Environmentally Friendly and Safe Technologies for Quality of Fruits and Vegetables

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The papers contained in this book report some of the peer reviewed Proceedings of the International Conference "Environmentally friendly and safe technologies for quality of fruit and vegetables", but also other papers related with the subject were included. The manuscripts were reviewed by the Editor and Editorial Board, and only those papers judged suitable for publication were accepted. The Editor wish to thank to all the reviewers and authors for their contribution.

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SECTION 3. QUALITY MANAGEMENT OF FRUIT AND VEGETABLES

17. INVESTIGATION ON THE ESSENTIAL MINERAL ELEMENT CONTENTS OF CULTIVATED AND WILD BLUEBERRY FRUITS IN LATVIA

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Abstract

Wild blueberry (*Vaccinium murtillus*) is one of the most popular wild-harvested fruit in Latvia, traditionally used in folk-medicine and food. Unfortunately there are wide fluctuations in yields. The recent years mark a tremendous boom in high-bush blueberry (*Vaccinium corymbosum*) cultivation in Latvia. As the total berry production increase, blueberries have found a place in a daily intake as excellent source of antioxidants, dietary fibber, vitamin C and minerals. Thus, the chemical composition of *Vaccinium* spp. has important implication on human health. 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. myrtillus* and *V. corymbosum*. Together, 48 (plant and berries) samples were collected from 3 main high-bush blueberry producing sites and 5 woodland areas during summer 2008. A comparison of two species showed similar concentrations for macroelements N, P, and Mg in fruits. N and K were the predominant minerals in blueberries. It should be stressed that wild blueberries had higher level of K (on average 98.77 mg 100 g^{-1} fresh fruit). The data indicated statistically significant differences in microelements composition of wild and cultivated blueberry fruits. The highest concentrations of Fe, Mo and B (0.53, 0.01 and 0.14 mg 100 g^{-1} FW, respectively) were found in high bush blueberries, while the highest Mn and Zn concentrations (1.53, 0.13 mg 100 g^{-1} FW, respectively) were found in wild blueberries. Plant leaf tissues analyses supported these differences. The present study shows that fruits of both *V. murtillus* and *V. corymbosum* are valuable sources of Mn (66.55% and 49.86% from recommended daily dose, accordingly) in human nutrition. The content of Fe, Cu, Mo and B in 100g fresh fruits of both blueberries also contributes from 3.75 to 20.50% of daily micronutrient requirement.

Keywords: *Vaccinium myrtillus*, *Vaccinium corymbosum*, mineral composition

Introduction

Wild blueberry (*Vaccinium murtillus*) is one of the most popular wild-harvested fruit in Latvia, traditionally used as healthy food as well as in folk-medicine. Unfortunately there are wide fluctuations in yields from year to year. The recent years mark a tremendous boom in high-bush blueberry (*Vaccinium corymbosum*) cultivation in Latvia. As the total berry production increase, blueberries have found a place in a daily intake as excellent tasty source of antioxidants, dietary fibber, vitamin C and minerals. 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 diseases such as cardiovascular diseases and certain cancers (WHO 2003). Thus, the chemical composition of *Vaccinium* spp. has important implication on human health. Many minerals are essential for normal metabolic functions and are required components in a balanced diet (Grusak & DellaPenna 1999). While nutritional research on blueberries has been done on low-bush, high-bush and rabbit-eye blueberry fruits in the main blueberry production countries (Dekazos 1978; Bushway *et al.* 1983; Rupasova *et al.* 2007), there are practically no information on mineral element content of blueberry crop in Latvia. Many external factors as growth environment (soil, geographical conditions), cultivation and fertilization practices are widely diverse in different blueberry production countries and could contribute to the mineral composition of fruits.

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

Materials & Methods

The present study was carried out on wild blueberry (*V. murtillus*) and highbush blueberry (*V. corymbosum*) crops in different regions of Latvia. Together, 48 (leaf and berries) samples were collected from 3 main high-bush blueberry producing sites and 5 woodland areas during summer 2008. Berry and leaf materials were collected at each site as a composite sample from an area of about 10×10 m.

The plant material was oven-dried at 60 °C and ground. Then the plant samples were dry-ashed in concentrated HNO_3 vapours and re-dissolved in HCl solution (HCl - distilled water mixture 3:100). The levels of Ca, Mg, Fe, Cu, Zn, and Mn were measured by atomic absorption spectrophotometer (Perkin Elmer Analyst 700, acetylene-air flame); those of N, P, Mo, B by colorimetry, S by turbidimetry, and K by flame photometer (Jenwey PFP7, air-propane butane flame) (Rinkis *et al*. 1987). Mineral elements content in berries were expressed as mg 100 g^{-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 mean element concentrations in *V. murtillus* and *V. corymbosum* fruits and leaves.

Results

To characterize the mineral content of cultivated and wild blueberry fruits, the levels of 12 biologically essential elements were estimated. Mean macro- and micronutrient concentrations, as well as concentration range are shown in Table 1. A comparison of two species studied showed similar concentrations for the macroelements N, P and Mg in fruits. Statistically significant differences ($p< 0.05$) were noted for K, Ca and S. The data indicated that nitrogen and potassium were the major mineral constituents in both blueberry fruits tested. The richest source of K and Ca (on average, 98.76 and 17.97 mg 100 g^{-1} fresh fruit) in this study was *V. murtillus*, while the highest S (22.93 mg 100 g^{-1} fresh fruit) contents were found in *V. corymbosum* fruits.

Table 1. Mineral composition of *V. corumbosum* and *V. murtillus* fruits in Latvia, 2008.

Element	*V. corumbosum*		*V. murtillus*	
	Range	Mean ± SE	Range	Mean ± SE
Macroelements (mg 100 g^{-1} fresh weight)				
N	88.0 – 97.6	93.87 ± 2.97 a[1]	72.0 – 160.0	97.49 ± 7.40a
P	17.6 – 19.2	18.67 ± 0.53 a	12.8 – 38.4	16.67 ± 0.56a
K	73.6 – 92.8	82.13 ± 5.64 a	64 – 192.0	98.77 ± 3.91b
Ca	11.2 – 14.4	12.80 ± 0.92 a	12.8 – 54.4	17.97 ± 1.25b
Mg	8.0 – 9.6	8.53 ± 0.53 a	6.4 – 30.4	10.20 ± 0.50a
S	22.4 – 24.0	22.93 ± 0.53 a	12.8 – 32.0	17.81 ± 1.20b
Microelements (mg 100 g^{-1} fresh weight)				
Fe	0.512 – 0.560	0.533 ± 0.024a	0.240 – 0.720	0.410 ± 0.01b
Mn	0.640 – 1.440	1.147 ± 0.131a	0.240 – 4.640	1.531 ± 0.21b
Zn	0.075 – 0.115	0.097 ± 0.021a	0.096 – 0.320	0.132 ± 0.04b
Cu	0.058 – 0.072	0.067 ± 0.008a	0.050 – 0.147	0.062 ± 0.02a
Mo	0.006 – 0.011	0.009 ± 0.003a	0.001 – 0.005	0.002 ± 0.001b
B	0.128 – 0.144	0.136 ± 0.008a	0.080 – 0.128	0.102 ± 0.001b

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

Statistically significant differences ($p<0.05$) were found in microelement (except Cu) composition of wild and cultivated blueberry fruits. The highest mean concentrations of Fe, Mo and B (0.53, 0.01 and 0.14 mg 100 g^{-1} fresh fruit, respectively) were found in high-bush blueberry, while the highest Mn and Zn (on average, 1.53 and 0.13 mg 100 g^{-1} fresh fruit, respectively) concentrations were found in wild blueberry. In general, plant leaf analysis supported these differences (Table 2).

Table 2. Mineral element concentrations in V.corumbosum and V.murtillus leaf samples in Latvia, 2008.

Element	*V. corumbosum*		*V. murtillus*	
	Range	Mean ± SE	Range	Mean ± SE
	Macroelements (% dry weight)			
N	1.0 – 1.35	1.18 ± 0.08a	0.8 – 1.5	1.08 ± 0.05a
P	0.14 – 0.15	0.14 ± 0.01a	0.08 – 0.17	0.12 ± 0.01b
K	0.58 – 0.74	0.69 ± 0.04a	0.64 – 1.0	0.77 ± 0.03a
Ca	0.42 – 0.65	0.49 ± 0.01a	0.56 – 1.12	0.84 ± 0.05b
Mg	0.15 – 0.22	0.17 ± 0.02a	0.17 – 0.54	0.32 ± 0.03b
S	0.23 – 0.31	0.25 ± 0.02a	0.12 – 0.18	0.15 ± 0.01b
	Microelements (mg kg^{-1} dry weight)			
Fe	68.0 – 102.0	85.5 ± 7.4a	54.0 – 128.0	81.9 ± 6.8a
Mn	176.0 – 360.0	224.0 ± 45.4a	130.0 – 1720.0	814.4 ± 146.4b
Zn	10.1 – 11.0	10.6 ± 0.2a	14.0 – 26.0	18.6 ± 1.0b
Cu	4.8 – 32.0	13.1 ± 6.4a	3.6 – 6.4	5.0 ± 0.2b
Mo	0.9 – 1.4	1.1 ± 0.1a	0.2 – 0.3	0.2 ± 0.01b
B	15.0 – 48.0	36.8 ± 7.4a	15.0 –30.0	22.7 ± 1.2b

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

Contribution of *V. murtillus* and *V. corymbosum* fruits as a dietary source of mineral elements was estimated from our study results. The potential contribution of 100 g of wild and cultivated blueberry fruits to the Recommended Dietary Allowances (RDA) (USDA RDA chart 2004) for mineral elements is presented in Table 3. Wild and cultivated blueberry fruits supplies 66.55 and 49.86%, respectively, of the adult daily requirement for Mn. The content of Fe, Cu, Mo, and B in 100 g fresh fruits of both blueberries studied also contributes with 3.75 to 20.50% of the daily micronutrient requirement. From macronutrients, only K in *V. murtillus* fruits was in appreciable amounts (3.95% of the RDA). One hundred grams of fresh wild and cultivated blueberry fruits may supply also a few percent of RDA for P, Ca, Mg, S and Zn.

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

Element	RDA*, mg	% of RDA supplied by 100 g blueberries	
		V. corumbosum	*V. murtillus*
P	700	2.67	2.38
K	2500	3.29	3.95
Ca	1000	1.28	1.80
Mg	420	2.10	2.43
S	850	2.70	2.10
Fe	8	6.67	5.12
Mn	2.3	49.86	66.55
Zn	11	0.88	1.20
Cu	0.9	7.47	6.92
Mo	0.045	20.50	3.75
B	1.5	9.07	6.78

* USDA RDA chart (2004)

Discussion

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 important source of dietary nutrients, especially with respect to minerals (Grusak & DellaPenna 1999). Among berry fruits, blueberries are considered to be not only an excellent source of phenolic compounds and vitamins, but also a valuable source of Mn, K, Cu (Bushway *et al.* 1983; USDA National Nutrient Database for Standard Reference 2006).

Our research revealed statistically significant differences between *V. murtillus* and *V. corymbosum* results for K, Ca, S, Fe, Mn, Zn, Mo, B in fruit samples and P, Ca, Mg, S, Mn, Zn, Cu, Mo, B in leaf samples. Cultivated high-bush blueberry fruits had higher content of S, Fe, Mo and B while wild blueberry fruits showed the highest levels of K, Ca, Mn and Zn. The sequences with regard to the content of macro- and microelements in *V. corymbosum* fruits were N > K > S > P > Ca > Mg and Mn > Fe > B > Zn > Cu > Mo. The order of macro- and micronutrient concentrations in *V. murtillus* was K = N > Ca = S > P > Mg and Mn > Fe > Zn > B > Cu > Mo.

The fruit mineral nutrient concentrations found in the Latvia studied species were similar or considerably higher (P, Ca, Mg, Fe, Mn) than values reported for high-bush blueberriy and rabbit-eye blueberry fruits (Eitenmiller *et al.* 1977; Dekazos 1978; USDA 2006; Rupasova *et al.* 2007). It should be mentioned that low-bush blueberries (*Vaccinium augustifolium*) are particularly high in Mn as well as Ca content. Reported mean values for Mn content (2.60 mg 100 g^{-1} fresh fruit) in low-bush blueberry fruits (Bushway *et al.* 1983) were almost twice higher than our Mn results for high-bush blueberries. To the author's knowledge, there are scarce comparable data in the literature which show the detailed mineral content of *V. murtillus*. Macronutrient content in wild blueberries analyzed was higher but, Mn concentrations were significantly lower than reported values for *V. murtillus* in Finland (Ekholm *et al.* 2007)

The nutritional significance of fruits as dietary source of minerals is related to the contribution it makes to the Recommended Dietary Allowance (RDA). The present study shows that fruits of both *V. murtillus* and *V. corymbosum* are excellent sources of Mn (66.55% and 49.86% from recommended daily dose, accordingly) in human nutrition. The content of Fe, Cu, Mo, and B in 100 g fresh fruits of both blueberries studied also contributes from 3.75 to 20.50% of daily micronutrient requirement. It should be stressed that cultivated high-bush blueberries had almost 5 times higher concentrations of Mo in their leaves and fruits, apparently due to use of Mo containing fertilizers. Therefore 100 g of high-bush blueberry fruits could provide 20.5% of RDA.

From macronutrients only K in *V. murtillus* fruits was stated in appreciable amounts (3.95% of the RDA). One hundred grams of fresh wild and cultivated blueberry fruits may supply also a few percent of RDA for P, Ca, Mg, S and Zn. The availability of Ca in the body to great extent depends on 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 ratio was characteristic for wild blueberry fruits.

As a conclusion, the present study reveals, that *V. murtillus* and *V. corymbosum* differ in their elemental composition. Cultivated high-bush blueberry fruits had higher content of S, Fe, Mo and B while wild blueberry fruits showed the highest levels of K, Ca, Mn and Zn. Both blueberries studied could be qualified as good source of microelements: excellent source of Mn and valuable source of Fe, Cu, Mo, and B in human nutrition.

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