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The content of minerals in Slovenian organic and conventional produced fruits, herbs and vegetables

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ABSTRACT

The present study aims to compare mineral composition of fruits, herbs and vegetables grown conventionally and according to organic practice. Fruits, herbs and vegetables have been identified as leading dietary source of antioxidants, vitamins and minerals. These compounds are very variable in the composition and in the concentration among cultivars and species. Determination of calcium (Ca), potassium (K), phosphorus (P) sulphur (S) and chlorine (Cl) was performed with Energy dispersive X-ray fluorescence spectrometry (EDXRF). We found that among organic crops basil, parsley, pears, peppers, rockets and celery had higher calcium contents in comparison to conventional ones. Organically produced broccoli, eggplant, parsley, rocket and celery had higher potassium contents as well as pepper, rockets, celery, beetroots and tomatoes had higher phosphorus contents. Likewise, higher sulphur content was found in organically produced parsley, rocket, celery and raspberries. Results of this study demonstrated that in general there are no rules in the content of minerals between different farming systems.

Key words: mineral content, EDXRF, organic farming, conventional farming, fruits, herbs, vegetables

IZVLEČEK

RAZLIKE V VSEBNOSTI MINERALOV MED SLOVENSKIM EKOLOŠKO IN KONVENCIONALNO PRIDELANIM SADJEM, ZELIŠČI IN ZELENJAVO

Namen opravljene študije je narediti primerjavo vsebnosti mineralov ekoloških in konvencionalnih pridelkov glede na način kmetovanja. Sadje, zelišča in zelenjava so poznani kot glavni vir prehranskih antioksidantov, vitaminov in mineralov. Te spojine se razlikujejo glede na sestavo in koncentracijo znotraj posameznih vrst. Energijsko disperzijska rentgenska fluorescentna spektrometrija (EDXRF) je bila uporabljena za določevanje vsebnosti kalcija (Ca), kalija (K), fosforja (P), žvepla (S) in klora (Cl). Ugotovili smo, da so imeli med ekološkimi pridelki večje vsebnosti kalcija bazilika, peteršilj, hruška, paprika, rukola in zelena. Večje vsebnosti kalija so bile v ekološkem brokoliju, melancanu, peteršilju, rukoli in zeleni, v primerjavi s konvencionalnimi pridelki. Večje vsebnosti fosforja so bile v ekološki papriki, rukoli, zeleni, rdeči pesi in paradižniku. Glede na konvencionalne pridelke je bila večja vsebnost žvepla izmerjena v peteršilju, rukoli, zeleni in malinah. Rezultati so pokazali, da se vsebnost mineralov v pridelkih ne razlikuje glede na različen načinov kmetovanja.

Ključne besede: vsebnost mineralov, EDXRF, ekološko kmetijstvo, konvencionalno kmetijstvo, sadje, zelišča, zelenjava

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1 INTRODUCTION

Minerals in the crops are beside vitamins, antioxidants, flavonoids and phytochemicals one of the most important nutrients, which have been reported to contribute to the human health (Rembialkowska, 2007; Crinnion, 2010). It has been suggested that fruits and vegetables may be important for bone health because of the alkaline salts they provide (Macdonald 2007; Žnidarčič et. al., 2011). Conventional farming utilise fertilizers which contain soluble inorganic nitrogen and other elements, which are directly available to plants (Rapisarda in sod., 2005). In addition, organic crops have a longer ripening period compared to conventional ones due to slower release of the supplied nutrients (Oplanić et al., 2009a). Consequently, there could be expected a higher content of these nutrients in the products (Brandt in Molgaard, 2001).

In the organic farming the use of chemical - synthetic pesticides and readily soluble mineral fertilisers are not allowed (Oplanić et al., 2009b). Organic farming practise is diverse range of crops rotation and sustainable soil tillage (Woese in sod., 1997). Although conventional practises results in the reliable high-yield crops, there are worries regarding the negative biological and environmental consequence (Worthington, 2001; Lairon, 2010). Regarding mineral content a number of comparative studies showed lower nitrate content and less pesticide residues, but usually higher levels of vitamin C and phenolic compounds as well as more minerals. Worthington, 2001 found more iron (21 %), magnesium (29 %) and phosphorus in organic crops, compare to conventional. More potassium, magnesium, phosphorus, sulphur and cooper but less iron and manganese were found by Wszelaki et al., 2005. High concentration of iron, potassium, calcium and phosphoruh and low levels of sodium was found in organic vegetables (Schuphan, 1975). In analysis which included only statisfactory quality studies organic products had a significantly higher content of phosphours and organic crops had significantly higher content of nitrogen (Dangour in sod., 2009).

During the last decades many studies compared organic and conventional crops. Most of the crops were bought in the markets (Ismail in sod., 2004; de Souza Araújo in sod., 2014) what is the easiest way for acquiring samples. However, it is hard to get information about environmental influences (Žnidarčič D., 2012). The main problem in the comparative studies between organic and conventional crops is how to select appropriate experimental fields that they truly represent expected environment. To minimize the effect of climatic conditions, variety, irrigation, ripening time and storage it is necessary to have a controlled field, where most of the factors could be either controlled or at least recorded (Perez-Lopez in sod., 2007; Aldrich in sod., 2010; Bavec in sod., 2010).

The objective of the present study was is to assess the influence of agricultural management system including organic and conventional on mineral composition of fruits, herbs and vegetables.

2 MATERIAL AND METHOD

2.1 Plant material

Herbs (basil, parsley, celery) and vegetables (broccoli, beetroot, cucumber eggplant, rocket, tomato, and cherry tomato) were grown in experimental field, where mineral fertilizers have not been used for more than 30 years. The same varieties of crops were used in both farming system. Basic soil cultivation, sowing, and harvesting dates and methods were identical for organic and conventional experimental plot. Organic crops were only irrigated while conventional crops were fertilized with Plantella extra plus NPK (15:15:15), according to instructions given by the manufacturer, on the 14th, 21st, 28th, 35th and 42nd day of growth period. The climatic conditions, variety, irrigation, ripening time, and storage conditions were the same for the vegetables and herbs grown organically and conventionally.

Samples of same variety of fruits (apple, cherry, pear and raspberry) were obtained from known organic and conventional farms in Slovenia. Organic fruits derived from certified organic productions and had certification for organic farming, according to the Institute of Certification (KON-CERT Maribor, Slovenia).Conventional fruit samples were from conventional farms.

2.2 Methods

The samples were nondestructively analysed by EDXRF (Energy Dispersive X-ray Fluorescence) in order to determine P, S, Cl, K and Ca. From 0.5 to 1.0 g of powdered sample material pellets were prepared using a pellet die and hydraulic press. As primary excitation sources, the radioisotope excitation sources of Fe-55 (25 mCi), and Cd-109 (20 mCi) from Eckert and Ziegler Isotope Products (Germany) were used. The emitted fluorescence radiation was measured by the EDXRF spectrometer composed of a Si(Li) detector (Canberra), a spectroscopy amplifier (Canberra M2024), ADC (Canberra M8075) and PC based MCA (S-100, Canberra). The spectrometer was equipped with a vacuum chamber. The energy resolution of the spectrometer was 175 eV at 5.9 keV. The measuring time was 4000 s. The analysis of complex X-ray spectra was performed by the AXIL (Van Espen, 1993) spectral analysis program. The evaluated uncertainty of this procedure included the statistical uncertainty of measured intensities and the uncertainty of the mathematical fitting procedure. The overall uncertainty of spectral measurement and analysis was in most cases better than 1 %. Quantification was then performed utilizing QAES (Quantitative Analysis of Environmental Samples) software developed in J. Stefan Institute (Nečemer, 2011). The estimated uncertainty of the analysis was around 5 % to 10 %. Rather high total estimated uncertainty is mainly due to contributions of matrix correction and geometry calibration procedures, which include errors of tabulated fundamental parameters, and also contributions of spectrum acquisition and analysis.

The results of elemental content were expressed as mg per kg of dry matter (mg/kg DM).

2.3 Statistical analysis

The data were analysed using SAS/STAT statistical software (SAS, 2012). Differences in mineral contents among three groups of crops and two farming systems were graphically presented using SGPLOT procedure. Pearson correlation coefficients were estimated using the CORR procedure.

3 RESULTS

3.1 Calcium content in organic and conventional crops

Calcium content in crops was in the most cases quite uniform regarding different methods of farming. Basil, parsley, rocket and celery had higher content of Ca in organic samples as compared to conventional one (Fig. 1). On the other hand, calcium content was higher in the conventionally grown broccoli and cucumber as compared to organic ones. Likewise, Ca content of eggplants, tomatoes and beetroots were quite higher in conventionally grown crops. The highest calcium content was found in the organic rocket with the value of 46,700 mg/kg. The lowest Ca content belonged to conventionally produced pear (350 mg/kg).

When we grouped samples, the order from the highest to the lowest contents of calcium was as follows: organic herbs> conventional herbs> conventional vegetable> organic vegetable> conventional fruits> organic fruits. This are not in accordance with many other studies (Worthington, 2001; Perez-Lopez et al., 2007; Roussos in Gasparatos, 2009; de Souza Araújo et al., 2014), where calcium content were higher in the organically produced fruits and vegetables as compared to conventionally produced.

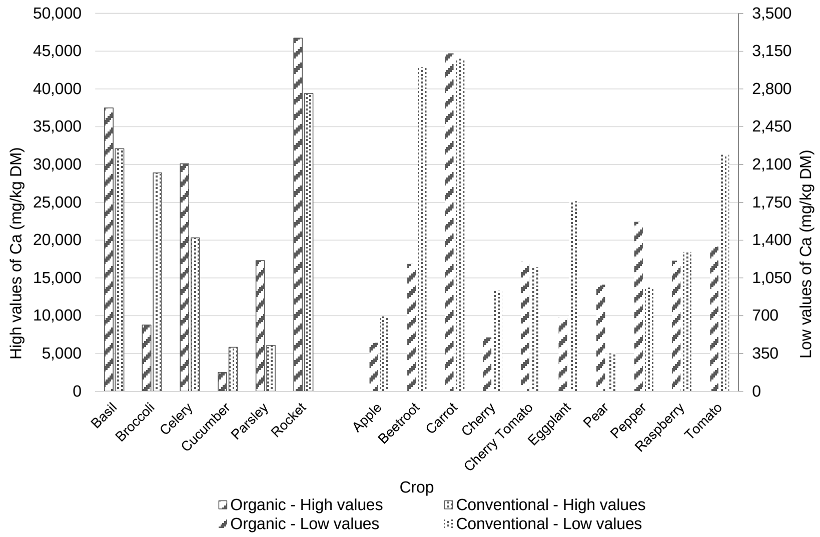

Figure 1: The comparison of calcium content (Ca) in the crops from two production systems

3.2 Potassium content in organic and conventional crops

Taking into consideration different farming systems potassium content was higher in organic broccoli, eggplant, parsley, rocket and celery compared to conventional the same crops (Fig. 2). On the other hand, potassium content was higher in conventionally grown basil, cherry, pear, apple, carrot, cucumber, raspberry, pepper, tomato, cherry tomatoes and beetroot. The highest potassium content was measured in the conventional beetroot with the value of 51,300 mg/kg. The lowest content had organic apple (5,310 mg/kg).

When we grouped samples the order from the highest to the lowest potassium content was as follows: organic herbs> conventional herbs> conventional vegetable> organic vegetables> conventional fruits> organic fruits. Most crops in this study had higher potassium content produced in conventional farming what is in accordance with Kristl et al. (2013) but it is not in agreement with the findings of Roussos and Gasparatos (2009). Higher calcium and potassium contents in the conventional green pepper as compared to organic one, is in accordance with Perez-Lopez et al. (2007).

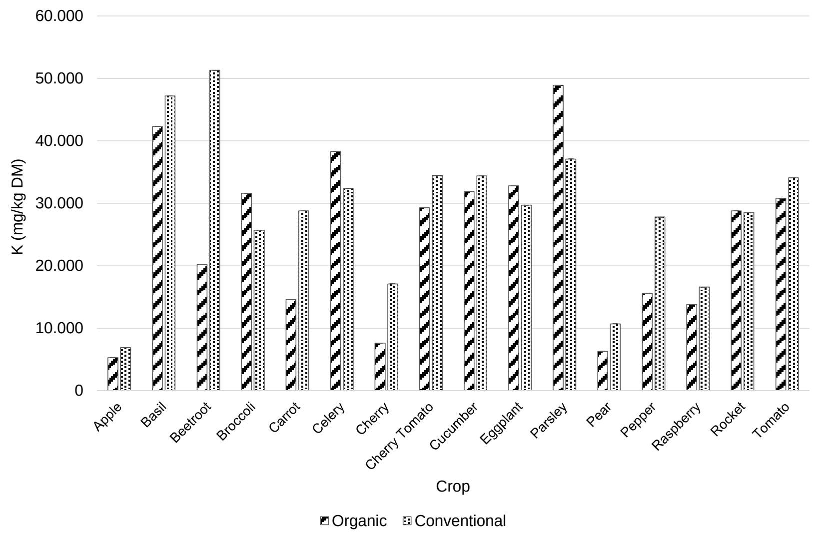

Figure 2: Comparison of potassium content (K) in the crops from two production systems

3.3 Phosphorus content in the organic and conventional crops

Phosphorus content was in most cases higher in conventionally grown crops as compared to organic crops. Only pepper, tomato, rocket, celery and beetroot had higher content of phosphorus in the organic samples as compared to conventional (Fig. 3) what is in accordance to Dangour et al. (2009). The highest content of phosphorus was determined in conventionally grown broccoli (7,270 mg/kg) and the lowest content in the organic apples (355 mg/kg).

Among three groups of crops, the highest average phosphorous content belonged to herbs, followed by vegetables and fruits. All conventional crops had higher phosphorous content as compared to organic crops.

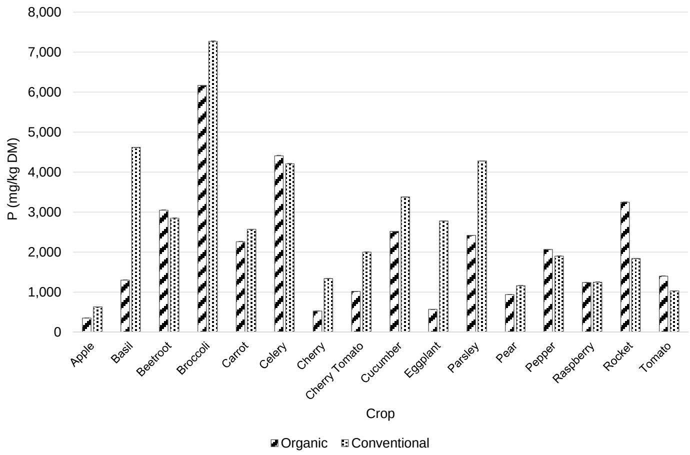

Figure 3: Phosphorus content (P) in the crops from two production systems

3.4 Sulphur content in the organic and conventional crops

Sulphur content was higher in conventional crops, except parsley, rocket and celery, where higher values were determined in organic crops (Fig. 4). The highest sulphur content was determined in conventional broccoli with the value of 13,600 mg/kg and the lowest content in the organic apple (181 mg/kg).

Among all three groups of crops, the highest average sulphur content belonged to herbs, followed by vegetables and fruits. All groups of conventionally grown products had higher sulphur contents than organic.

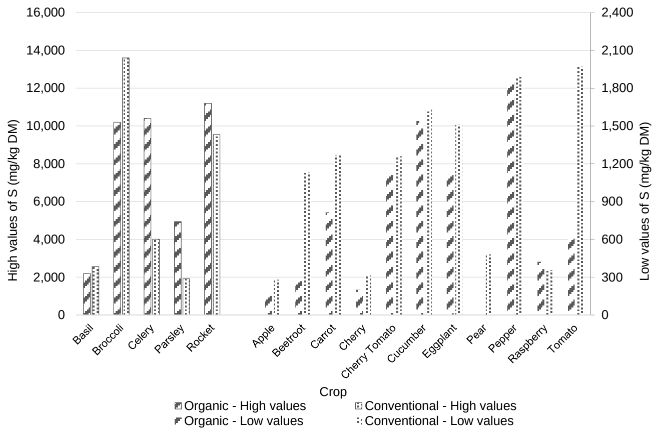

Figure 4: Sulphur content (S) in the crops from two production systems

3.5 Chlorine content in the organic and conventional crops

For chlorine content there the highest value in the beetroot from conventional farming and in the celery from organic production (Fig. 5). Cherry tomatoes, rocket, parsley, eggplant, broccoli and basil had a higher content of chlorine in organic production; while others in conventional farming.

The highest chlorine content was determined in organic celery with value 14,100 mg/kg. The lowest content had organic apple (70.3 mg/kg).

When we grouped samples in crops the order from the highest to the lowest chlorine content was as follows: organic herbs > conventional vegetables > conventional herbs > organic vegetable > conventional fruits > organic fruits.

On the non-selective medium, 3.0% of regenerants failed (Table 3).

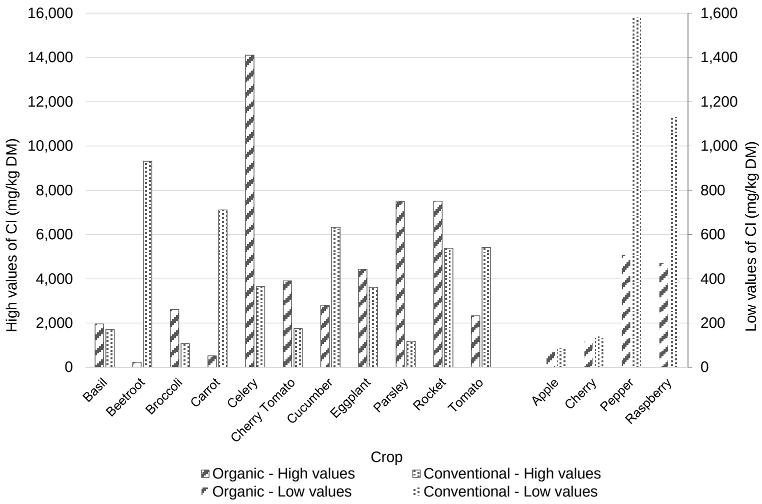

Figure 5: Chlorine content (Cl) in the crops from two production systems

3.6 Correlation between the contents of determined minerals

Table 1 presents the correlations between minerals. Estimated correlations were high and statistically significant between sulphur and calcium (r = 0.75), between phosphorus and sulphur (r = 0.70) and between chlorine and potassium (r = 0.61). However all other correlations were statistically significant, but with low Pearsons correlations coefficients, with the exception of estimated correlations between phosphorus and chlorine as well as between sulphur and potassium, where correlations were not statistically significant.

Table 1: Pearson correlation coefficients among minerals contents

			S	Cl	Ca	K
Phosphorus	(P)	Correlation	**0.697**	0.218	**0.456**	**0.445**
		p-value	<0.001	n.s.	0.01	0.01
		n	31	30	32	32
Sulphur	(S)	Correlation		**0.427**	**0.750**	0.280
		p-value		0.02	<0.001	n.s.
		n		30	31	31
Chlorine	(Cl)	Correlation			**0.381**	**0.611**
		p-value			0.04	<0.001
		n			30	30
Calcium	(Ca)	Correlation			1.	**0.425**
		p-value				<0.02
		n				32

n-number of observation; Correlation-Pearson correlation coefficient; n.s. – not statistical significant.

4 DISSCUSSION AND CONCLUSIONS

Worthington (2001) compared results from 1240 studies and shown that organic fruits and vegetables contained more minerals than conventionally grown crops. Likewise, Wszelaki et al. (2005) found more K, Mg, P, S and Cu in organically grown potatoes in comparison to the conventional potatoes. Comparing the effect of organic and conventional farming systems on fruit quality is inherently difficult due to the wide range of factors that can potentially affect crop composition such as climate, soil conditions, cultivar, soil type, planting date, harvesting time and growing seasons (Lopez in sod., 2013). Widely excepted reason is that organic matter in soil make minerals due to slower release less prone to leaching and thus more available to be absorbed by the roots (Brandt in Molgaard, 2001). Soil's pH have been shown to modulate the uptake of the macronutrients Ca and Mg and micronutrients zinc, manganese and iron (Lammerts van Bueren in sod., 2011).

Regardless many authors (Schuphan,1975, Roussos and Gasparatos, 2009; de Souza Araújo et al., 2014) reported higher contents of minerals (Ca, K and P) in the crops from organic farming in our study higher mineral contents were determined mostly in conventional crops. Among organically grown samples more calcium was determined in basil, parsley, pear, pepper, rocket and celery. Higher potassium contents had broccoli, eggplant, parley, rockets and celery while higher phosphorus contents had pepper, rocket, celery, beetroot and tomato from organic compared to conventional farming. The mineral content of these crops were in accordance with literature mentioned above.

Higher sulphur content in the organic samples from this study was determined only in parsley, rocket, celery and raspberries.

Dangour et al. (2009) compare 46 studies and found no evidence of a difference between organic and conventional production method for contents of minerals (magnesium, potassium, calcium, zinc and copper).Only phosphorus was significantly higher in organically produced crops.

In conclusion we could say that our results demonstrated mineral content varied considerably depending on the cultivars and species. Differences in mineral content among three groups of crops were higher than differences in mineral content between organic and conventional farming system. Generally we could not confirm higher content of minerals in the organic crops, neither in the conventional crops.

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