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COMPARATIVE STUDY ON MINERAL CONTENT OF ORGANIC AND CONVENTIONAL CARROT, CELERY AND RED BEET JUICES

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Abstract. The consumption of organic food has been growing all over the world. Clean soil environment and extensive methods of production make Poland particularly suitable for developing organic forms of farming. The nutritional quality of food grown by organic and conventional methods is the subject of much controversy. The nutritious quality of organic products is the subject of numerous scientific research. The study conducted in 2009 presents comparison of some nutritional values of juices made from organic and conventionally grown vegetables (carrot, red beet, celery). For the experiment 39 vegetable fields located in the south and east of Poland were chosen. All organic farms were certified according to UE Council Regulation no. 2092/91 and obtained valid certificates. Unclarified juices were obtained with cold press juicer. After microwave mineralization in HNO_3 the following nutrient elements were measured: P, K, Mg, Ca, S, Fe, Zn, Mn, Cu, B as well as Na, Cd, Pb, and Ni. Moreover, ammonium N and nitrates content were evaluated using FIA method. Celery juices were the richest in P, K, Mg, Ca, Fe, Zn, B and heavy metals Cd, and Pb, while carrot juices were having the highest level of S and Na. Cultivation methods significantly differentiated Ca, Mg and Na content. Generally, the conventional farming method favored higher accumulation of N-NO_3 (only in carrot), Mg and Na, whereas the higher Ca amounts were measured for bio juices. Significantly higher N-NH_4 amounts were observed for all conventionally vegetable juices than for organic. Higher levels of Cd were found for conventional juices made from carrot and beet, however in the celery juice the values differences were not significant.

Key words: organic farming, nutritional value, vegetable juices, nitrates, macro- and microelements

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INTRODUCTION

The consumption of organic food has been growing all over the world. Studies indicate that many consumers buy organic products because of the perceived health and nutrient benefits and avoided pesticides or genetically modified foods [Winter and Davis 2006]. Kucińska et al. [2008] demonstrate that poor condition of Polish agriculture, lean soil environment and extensive methods of production make Poland particularly suitable for developing organic farming.

Therefore, the organic food quality issues attracts the interest [Hornick 1992, Caswell 2000, Heaton 2002, Bonti-Ankomah and Yiridoe 2006]. There is debate about whether organic farming is better for both consumers and the environment [Heaton 2001]. Several of the studies reported that organic products have lower nitrate content, and higher dry matter and mineral content compared to conventionally grown alternatives [e.g., Mader et al., 1993, Rembiałkowska 2000b]. Some reviews of the comparative studies [e.g. Woese et al., 1997, Bourn and Prescott 2002] indicated contrasting conclusions. It is explained that crop variety, soil type, climate, duration of experiment, post-harvest practices and statistical design can all influence conclusions on the nutritive and sensory characteristics of a product [Hornick, 1992, Woese et al. 1997, Heaton 2002, Bourn and Prescott 2002]. In 2009 the United Kingdom Food Standard Agency (FSA) published an extensive report on organic food that concluded there was no evidence of a difference in nutritional quality between organically and conventionally produced foodstuffs. The finding-based on a review of 55 relevant studies conducted over the past 50 years [Dangor et al. 2009]. Scientists convened by The Organic Center (TOC) carried out the similar, but more rigorous review of the same literature [Benbrook et al. 2008]. The TOC team analysed published research just on plant-based foods. Results differed significantly from the narrower FSA review included studies over a 50 years period (1958–2008). Since 2008 the cut of date of the London study some 15 new studies have been published most of which use superior design and analytical methods based on criticism of older studies [Benbrook et al. 2008].

The agriculture methodologists distinguish two types of comparative experiments: “market survey” and “on farm research’. The latter is thought as more suitable for practice [David 1998] and this type is used in the presented experiment.

As vegetable and fruit juices and soft drinks are some of the most widespread beverages in the habitual diet, and they can contribute to trace element dietary intake we tried to assess the differences in element content of juices produced from organic and conventional vegetables.

MATERIAL AND METHODS

The comparative study on nutrient content of organic foods was conducted in the years 2009. The following conventional and organic crops were evaluated:

1. Carrot (*Daucus carota* cv. ‘Perfection’),
2. Red beet (*Beta vulgaris* cv. ‘Czerwona Kula’),
3. Celery (*Apium graveolens* cv. ‘Jabłkowy’),

For the experiment 39 fields producing organic (19) and conventional (20) crops were chosen. The area of the trial covered four districts (Małopolskie, Podkarpacie, Mazowieckie and Lubelskie) located in the south and east of Poland. The study design was both careful and comprehensive in object. For each crop at least six matched-pair sets (conventional /organic) were established. The climate as well as soil conditions were similar for each pair of farms. All organic sites were certified according to UE Council Regulation no. 2092/91 and obtained valid certificates. During the study the soil properties of each site were evaluated (granulometric, organic matter content, pH, EC as well as macro- and microelement content – data not presented). In addition, crop rotation, fertilization routine, pest management and other cultural practices for each field were recorded. At harvest the total yield and an average weight of root was noted (data not presented).

Chemical analyses. Four samples of vegetables from each field were taken (each about 2 kg). They were washed, sorted, trimmed in the usual manner and consequently crushed with peel. Unclarified juices were obtained with cold press juicer. In the samples of juices the following parameters were investigated:

– ammonium and nitrate content in juices after hot water extraction (70^{o}C) were measured by Flow Injection Analysis (FIA) technique with spectrometric detection [PN-A-75112: 1992, PN-EN ISO 13395, 2001],

– collected juice samples were mineralized in 65% extra pure HNO_3 (Merck no 100443.2500) in a CEM MARS-5 Xpress microwave oven [Pasławski and Migaszewski 2006]. Macroelements (P, K, Ca, Mg, S) and microelements (Cu, Fe, Zn, Mn, Sr, B) as well as heavy metals (Cd, Pb and Ni) content was assessed using by inductively coupled argon plasma atomic emission spectroscopy ICP-OES technique (ICP-OES Teledyne Prodigy, Leeman Labs spectrophotometer).

The determinations were made in triplicate for each sample. All results are reported on a fresh weight basis. Results, that were less than the detection limit, were considered as being equal to this limit when calculated mean values.

Statistical analysis. The measurements were listed and subjected to a two-way analysis of variance. Differences between the means were ascertained with a multiple Duncan Test, using Statistica 9.0 software (Statsoft, Inc.). The mean values for the combinations labeled with the same letters do not significantly differ at the significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

Celery juices were the richest in P, K, Mg, Ca, Fe, Zn, B, Cd and Pb, while carrot juices were having the highest level of S and Na (tab. 1, 2, 3). The red beet juices were the rich source of Mg, Zn, Cu and Mn in comparison to carrot juices.

Macronutrients. Nitrogen. Worthington [2001] summarized the results of 41 studies comparing nitrate levels of organic and conventional foods and found 127 cases where nitrate levels were higher in conventional foods, 43 cases where nitrate levels were higher in organic foods, and 6 cases where no difference was observed. On conventional farms the majority of nitrogen available to plants in the production is applied as a synthetic fertilizer, which is easily and rapidly available for plant. In Benbrook [2008] study across 18 matched pairs organic/conventional product, nitrate level in the conventional samples were higher in 83% of the pairs. At organic farms, nitrogen is supplied in a organic matter based fertilizers, and N fixed by legumes from nitrogen in the air. These forms and sources of nitrogen are slowly delivered and available to the plant [Lemaire et al. 2008].

Table 1. Mean nitrate, ammonium nitrogen and macroelement content (mg kg^{-1} f.m.) of investigated juices as influenced by different species
Tabela 1. Wpływ gatunku na średnią zawartość azotu azotanowego, amonowego oraz makroelementów (mg kg^{-1} ś.m.) w badanych sokach warzywnych

Species Gatunek	$N\text{-}NO_3$	$N\text{-}NH_4$	Ca	K	Mg	P	S
Celery – Seler	97.3 b	84.1 b	224.9 b	4098 c	280.7 c	897.9 b	123.6 a
Carrot – Marchew	21.8 ab	76.7 b	64.8 a	2306 a	135.6 a	378.0 a	153.3 b
Red Beet – Burak	419.4 c	137.1 c	73.2 a	2676 b	189.5 b	346.2 a	124.7 a

Table 2. Microelement content (mg kg-1 f.m.) of investigated juices as influenced by different species
Tabela 2. Wpływ gatunku na średnią zawartość mikroelementów (mg kg^{-1} ś.m.) w badanych sokach warzywnych

Species Gatunek	Fe	Zn	Cu	Mn	B
Celery – Seler	66.7 b	4.02 b	1.32 c	5.43 c	2.27 c
Carrot – Marchew	3.48 a	2.05 a	0.56 a	0.63 a	0.76 b
Red Beet – Burak	4.57 a	3.68 b	0.79 b	3.47 b	0.10 a

Table 3. Sodium, strontium and heavy metals content (mg kg^{-1} f.m.) of investigated juices as influenced by different species
Tabela 3. Wpływ gatunku na średnią zawartość metali ciężkich (mg kg^{-1} ś.m.) w badanych sokach

Species Gatunek	Na	Sr	Cd	Pb	Ni
Celery – Seler	171.4 a	0.66 b	0.10 c	0.073 b	0.21 a
Carrot – Marchew	363.9 b	0.17 a	0.06 b	0.009 a	0.18 a
Red Beet – Burak	267.3 ab	0.22 a	0.03 a	0.008 a	0.14 a

In our study, the highest nitrates content was proved for red beet juices (419.4 mg $N\text{-}NO_3$ kg^{-1} FW), followed by celery (97.3 mg $N\text{-}NO_3$), and carrot (21.8 mg $N\text{-}NO_3$). As compared to organic ones, the higher level of nitrates was found in conventional carrot juice (tab. 4, 5 and 6). Ammonium content (N-NH_4) was influenced by both of investigated factors: species and cultivation methods. The highest level of N-NH_4 was detected in red beet juices (137 mg N-NH_4 kg^{-1} FM), whereas celery and carrot juices contained 84.1 mg and 76.7 mg N-NH_4 respectively. Significantly higher N-NH_4 amounts were observed for all conventionally vegetable juices than for organic (tab. 4, 5 and 6). Conventional juices contained twice and more ammonium ions as compared to 'bio' juices. Organic crop often experience limited macronutrients, mainly nitrogen and phosphorus availability particularly during periods with low biological activity reduced by low soil temperature or water deficient [Lammerts von Bueren et al. 2010]. Lairon [2010] demonstrate in a review based on the French Agency for Food Safety (AFSSA) report that organic vegetables contain about 50% less nitrates in relation to conventional ones. This is in agreement with study of Woese et al [1997], Rembiałkowska [2000a, 2003], Rembiałkowska et al. [2001], Györéné et al. [2006] and Amarante et al. [2008],. The lower nitrates in organic carrot and beetroots proved also Abele [1987] and Kopp [1992].

Table 4. Nitrate, ammonium nitrogen and mineral element content (mg kg^{-1} f.m.) of juices made from organically and conventionally produced carrots

Tabela 4. Wpływ sposobu uprawy na średnią zawartość azotu azotanowego, amonowego oraz makroelementów (mg kg^{-1} ś.m.) w soku z marchwi

Element Składnik %	Cultivation method Metoda uprawy		Element składnik mg kg^{-1}	Cultivation method Metoda uprawy	
	organic ekologiczna	conventional konwencjonalna		organic ekologiczna	conventional konwencjonalna
N-NO_3	11.7 ± 13.6 a	37.6 ± 20.7 a	Fe	3.38 ± 0.76 a	3.81 ± 1.05a
N-NH_4	49.4 ± 28.0 a	119 ± 68.9 b	Zn	1.98 ± 0.32 a	2.25 ± 0.51a
Ca	67.9 ± 11.5 a	54.4 ± 9.0 a	Cu	0.53± 0.05 a	0.66 ± 0.07 b
K	2369 ± 408 a	2099 ± 297 a	Mn	0.61 ± 0.12a	0.73 ± 0.27 a
Mg	126 ± 14 a	166 ± 5b	B	0.72 ± 0.18 a	0.91 ± 0.14 a
P	376 ± 39 a	384 ± 64 a	Cd	0.05 ± 0.02 a	0.09 ± 0.03 b
S	141 ± 15 a	194 ± 13 b	Pb	0.009 ± 0.004 a	0.010 ± 0.003a
Na	346 ± 198 a	423 ± 80 a	Ni	0.16 ± 0.07 a	0.29 ± 0.08 b
Sr	0.19 ± 0.09 a	0.08 ± 0.02 a			

Phosphorus and potassium. The cultivation method significantly influenced phosphorus content only in the case of red beet (tab. 5). Juices made from organic beets contained more P (381 mg P kg^{-1}) than conventional (207 mg P kg^{-1}). These results not confirm the conclusions of Mader et al. [1993] and Worthington [2001] who proved lower level of phosphorus and nitrogen in beetroot in biological systems. In contrast, Weibel et al. [2000] identified fruit samples from organic orchard had found P-content 31% higher than from conventional ones. Generally, farmyard manure, compost and crop residues as used in organic farming and slow-releasing mineral fertilizers such as rock phosphate may promote arbuscular mycorrhizal fungi and higher nutrient-use efficiency can be observe [Hildermann et al. 2010].

Although some differences in potassium content were found, they were not statistically significant (tab. 4, 5 and 6). Benbrook et al. [2010] compared 32 matched pairs organic/conventional and summarized that level of potassium in conventional plant samples was higher in 58% of the pairs. However, Abele [1987] pointed out higher K content in organic vegetables. Also Rembiałkowska [2000a] found organically grown white cabbage contained more (35%) potassium than conventionally.

Table 5. Nitrate, ammonium nitrogen and mineral element content (mg kg^{-1} f.m.) of juices made from organically and conventionally produced red beets

Tabela 5. Wpływ sposobu uprawy na średnią zawartość azotu azotanowego, amonowego oraz makroelementów (mg kg^{-1} ś.m.) w soku z buraka

Element Składnik %	Cultivation method Metoda uprawy		Element składnik mg kg^{-1}	Cultivation method Metoda uprawy	
	organic ekologiczna	conventional konwencjonalna		organic ekologiczna	conventional konwencjonalna
$N\text{-}NO_3$	229 ± 189 a	846 ± 458 b	Fe	4.73 ± 1.25 a	3.92 ± 0.07 a
$N\text{-}NH_4$	110 ± 53.7 a	199 ± 23.0 b	Zn	3.62 ± 1.00 a	3.91 ± 0.07a
Ca	76.9 ± 25.3 a	58.1 ± 7.5 a	Cu	0.81 ± 0.08 a	0.71 ± 0.05 a
K	2685 ± 215 a	2641 ± 60 a	Mn	3.75 ± 0.71 b	2.37 ± 0.17 a
Mg	179 ± 18.3 a	231 ± 4.8 b	B	0.09 ± 0.05 a	0.13 ± 0.03 a
P	381 ± 29 b	207 ± 15 a	Cd	0.02 ± 0.008a	0.05 ± 0.003 b
S	126 ± 8 a	119 ± 8 a	Pb	0.009 ± 0.003 a	0.002 ± 0.002 a
Na	191 ± 72 a	574 ± 82 b	Ni	0.14 ± 0.007a	0.15 ± 0.001 a
Sr	0.24 ± 0.12 a	0.11 ± 0.02 a			

Potassium fertilizers used in conventional system of production dissolve easily in soil affecting plant with great quantities of K in tissues [Domagała-Świątkiewicz 2005].

Calcium, magnesium and sulphur. There were no significant effects of production system on calcium concentration in carrot and red beet juices (tab. 4, 5). Production method had an impact on Ca content only in celery juice. Organic ones were having twice more of this element in comparison to conventional (247 mg Ca kg^{-1} vs. 129 mg Ca kg^{-1}) (tab. 6). Contrary, Rembiałkowska [2000a] demonstrated less calcium level (19%) in organic white cabbage than conventional.

Amarante et al. [2008] report the organic management system resulted in lower concentration of K, Mg and N in fruit. This is agree with results of our study showing organic juices made from carrot and red beet revealed lower levels of magnesium than conventional. Contrary, Lairon [2010] reported that organic plant products contain more magnesium and iron. Also Kopp [1992] measured higher Mg content in organic root vegetables. Worthington [2001] found significantly more Mg, Fe and P in organic than conventional crops. The Author demonstrated for each of the significant nutrients, the organic crop had a higher nutrient content in more than half of the comparisons.

The concentration of sulphur in examinated juices was similar and ranged between 153.3 (carrot) to 124.7 mg S kg^{-1} FM (red beet) (tab. 1). Sulphur amounts measured for organic carrot juices were lower (141 mg S kg^{-1}) as compared to conventional (194 mg S kg^{-1}) (tab. 4). However, the opposite tendency was proved for celery (133 mg S kg^{-1} *vs*. 86 mg S kg^{-1}) (tab. 6). These received results are difficult to explain. In biological management systems organic matter based fertilizers added to soil release plant available sulphates during biological and biochemical mineralization. Mineralization is strictly dependent on microbial activity usually higher in soil amendment organic fertilizers. Biologically active soil will decompose organic matter faster. In conventional systems S deficiency has been reported in many European countries caused by the environmental control of sulphur dioxide emission and using low S-containing fertilizers [Eriksen 2005].

Microelements, sodium and strontium. The method of plant cultivation did not influence the sodium content in carrot and celery (tab. 4, 6). Nevertheless, the conventional red beet juices contained fourfold more Na than 'bio' juices (574 mg Na kg^{-1} *vs*. 191 mg Na kg^{-1}). Lampkin [1990] summarized the 12-years study of Schuphan [1974] demonstrates higher concentration of Fe, K, Ca and P and lower levels of sodium in organic vegetables.

Table 6. Nitrate, ammonium nitrogen and mineral element content (mg kg^{-1} f.m.) of juices made from organically and conventionally produced celery

Tabela 6. Wpływ sposobu uprawy na średnią zawartość azotu azotanowego, amonowego oraz makroelementów (mg kg^{-1} ś.m.) w soku z selera

Element Składnik %	Cultivation method Metoda uprawy		Element składnik mg kg^{-1}	Cultivation method Metoda uprawy	
	organic ekologiczna	conventional konwencjonalna		organic ekologiczna	conventional konwencjonalna
$N-NO_3$	104 ± 105 a	88.9 ± 60.0 a	Fe	75.1 ± 34.1 a	33.2 ± 15.0 a
$N-NH_4$	52.5 ± 21.3 a	126 ± 20.1 b	Zn	4.20 ± 0.47 a	3.29 ± 0.36 a
Ca	248.8 ± 41 b	129.2 ± 21 a	Cu	1.40 ± 0.14 b	1.01 ± 0.10 a
K	4156 ± 159 a	3863 ± 146 a	Mn	6.06 ± 1.45 a	2.93 ± 0.70 a
Mg	284.8 ± 23 a	264.6 ± 21 a	B	2.05 ± 0.36 a	3.18 ± 0.55 b
P	921 ± 89 a	806 ± 77 a	Cd	0.106 ± 0.03 a	0.086 ± 0.02 a
S	133 ± 5 b	86 ± 3 a	Pb	0.08 ± 0.04 b	0.03 ± 0.0 a
Na	154 ± 37 a	242 ± 58 a	Ni	0.214 ± 0.55 a	0.222 ± 0.57 a
Sr	0.73 ± 0.15 a	0.41 ± 0.08a			

Inorganic environmental contaminants, such as heavy metals, are presented in food accidentally as a result of human activity or from natural sources [Kabata-Pendias and Pendias 1999]. Application of fertilizers, lime and other materials to soils can affect bioavailability by introducing trace elements into the soil and/or adsorptive phases causing redistribution of trace elements into different chemical pools or chemical “species” [Basta et al. 2005]. Generally, in presented study there are no major differences in respect of the levels of the heavy metals between vegetables juices made from material from conventional and organic production (tab. 4, 5 and 6). These results are consistent with those of Woese et al. [1997]. No significant differences in strontium as well as in zinc content were recorded. However, some studies [Leclerc et al. 1991] showed higher Zn content in conventional celery. It was linked with a pesticide usage. Mean iron content did not varied significantly, however we observed a tendency to higher Fe level for organic celery juices. Higher level of Fe in organic food demonstrated Lampkin [1990] and Worthington 2001].

Although the copper content was higher for conventional carrot juices (0.66 mg Cu kg^{-1} as compared to 0.53 mg Cu kg^{-1} for organic carrot), the reverse was true for celery (1.01 and 1.40 mg Cu kg^{-1}, respectively) (tab. 4 and 6). Buffered copper sulphate could be used as a fungicide in organic farming. No differences in S concentration in juices were found for red beet. Organic production slightly favored higher manganese content in red beet juices. No definitive influence of plant methods cultivation (organic vs. conventional) on boron concentration in vegetable juices was found. In carrot and red beet juices no statistically differences was observed, nevertheless in conventional celery juice higher B level was detected than in organic ones.

Heavy metals. As far as heavy metals content is concerned, the higher cadmium content for juices made from conventional carrot and red beet was measured. Phosphate fertilizers often contaminated by cadmium. Also, liming materials derived from industrial waste can contain a number of heavy metals. As a consequence, it might be expected that organic production without industrial waste and trace mineral fertilizers would guarantee lower amounts of heavy metals. The same reported Rembiałkowska [2000a] in organic carrot. Moreover, conventional carrot juices contained more nickel (0.29 mg Ni kg^{-1}*vs*. 0.16 mg Ni kg^{-1} for organic) (tab. 4). On the contrary, organic production increased lead accumulation in red beet and celery (tab. 5, 6). The pH and dissolved organic carbon (DOC) are the major factors controlling the speciation in soil and availability for plants of Pb [Kabata-Pendias and Pendias 1999]. Lead is totally acidolabile in the soil. In the presented study pH of soil from organic farms was lower and organic matter was higher than from conventional (data not presented). This might explain observed results in red beet and celery juices.

CONCLUSION

The presented study confirmed the superiority of organic juices in terms of higher Ca content and lower Cd and nitrates (carrot) level. The impact of cultivation method organic/conventional on the rest of investigated elements was slight or inconsistent. None of the samples analyzed were found to be above regulatory limits for heavy metals. Organic production provides agronomic and environmental benefits, conserves natural resources, reduces the pollution of air, water, soil and food. Poland with clean soil environment and more extensive cultivation method is perfectly suited for organic farming.

However, a lot of research is needed in improving organic agriculture, and thus, more study is required to clarify the exact relationship between cultivation method and nutritional quality of plants. The most important benefits for carrying out nutrient research at this area are correcting misleading information, already exist in public opinion generated on the basis of the limited published information for organic foods. Consumers who are willing to pay the price premium for organic products need more unbiased information on its nutritional composition.

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PORÓWNANIE SKŁADU MINERALNEGO SOKÓW Z KORZENI SPICHRZOWYCH MARCHWI, SELERA I BURAKA ĆWIKŁOWEGO UPRAWIANYCH METODAMI EKOLOGICZNĄ I KONWENCJONALNĄ

Streszczenie. Od wielu lat na świecie obserwuje się wzrost spożycia żywności ekologicznej. Polska, z relatywnie czystym środowiskiem i mało intensywnym rolnictwem, jest krajem szczególnie predestynowanym do prowadzenia upraw metodami ekologicznymi. Lepsza jakość odżywcza żywności ekologicznej w porównaniu z żywnością konwencjonalną jest tematem wielu kontrowersji. Badania dotyczące porównania wpływu uprawy konwencjonalnej i ekologicznej na właściwości soków z marchwi, selera i buraka ćwikłowego prowadzone były w roku 2009. Analizami objęto 39 plantacji zlokalizowanych w czterech województwach: małopolskim, podkarpackim, mazowieckim oraz lubelskim. Wszystkie gospodarstwa prowadzące uprawy ekologiczne posiadały ważne certyfikaty zgodne z rozporządzeniem UE 2092/91. Z pobranych surowców warzywnych tłoczono w prasie hydraulicznej soki mętne. Po mineralizacji mikrofalowej soków w HNO_3 oznaczono w nich zawartość składników pokarmowych: P, K, Mg, Ca, S, Fe, Zn, Mn, Cu, B, jak również Na, Cd, Pb i Ni metodą ICP-OES. Ponadto oznaczono zawartość azotu amonowego i azotanowego metodą FIA. Soki z selera posiadały największą zawartość P, K, Mg, Ca, Fe, Zn, B oraz metali ciężkich Cg i Pb, podczas gdy soki z marchwi zawierały najwięcej S i Na. Generalnie konwencjonalny sposób uprawy warzyw istotnie zwiększał zawartość $N\text{-}NO_3$ (tylko w marchwi), Mg i Na w sokach, natomiast w sokach uzyskanych z warzyw uprawianych metodą ekologiczną wykazano najwięcej Ca. Istotnie wyższe zawartości $N\text{-}NH_4$ oznaczono w sokach z surowców konwencjonalnych niż ekologicznych. Wyższe zawartości kadmu stwierdzono w sokach z marchwi i buraka ćwikłowego z surowców konwencjonalnych w stosunku do ekologicznych, ale analiza statystyczna nie potwierdziła istotności obserwowanych różnic.

Słowa kluczowe: rolnictwo ekologiczne, wartość odżywcza, soki warzywne, azotany, makro- i mikroelementy

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