

There was a significant correlation established only between the antioxidant activity and the total phenolic content ($r=0.886$).

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RESEARCH ON THE MINERAL COMPOSITION OF AMERICAN CRANBERRIES AND WILD CRANBERRIES IN LATVIA AMERIKAS LIELOGU UN SAVVAĻAS DZĒRVEŅU OGU MINERĀLĀ SASTĀVA SALĪDZINOŠS IZVĒRTĒJUMS

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Abstract

Wild cranberry (*Vaccinium oxycoccus* L.) is one of the small fruit species of commercial importance in Latvia, traditionally used in folk-medicine and food. Typically, there are wide fluctuations in yield annually and between different parts of the country. The commercial cultivation of American cranberry (*Vaccinium macrocarpon* Ait.) was successfully started during last 15 years and today Latvia is the fourth major cranberries producing country. With the increase in consumption of cranberries, widely considered being as one of the healthiest foods, it becomes important to have detailed information on the nutritional content of cranberries. The aim of this study was to compare the contents of twelve biologically essential elements (N, P, K, Ca, Mg, S,

Fe, Mn, Zn, Cu, Mo, B) in berries of two *Vaccinium* species: *V. oxycoccus* and *V. macrocarpon*. Together 78 (leaf and berry) samples were collected from 4 main cranberry producing sites and 3 native bogs during autumn 2004.

The present study revealed significant differences in the mineral composition of *V. oxycoccus* and *V. macrocarpon*. Cultivated cranberry fruits had a higher content of P and Fe while wild cranberries showed higher levels of Ca, Mg, Mn, Zn, Cu and B. Plant leaf analysis revealed organ-specific distribution of mineral elements in both cranberries studied. The present study shows that fruits of both *V. macrocarpon* and *V. oxycoccus* are a valuable source of the microelements: Mn, Fe, Cu, Mo, and B in human nutrition. Since the wild cranberry has a especially high concentrations of Mn, 100 g of fresh berries could supply 121% of the adult daily requirement.

Kopsavilkums

Savvaļas dzērvenes (*Vaccinium oxycoccus* L.) ir Latvijā augoša ogu suga, kuru tradicionāli izmanto pārtikā un tautas medicīnā. Raksturīgi, ka savvaļas dzērveņu ražas lielums ievērojami atšķiras gadu no gada, kā arī variē dažādās Latvijas vietās. Pēdējos 15 gados uzsākta Latvijā Amerikas lielogu dzērveņu (*Vaccinium macrocarpon* Ait.) kultivēšana un šobrīd Latvija ir ceturta lielākā Amerikas lielogu dzērveņu ražojošā valsts pasaulē. Palielinoties dzērveņu, kā īpaši veselīga produkta, patēriņam ir svarīgi gūt pēc iespējas pilnīgāku priekšstatu par šo ogu minerālo sastāvu. Šī pētījuma mērķis bija salīdzināt divas *Vaccinium* ģints sugas *V. oxycoccus* un *V. macrocarpon* pēc 12 biogēno elementu (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B) satura ogās. 2004 gada rudenī tika ievākti 78 lapu un ogu paraugi četrās ražojošās saimniecībās un trīs dabiskos purvos Latvijā.

Pētījumā tika konstatētas ievērojamas atšķirības savvaļas un Amerikas lielogu dzērveņu ogu minerālajās sastāvā. Kultivēto dzērveņu ogās bija augstāks P un Fe, bet savvaļas dzērvenēs augstāks Ca, Mg, Mn, Zn, Cu un B līmenis. Pētījums apstiprina, ka *V. oxycoccus* un *V. macrocarpon* ogas ir vērtīgs mikroelementu Mn, Fe, Cu, Mo un B avots cilvēka pārtikā. Jāatzīmē īpaši augsts mangāna saturs, 100 g svaigas ogas nodrošina 121 % no pieauguša cilvēka nepieciešamās Mn diennakts devas.

Key words: *Vaccinium oxycoccus* L., *Vaccinium macrocarpon* Ait., fruit mineral composition

Introduction

Wild cranberry (*Vaccinium oxycoccus* L.) is one of the small fruit species of commercial importance in Latvia, traditionally used in folk-medicine and food. Typically, there are wide fluctuations in yield annually and between different parts of the country (Ripa 1988; Yudina 1988). The yield of *V. oxycoccus* ranges from a few kilograms to 1000 kg ha⁻¹ (from 5 to 100 berries m²) (Cherkasov, 1988; Ripa, 1988; Yudina, 1988). *Vaccinium oxycoccus* usually is found on acid soils with humus type peat, dismoder or mor, and all the soils are poor in nutrients (Stewart and Nilsen, 1993; Schaminee *et al.*, 1995).

The commercial cultivation of the American cranberry (*Vaccinium macrocarpon* Ait.) was started only during last 15 years and is one of the youngest branches of agriculture in Latvia with a high potential in country's economical and ecological future. Today with more than 100 ha of commercial plantings Latvia is the fourth major cranberry producing country in the world. American cranberry producing plantings are mostly developed in high bog territories. *V. macrocarpon*, fruit indigenous to North America, are characterized as high yielding crop with significantly higher productivity (to 40 t ha⁻¹) in comparison with the wild cranberry (Karlsone and Osvalde, 2007).

Cranberries are valued for their fresh taste, high dietary and health values, as well as their great potential for being processed. Cranberry juice, sugared fruits, raisins, and other products have become increasingly popular in Latvia. A growing body of research suggests that the cranberry is a relatively unique fruit which accumulates one of the highest concentrations of phenolic compounds among fruit species with demonstrable human health benefits (Vinson *et al.*, 2001; Leahy *et al.*, 2002; Howell *et al.*, 2005). Cranberries are a good source of anthocyanins and their antioxidants, which plays a vital role in the prevention of neuronal and cardiovascular illnesses, cancer and diabetes (Konczak and Zhang, 2004). There are several reports focused on the effect of anthocyanins in cancer treatments (Castaneda-Ovando *et al.*, 2008; Lule and Xia, 2005;

Nichenametla *et al.*, 2006), human nutrition (Stintzing and Carle, 2004), and its biological activity (Kong *et al.*, 2003).

Increased consumption of fruits and vegetables can help replace foods high in saturated fats, sugar and salt and thus improve the intake of most micronutrients and dietary fibre (Ekholm *et al.*, 2007). Daily consumption of fresh fruits and vegetables (>400 g·d⁻¹) is recommended to help prevent major non-communicable diseases such as cardiovascular diseases and certain cancers (WHO, 2003). Thus the chemical composition of *Vaccinium spp.* has important implications for human health. Many minerals are essential for normal metabolic functions and are required components in a balanced diet (Grusak and DellaPenna, 1999).

The mineral element contents of plants are known to be affected by the species and cultivar of the plant, soil conditions, weather conditions, the use of fertilizers and the state of the plants maturity at harvest (Pietola and Salo, 2000; Bálint *et al.*, 2001).

The aim of this study was to compare the contents of twelve biologically essential elements (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B) in berries of two *Vaccinium* species: *V. oxycoccus* and *V. macrocarpon*.

Materials and methods

The study was carried out on the wild cranberry (*V. oxycoccus*) and the American cranberry (*V. macrocarpon*) crops in different regions of Latvia. Together 78 (leaf and berry) samples were collected from 4 main cranberry producing sites (Aluksne, Talsu, Madonas and Riga district) and 3 native bogs (Riga, Jelgava and Saldus district) during autumn 2004.

For each leaf sample 200 current season upright tips and for the berry sample about 400g of cranberry berries were collected from locations representative of the planting. The leaf and berry material was oven-dried at 60 °C and ground. Then the samples were dry-ashed in concentrated HNO₃ vapours and re-dissolved in HCl solution (HCl - distilled water mixture 3:100) (Rinkis *et al.*, 1987).

Concentrations of 12 biogenous elements (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B) were determined in all berry and leaf samples. The levels of Ca, Mg, Fe, Cu, Zn, and Mn were estimated by atomic absorption spectrophotometer (Perkin Elmer AAnalyst 700, acetylene-air flame), those of N, P, Mo, B by colorimetry, S by turbidimetry, and K by flame photometer (Jenway PFP7, air-propane butane flame).

The mineral element content in the berries was expressed as mg·100g⁻¹ fresh fruit. All chemical analyses were done in the Laboratory of plant mineral nutrition of the Institute of Biology, University of Latvia. The levels of statistical significance were determined with MS Excel 2003. T-test “Two-Sample Assuming Unequal Variances” (p<0.05) was used to compare the mean element concentrations in *V. oxycoccus* and *V. macrocarpon* fruits and leaves.

Results and Discussion

To characterize the mineral content of cultivated and wild cranberries, the levels of 12 biologically essential elements were estimated. Mean macro- and micronutrient concentrations, as well as the concentration range are shown in Table 1.

A comparison of two species studied showed similar concentrations for the macronutrients N, K and S in the cranberries. Statistically significant differences (p < 0.05) were noted for Ca, Mg and P. The data indicated that nitrogen and potassium were the major mineral constituents in the both cranberry species tested. The richest source of Ca and Mg (on average, 13.1 and 7.8 mg·100g⁻¹ fresh fruit) in this study was *V. oxycoccus*, while highest P (9.1 mg 100 g⁻¹ fresh fruit) contents were found in *V. macrocarpon* fruits.

Table 1. Nutrient concentrations in cranberry berry samples from producing plantings (Aluksne, Talsu, Madonas and Riga district) and woodlands (Riga, Jelgava and Saldus district) in Latvia.

Element	<i>V. macrocarpon</i>		<i>V. oxycoccus</i>	
	Range	Mean ± SE	Range	Mean ± SE
Macroelements (mg·100g ⁻¹ fresh berries)				
N	10.4 – 65.0	40.3 ± 3.38 a ¹	13.0 – 78.0	35.1 ± 9.36 a
P	6.5 – 11.7	9.1 ± 0.26 a	6.5 – 7.8	6.5 ± 0.13 b
K	52.0 – 98.8	79.3 ± 2.08 a	78.0 – 93.6	81.9 ± 1.82 a
Ca	7.8 – 14.3	10.4 ± 0.39 a	9.1 – 18.2	13.0 ± 1.30 b
Mg	5.2 – 9.1	6.5 ± 0.13 a	7.8 – 9.1	7.8 ± 0.13 b
S	5.2 – 14.3	9.1 ± 0.39 a	6.5 – 18.2	11.7 ± 1.43 a
Microelements (mg·100g ⁻¹ fresh berries)				
Fe	0.22 – 1.17	0.51 ± 0.049 a	0.33 – 0.42	0.36 ± 0.010 b
Mn	0.06 – 0.57	0.21 ± 0.005 a	2.18 – 3.95	2.78 ± 0.194 b
Zn	0.07 – 0.17	0.12 ± 0.005 a	0.14 – 0.19	0.16 ± 0.007 b
Cu	0.04 – 0.08	0.05 ± 0.002 a	0.06 – 0.08	0.07 ± 0.002b
Mo	0.01 – 0.02	0.01 ± 0.001 a	0.01 – 0.02	0.01 ± 0.001 a
B	0.03 – 0.12	0.07 ± 0.005 a	0.10 – 0.17	0.13 ± 0.008 b

¹Means with different letters in a row were significantly different (t-Test, p < 0.05)

Statistically significant differences (p<0.05) were found in the micronutrients (except Mo) composition of wild and cultivated cranberries.

The highest mean concentration of Fe (0.51 mg 100 g⁻¹ fresh fruit) were found in the American cranberry, while the highest Mn, Zn, Cu and B (on average, 2.78, 0.16, 0.07 and 0.13 mg 100 g⁻¹ fresh fruit, respectively) concentrations were found in the wild cranberry. Plant leaf analysis revealed organ-specific distribution of mineral elements in both cranberries studied (Table 2). Statistically significant differences were found between *V. macrocarpon* and *V. oxycoccus* for P, K, Ca, Mg, S, Fe, Mn, Zn and B results in leaf samples.

Table 2. Nutrient concentrations in cranberry leaf samples from producing plantings (Aluksne, Talsu, Madonas and Riga district) and woodlands (Riga, Jelgava and Saldus district) in Latvia.

Element	<i>V. macrocarpon</i>		<i>V. oxycoccus</i>	
	Range	Mean ± SE	Range	Mean ± SE
Macroelements (% dry weight)				
N	0.52 – 0.78	0.66 ± 0.013 a	0.54 – 0.78	0.65 ± 0.032 a
P	0.06 – 0.27	0.12 ± 0.010 a	0.04 – 0.08	0.06 ± 0.005 b
K	0.29 – 0.80	0.56 ± 0.024 a	0.30 – 0.44	0.35 ± 0.013 b
Ca	0.64 – 1.45	0.84 ± 0.033 a	0.50 – 0.75	0.63 ± 0.029 b
Mg	0.15 – 0.29	0.22 ± 0.007 a	0.09 – 0.14	0.12 ± 0.006 b
S	0.06 – 0.17	0.11 ± 0.006 a	0.07 – 0.11	0.09 ± 0.004 b
Microelements (mg·kg ⁻¹ dry weight)				
Fe	25.00 – 132.00	63.10 ± 5.28 a	36.00 – 360.00	137.44 ± 34.456 b
Mn	86.00 – 920.00	282.87 ± 45.60a	820.00 – 2860.00	1583.00 ± 259.850b
Zn	15.00 – 39.00	26.00 ± 1.13 a	28.00 – 50.00	37.67 ± 2.321 b
Cu	2.00 – 21.90	7.89 ± 1.07 a	5.60 – 7.60	6.52 ± 0.194 a
Mo	0.20 – 0.68	0.39 ± 0.03 a	0.25 – 0.50	0.34 ± 0.029 a
B	13.00 – 60.00	35.07 ± 2.16 a	18.00 – 34.00	21.78 ± 1.623 b

¹Means with different letters in a row were significantly different (t-Test, p < 0.05)

The contribution of *V. macrocarpon* and *V. oxycoccus* fruits as a dietary source of mineral elements was estimated from our study results. The potential contribution of 100 g of cultivated and wild cranberries to the Recommended Dietary Allowances (RDA) (USDA RDA chart, 2004) for mineral elements is presented in Table 3.

Table 3. Contribution of 100 g of cranberries to the Recommended Dietary Allowance (RDA) for adults per day.

Element	RDA*, mg	Element concentration mg 100 g ⁻¹ g fresh fruit		% of RDA supplied by 100 g cranberries	
		<i>V. macrocarpon</i>	<i>V. oxycoccus</i>	<i>V. macrocarpon</i>	<i>V. oxycoccus</i>
P	700	9.1	6.5	1.32	0.97
K	2500	79.3	81.9	3.16	3.28
Ca	1000	10.4	13.0	1.07	1.31
Mg	420	6.5	7.8	1.64	1.93
S	850	9.1	11.7	1.06	1.39
Fe	8	0.51	0.36	6.33	4.46
Mn	2.3	0.21	2.78	9.26	120.96
Zn	11	0.12	0.16	1.11	1.49
Cu	0.9	0.05	0.07	6.00	7.67
Mo	0.045	0.01	0.01	8.89	8.89
B	1.5	0.07	0.13	4.73	8.73

* USDA RDA chart (2004)

Wild and cultivated cranberries supply 9.26 % and even 120.96 %, respectively, of the adult daily requirement for Mn. The content of Fe, Cu, Mo, and B in 100 g fresh fruits of both cranberries studied also contributes from 4.46 % to 8.89 % of the daily micronutrient requirement. From macronutrients only K in *V. macrocarpon* and *V. oxycoccus* fruits was found in appreciable amounts (3.16 and 3.28 %, respectively of the RDA). One hundred grams of fresh wild and cultivated cranberries may supply also a few percent of RDA for P, Ca, Mg, S and Zn.

The relationship between food and health becomes increasingly significant as consumers now demand healthy, tasty and natural foods that have been grown in uncontaminated environments. Numerous studies have shown that among horticultural crops fruits are an important source of dietary nutrients, especially with respect to minerals (Grusak and DellaPenna, 1999). Among berry fruits, cranberries are considered to be not only an excellent source of phenolic compounds and vitamins, but also as valuable source of mineral nutrients (Ekholm *et. al.*, 2007).

Our research revealed statistically significant differences between *V. macrocarpon* and *V. oxycoccus* results for P, Ca, Mg, Fe, Mn, Zn, Cu and B in fruit samples and P, K, Ca, Mg, S, Fe, Mn, Zn and B in leaf samples. Nitrogen is the controlling element for American cranberry nutrition and adequate fertilization, in general, is used to maintain renewal growth, crop production, and flower bud development for the next crop (DeMoranville, 1997). However surprisingly similar N concentrations were found in the cultivated American cranberry and wild cranberry leaf samples. It should be stressed that *V. oxycoccus* growing medium – sphagnum peat are especially N poor (Stewart and Nilsen 1993). Our research revealed a considerably higher content of Mn in *V. oxycoccus* leaves (1583.0 mg kg⁻¹) in comparison to American cranberry leaves (282.9 mg kg⁻¹). This phenomenon could be explained by the different pH of the growing substrata for both species studied. Significantly lower pH and consequentially higher availability of Mn in natural high bogs was found in our previous studies (Karlsons and Osvalde, 2007). Both cranberry fruit Mn contents supported these differences.

Cultivated cranberry fruits had higher content of P and Fe while wild cranberry fruits showed the highest levels of Ca, Mg, Mn, Zn, Cu and B. The sequences with regard to the content of macro- and microelements in *V. macrocarpon* fruits were as K > N > Ca > P = S > Mg and Fe > Mn > Zn

> B > Cu > Mo, respectively. The order of macro- and micronutrient concentrations in *V. oxycoccus* was N > K > Ca = S > Mg > P and Mn > Fe > Zn > B > Cu > Mo.

In general, the fruit mineral nutrient concentrations found in the studied species in Latvia were similar or considerably higher (Ca, Mg, Fe, Zn and Cu) than values reported for the American cranberry (USDA, 2008). Reported mean values for Fe content (0.25 mg·100g⁻¹ fresh fruit) in *V. macrocarpon* fruits (USDA, 2008) were almost twice lower than our Fe results for American cranberries. To the author's knowledge, there is little comparable data in the literature which show the detailed mineral content of *V. oxycoccus*. However the macronutrient content in wild cranberries analyzed was lower (except Ca), but Mn concentrations significantly higher than the reported values for *V. oxycoccus* in Finland (Ekholm *et al.*, 2007)

The nutritional significance of fruits as a dietary source of minerals is related to the contribution they make to the Recommended Dietary Allowance (RDA). The present study shows that fruits of both *V. macrocarpon* and *V. oxycoccus* are a good sources of Mn (9.26 % and 120.96 % of the recommended daily dose, accordingly) in human nutrition. The content of Fe, Cu, Mo, and B in 100 g of fresh fruits of both cranberries studied also contributes from 4.46 % to 8.89 % of the daily micronutrient requirement.

All macronutrients, except K, in both species of cranberries were stated in relatively low concentrations. Only K in *V. oxycoccus* berries was found in appreciable amounts (3.28 % of the RDA). One hundred grams of fresh wild and cultivated cranberries may supply also a few percent of the RDA for P, Ca, Mg, S and Zn. The availability of Ca in the body to great extent depends on the calcium to phosphorous ratio. The recommended optimal Ca : P ratio in the diets is 1.0 to 1.3 (Calvo & Park, 1996). In our study such a Ca : P ratio was characteristic only for American cranberries.

Conclusions

The present study revealed significant differences in the mineral composition of *V. oxycoccus* and *V. macrocarpon*. Cultivated cranberry fruits had higher content of P and Fe while wild cranberries had higher levels of Ca, Mg Mn, Zn, Cu and B. Plant leaf analysis revealed organ-specific distribution of mineral elements in both species of studied cranberries.

The present study shows that fruits of both *V. macrocarpon* and *V. oxycoccus* are a valuable source of microelements: Fe, Cu, Mo, B and especially Mn, in human nutrition.

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**CLIMATIC EFFECTS ON THE PRODUCTION AND QUALITY OF BILBERRIES
(VACCINIUM MYRTILLUS)
KLIMATA IETEKME UZ MELLEŅU (VACCINIUM MYRTILLUS)
RAŽU UN KVALITĀTI**

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Abstract

The bilberry (*Vaccinium myrtillus*), also called European blueberry, is one of the most significant wild berries in the Nordic countries. The berries are recognized for their bioactive properties and distinctive aroma and flavour. The effects of climate on the production and the quality of bilberries have been studied in a controlled experiment in a phytotrone using clonal material. In the experiment individual plants from two Northern clones and two Southern clones of bilberry were grown at 12° and 18 °C. At each temperature 2 different light treatments were tested; 1) 24 hour (h) natural light (long day) and 2) 12 h natural light (short day). All plants were kept outside during flowering to ensure pollination by insects. Berries were sampled when ripe, weighed and stored at -80°C for later analysis.

Kopsavilkums

Mellenes (*Vaccinium myrtillus*), sauktas arī Eiropas mellenes, ir ļoti nozīmīgas savvaļas ogas Ziemeļu valstīs. Ogas ir atzītas to bioloģiski aktīvo vielu satūra un īpašās smažas un garšas dēļ. Klimata ietekme uz ražu un tās kvalitāti tika pētīta kontrolējamā eksperimenta apstākļos,