Аргунов, В.А., 2008. Антиоксидантные системы защиты организмов и биотехнологические пути коррекции их нарушений в условиях севера. Издательство ЯНЦ СО РАН, Якутск, Россия, 128 с.

Присяжный, М.Ю., 2003. Географические основания развития отдельных частей Якутии в кратких описаниях улусов, наслегов и населенных мест республики. Сахаполиграфиздат, Якутск, Россия, 696 с.

Тарантул, А., Елисеева, Т., 2020. Голубика (лат. *Vaccínium uliginósum*). *Журнал здорового питания и диетологии* **13**, 14–25. https://doi.org/10.59316/.vi13.80

Черкасов, А.Ф., Горбунов, А.Б., Тяк, Г.В., Макеев, В.А., Левгерова, Н.С., 1999. Клюква, брусника и голубика. В: Седов, Е.Н., Огольцова, Т.П. (ред.), *Программа и методика сортоизучения плодовых, ягодных и орехоплодных культур.* ВНИИСПК, Орел, Россия, 481–492.

Юдина, В.Ф., Максимова, Т.А., 1993. Сезонное развитие растений болот. КарНЦ РАН, Петрозаводск, Россия, 168 с.

Dróżdż, P., Šėžienė, V., Wójcik, J., Pyrzyńska, K., 2018. Evaluation of bioactive compounds, minerals and antioxidant activity of lingonberry (*Vaccinium vitis-idaea* L.) fruits. *Molecules* **23** (1), 53. https://doi.org/10.3390/molecules23010053.

Ek, S., 2006. Characterization of phenolic compounds from lingonberry (*Vaccinium vitis-idaea*). *Journal of Agricultural and Food Chemistry* **54** (26), 9834–9842.

Kowalska, K., Olejnik, A., Zielińska-Wasielica, J., Olkowicz, M., 2019. Inhibitory effects of lingonberry (*Vaccinium vitis-idaea* L.) fruit extract on obesity-induced inflammation in 3T3-L1 adipocytes and RAW 264.7 macrophages. *Journal of Functional Foods* **54**, 371–380. https://doi.org/10.1016/j.jff.2019.01.040

Lin, L.-Z., Harnly, J.M., 2007. A screening method for the identification of glycosylated flavonoids and other phenolic compounds using a standard analytical approach for all plant materials. *Journal of Agricultural and Food Chemistry* **55** (4), 1084–1096. https://doi.org/10.1021/jf062431s

Olennikov, D.N., Chekhirova, G.V., 2013. 6″-Galloylpicein and other phenolic compounds from *Arctostaphylos uva-ursi*. *Chemistry of Natural Compounds* **49** (1), 1–7. https://doi.org/10.1007/s10600-013-0491-6

Panusa, A., Petrucci, R., Marrosu, G., Multari, G., Gallo, F.R., 2015. UHPLC-PDA-ESI-TOF/MS metabolic profiling of *Arctostaphylos pungens* and *Arctostaphylos uva-ursi*. A comparative study of phenolic compounds from leaf methanolic extracts. *Phytochemistry* **115**, 79–88. https://doi.org/10.1016/j.phytochem.2015.01.002

Radulovic, N., 2010. Comparative study of the leaf volatiles of *Arctostaphylos uva-ursi* (L.) Spreng. and *Vaccinium vitis-idaea* L. (Ericaceae). *Molecules* **15** (9), 6168–6185. https://doi.org/10.3390/molecules15096168

Singleton, V.L., Orthofer, R., Lamuela-Raventós, R.M., 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods in Enzymology* **299**, 152–178. https://doi.org/10.1016/S0076-6879(99)99017-1

Ştefănescu, B.E., Szabo, K., Mocan, A., Crişan, G., 2019. Phenolic compounds from five Ericaceae species leaves and their related bioavailability and health benefits. *Molecules* **24** (11), 2046. https://doi.org/10.3390/molecules24112046