Bioaccumulation potential of 'Meeker' and 'Willamette' raspberry (*Rubus idaeus* L.) fruits towards macro- and microelements and their nutritional evaluation

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Abstract: Raspberry (*Rubus idaeus* L.) is the most important type of berry fruit in the Republic of Serbia. The bioaccumulation factor (BF) for the elements detected in the fruits of the raspberry cultivars 'Willamette' and 'Meeker' was calculated to determine their bioaccumulation potential. In addition, the nutritional quality of fruits in relation to nutritionally essential elements was evaluated and compared with the recommended daily intake. For determining the concentrations of 19 macro- and microelements in fruits and the soil, the analytical technique of optical emission spectrometry with inductively coupled plasma was used. Among the analyzed elements, As, Cd, Co, Cr, Li and Mo were below the limit of detection in the fruits of both raspberry cultivars, whereas Na and Ni were detected only in fruits of the 'Meeker' cultivar. All analyzed elements were detected in the soil. The results of the work indicated the high potential of the studied cultivars to accumulate nutritional elements K and Ca. In both raspberry cultivars, there were no substantial differences in the bioaccumulation of most elements. However, two elements (B and Mn) can be singled out; the BF for B in the 'Willamette' fruit was 3 times lower compared to the BF in the 'Meeker' fruit, whereas the BF value for Mn in the 'Willamette' fruit was almost 8 times higher compared to the BF value for the 'Meeker' fruit. Furthermore, the cultivars did not tend to accumulate potentially toxic elements such as Ba, Co, Cu and Ni. The nutritional evaluation revealed that the studied raspberry fruits are a good source of K, Ca, Mg, Fe, Mn and Cu. Based on the BF values, differences observed in the accumulation of B, Ba, Na, Ni and Mn may be attributed to the characteristics of the cultivars.

Keywords: raspberry fruit, 'Willamette', 'Meeker', soil, bioaccumulation

1. Introduction

Raspberry (*Rubus idaeus* L.) is the most important type of berry fruit in the Republic of Serbia, taking into account the volume of production, total production area and realized export [1]. In addition, the Republic of Serbia is one of the largest producers and exporters of frozen raspberries in the world, while domestic consumption and export of

fresh raspberries from Serbia are quite limited. Dehydrated fruits are used for fruit mixes, as well as for long-distance transport, whereas fresh fruits are used processed into jam, jelly, topping for desserts, ice cream and yogurt [2]. About 30 chemical elements (called biogenic elements) are involved in physiological and biochemical activities in the human body, so they must be present in a regular daily diet [3]. Besides, non-essential elements (Al, As, Ba, Cd, Hg, Ni, Pb, Sb) could be also found in the food and are considered food contaminants. Due to cumulative properties, these elements are harmful to humans [3,4]. The bioaccumulation factor (BF) indicates the ability of plants to accumulate elements and tolerate toxic elements, depending on the concentration of elements and their bioavailability in the soil, and BF is used to calculate the transfer of elements from the soil to different parts of the plant. [5]. The study aimed to determine the bioaccumulation factor in fruits of raspberry cultivars 'Willamette' and 'Meeker' grown in the Toplica district (Serbia), based on the content of 19 elements analyzed in the fruits and in the soil. In addition, the nutritional quality of the fruits concerning the content of nutritionally essential elements was evaluated.

2. Materials and Methods

Plant material - Raspberry plantations of the 'Willamette' and 'Meeker' cultivars are located in the village of Igrište (on the administrative border with Kosovo), municipality of Kuršumlija, southern Serbia (coordinates 43° 11′ N/ 21° 08′ E, at an altitude of 938 m). The fruits of the examined cultivars (approx. 200 grams for each) were harvested at the maturity stage and then frozen at -20 °C.

Instrumental analysis - To determine the content of 19 elements in raspberry fruits and the soil, the analytical technique of inductively coupled plasma with optical emission spectrometry (ICP-OES) was applied as described in the literature [6]. The content of the elements in the fruits was expressed as milligrams per kg (mg/kg) of fresh weight.

Calculation of the bioaccumulation factor - The bioaccumulation factor (BF) of the analyzed elements in the fruits of the examined cultivars was calculated according to the literature [6], using the equation $BF = C_{fruit}/C_{soil}$ (1)

where C_{fruit} and C_{soil} represent the concentration of the element in the raspberry fruit and in the soil, respectively.

Nutritional assessment of fruit quality - The nutritional quality of the studied cultivars' fruits was evaluated for Ca, Cu, Fe, K, Mg, Mn and Zn, as previously reported [3].

3. Results and Discussion

Content of aluminum (Al), arsenic (As), barium (Ba), boron (B), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), potassium (K), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), sodium (Na), nickel (Ni), lead (Pb) and zinc (Zn) was measured in the samples of studied raspberry cultivars and in the soil. The concentrations of As, Cd, Co, Cr, Li and Mo were below the limit of detection (LD) in the raspberry fruits of the cultivars 'Willamette' and 'Meeker'. In

addition, concentrations of Na and Ni in the fruit of the cultivar 'Willamette' were below the LD. The lowest concentration in fruits of the cultivars 'Willamette' and 'Meeker' was measured for Ba (0.005 mg/kg) and Pb (0.498 mg/kg), respectively. On the other hand, K was measured in the highest concentration of both cultivars' fruits; 1877.701 mg/kg - 'Willamette' and 2019.861 mg/kg - 'Meeker'. The content of elements in raspberry fruits may depend on the cultivar and/or cultivation practice (conventional, organic, wild-growing) [7]. All tested elements were detected in the soil (data are not shown).

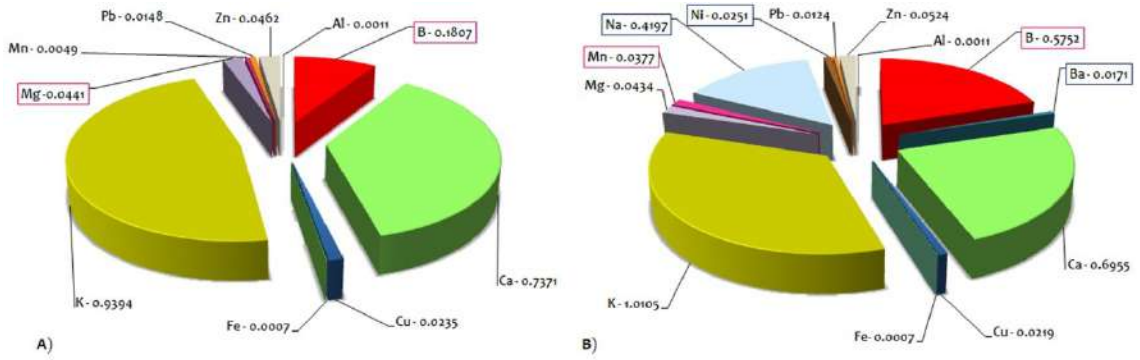

Figure 1. Bioaccumulation factor values for 'Willamette' (A) and 'Meeker' (B) fruits.

The results were used for the calculation of the bioaccumulation factor (BF) of the analyzed elements for both raspberry cultivars, Figure 1. The BF values in the fruits were in the following order: 'Willamette': K > Ca > B > Zn > Mg > Cu > Pb > Mn > Al > Fe; 'Meeker': K > Ca > B > Na > Zn > Mg > Mn > Ni > Cu > Ba > Pb > Al > Fe.

In fruits of both raspberry cultivars, there were no significant deviations in the bioaccumulation of most elements. Values of BF > 1 indicate that the accumulation in the plant is greater than the accumulation of the medium (e.g. soil or water) from which the element is taken [5]. In this study, only BF for K in 'Meeker' fruits was > 1. Boron and manganese can be singled out, with the BF values substantially lower in fruits of the cultivar 'Willamette' than in the cultivar 'Meeker', Figure 1.

Table 1. Daily recommended intake (DRI) of essential elements (mg/day), the content in 100 g of fruits (mg/100 g) and the percentage of DRI in fruits of 'Willamette' and 'Meeker' cultivars.

	DRI* (mg/day)	**'Willamette' (mg/100 g)**	**% of DRI****	**'Meeker' (mg/100)**	**% of DRI**
Ca	2000	187.77	9.4	201.99	10.1
K	800	32.89	4.1	31.03	3.9
Mg	375	27.98	7.5	27.54	7.3
Fe	14	1.78	12.7	1.79	12. 8
Zn	10	0.54	5.4	0.62	0.6
Mn	2	0.43	21.3	3.24	162.1
Cu	1	0.11	10.7	0.10	10.0

* DRI - Daily recommended intake [8]; ** Percentage of DRI expressed in 100 g of fruits

The content in 100 g of fruits was expressed as a percentage in relation to the recommended daily intake (RDI) of elements, Table 1. Based on the obtained results it can be noted that the fruits of the cultivars 'Willamette' and 'Meeker' are a good source

of essential elements. Consumption of 100 g of the fruits of examined raspberry cultivars can cover the RDI of Mg, K, Fe, Cu and Mn to a significant percentage (7.3-21.3%).

3. Conclusions

The results indicated a high potential of the tested cultivars to accumulate nutritional elements K and Ca. On the other side, fruits did not tend to accumulate potentially toxic elements such as Ba, Co, Cu and Ni. Differences observed in the accumulation of B, Ba, Na, Ni and Mn may be attributed to the characteristics of the cultivars.

Acknowledgment

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References

[1] J. Milivojević, *Posebno voćarstvo 3 - Jagodaste voćke*, (2022) Poljoprivredni fakultet, Beograd.
[2] A.L. Vara, J. Pinela, M.I. Dias, J. Petrović, A. Nogueira, M. Soković, I.C.F.R. Ferreira, L. Barros, *Compositional features of the "Kweli" red raspberry and its antioxidant and antimicrobial activities*, Foods 9 (2020) 1522.
[3] J.B. Popović-Djordjević, A.Ž. Kostić, M.B. Rajković, I. Miljković, Đ. Krstić, G. Caruso, S. Siavash Moghaddam, I. Brčeski, *Organically vs. conventionally grown vegetables: multi-elemental analysis and nutritional evaluation*, Biological Trace Element Research 200 (2022) 426–436.
[4] N. Zand, T. Christides, E. Loughrill, *Dietary intake of minerals*. In: Handbook of mineral elements in food. Editors: de la Guardia M., Garrigues S. (2015) 41–68, John Wiley & Sons. Chichester, UK.
[5] B. Balabanova, T. Stafilov, *Bio-accumulation of essential and heavy metals in plant food—multielements characterization of plant food*, (2017) Lap Lambert Academic Publishing: Saarbrücken, Germany.
[6] J. Popović-Djordjević, S.Ž. Marjanović, N. Gršić, T. Adžić, B. Popović, J. Bogosavljević, I. Brčeski, *Essential elements may be distinguishing factors between mycorrhizal potentials of Tuber magnatum Pico and Tuber brumale Vitt. as cohabiting truffle species in riparian forest habitat in Serbia*. Chemistry and Biodiversity 16 (2019) e1800693.
[7] M. Kotuła, J. Kapusta-Duch, S. Smoleń, *Evaluation of selected heavy metals contaminants in the fruits and leaves of organic, conventional and wild raspberry* (*Rubus idaeus* L.). *Applied Sciences 12* (2022) 7610.
[8] *Pravilnik o deklarisanju, označavanju i reklamiranju hrane* ("Sl. glasnik RS". No. 19/2017, 16/2018, 17/2020, 118/2020, 17/2022, 23/2022 i 30/2022).