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ACCUMULATION OF ELEMENTS IN SOME ORGANICALLY GROWN ALTERNATIVE HORTICULTURAL CROPS IN LITHUANIA

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Abstract. Oil pumpkin (*Cucurbita pepo* L. var. *styriaca*) seeds and Jerusalem artichoke (*Helianthus tuberosus* L.) tubers are alternative horticultural products containing important biologically active components. The objective of the three-year study was to determine dry matter and micro-, macroelements accumulation in seeds of oil pumpkin *Cucurbita pepo* L. var. *styriaca* – 'Miranda', 'Golosemiannaja', 'Herakles', 'Danaja', 'Olga'; and in tubers of Jerusalem artichoke (*Helianthus tuberosus* L.) – 'Rubik', 'Albik', 'Sauliai' and selection lines Nr. 05-1, Nr. 05-7. Macro- and microelements were determined by mass spectrometer. The highest amount of Ca, K, Fe, Mn, Se and Al was accumulated in oil pumpkin seeds of cv. 'Miranda' and amount of Ca, Mg and Se was identified in cv. 'Rubik' and K, Na, in 'Albik' Jerusalem artichoke tubers.

Key words: mineral elements, dry matter, oil pumpkin seeds, Jerusalem artichoke tubers

INTRODUCTION

In Lithuania recently has become increasingly popular non-traditional crops such oil pumpkin seeds, Jerusalem artichoke, use for improving the better quality food, because they are wealthy in micro- and macroelements. There are so much raw materials of animal and vegetable which are little studied in Lithuania, also the traditional materials used highly irrational. Oil pumpkin (*Cucurbita pepo* L. var. *styriaca*) and Jerusalem artichoke (*Helianthus tuberosus* L.) are alternative, not widely spread horticultural plants, containing components important for humans. The suitability of oil pumpkin

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seeds for curing various human diseases was documented [Danilcenko et al. 2009]. This vegetable is valued not only for its nutritious and medical qualities but also for simple growing technology. Compared to other vegetables, cucurbits produce the biggest yield [Brech 2004]. Studies on nutritive value of Jerusalem artichoke tubers showed that they contain many biologically active components and show high dry matter content [Ben Chekroun et al. 1996, Praznik et al. 1998, Cieślik et al. 2005, Danilcenko et al. 2008]. However, there are few data on mineral profile of the crops, especially for organically grown produce.

According to the researches food quality can be characterized by the content of mineral elements. The elements are involved in many important body enzymatic reactions, bone mineralization, as well as in protection of cells and lipids in biological membranes. They are also construction elements of teeth, provide electric signal transfers, and are cofactor in oxygen transport [Kang et al. 2007, Ekholma et al. 2007]. World Health Organization (WHO) published recommendations for the daily intake (RDI) of minerals [FAO/WHO 2004]. Some of the elements may constitute a potential health risk when are consumed in amounts above the permitted ones [Melų et al. 2008]. Calcium, magnesium, sodium, potassium, sulphur, phosphorus, and chlorine have a recommended daily intake above 100 mg per a body. Microelements, i.e. minerals required in small amounts (less then 100 mg per day) include copper, zinc, iron, manganese, chromium, selenium, boron, cobalt and molybdenum. Arsenic, beryllium, mercury, cadmium, lead, and aluminium are toxic elements in a high dose [Kang et al. 2007, Watts 1995].

The main objective of this study was to investigate in Lithuania organically grown the non-traditional crops (oil pumpkin seeds and Jerusalem artichoke tubers) quality indentifying the content of macro- and microelements.

MATERIALS AND METHODS

The experiments were carried out in 2007–2009 at the Experimental Station of the Lithuanian University of Agriculture in Kaunas, in the certificated organic field. Plants were grown in the soil of the following characteristics: limnoglacial loam on moraine loam, carbonate deeper gleyic luvisol (*Calearie Luvisol*), slightly neutral and neutral, medium humus content, phosphorus-rich and potassium-rich. The field was not fertilized with a mineral fertilizer. The soil was drained by drainage, the relief was artificially levelled. Following cultivars were chosen for the investigations: *Cucurbita pepo* L. var. *styriaca* – cvs. 'Miranda', 'Golosemiannaja', 'Herakles', 'Danaja', 'Olga'; *Helianthus tuberoses* L. – cvs. 'Rubik', 'Albik', 'Sauliai' and breeding lines No. 05-1 and No. 05-7.

Dry matter was determined with drying method. Macro- and microelements in the samples were determined by a mass spectrometer (Thermo Finnigan MAT, Bremen, Germany). Following macroelements were determined: calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and microelements: iron (Fe), manganese (Mn), boron (B), copper (Cu), chromium (Cr), selenium (Se), vanadium (V), zinc (Zn), aluminium (Al), nickel (Ni), lead (Pb).

The data obtained were statistically analyzed by Anova (STATISTICA software). Standard deviation and the least significant difference at the 95% probability level were calculated with Fisher's LSD test. Data presented in tables are mean values of the three years of study.

RESULTS AND DISCUSSION

Content of dry matter in seeds of oil plants depends on a plant genotype, weather conditions and other factors. According to literature, dry matter in oil pumpkin seeds ranges from 86 to 94% [Tarek et al. 2001, Ekpedeme et al. 2000] and from 20 to 32% in Jerusalem artichoke tubers [Ben Chekroun 1996, Kotshniev and Kalinitsheva 2002]. Our results showed that dry matter content in the case of both plants depended on the cultivar. Considerably higher dry matter content was accumulated oil pumpkin seeds of cvs. 'Herakles', 'Danaja' and 'Olga' matter and the lowest in seeds of cv. 'Miranda' (tab. 1). Dry matter in Jerusalem artichoke tubers was very similar and varied from 20.23 to 24.65%, depended on the cultivar and the highest and the lowest contents were accumulated in cvs. 'Rubik' and 'Albik', respectively (tab. 2).

Table 1. Dry matter in seeds of oil pumpkin cultivars, %
Tabela 1. Sucha masa nasion dyni oleistej badanych odmian, %

Cultivars – Odmiana	Dry matter – Sucha masa
Herakles	94.49 ± 0.27[a]
Golosemiannaja	93.72 ± 0.12 [b]
Miranda	90.83 ± 0.11[c]
Danaja	95.02 ± 0.29 [a]
Olga	94.18 ± 0.22 [a]

Means followed by the same letter are not significantly different at $P \leq 0.05$
Średnie oznaczone tymi samymi literami nie różnią się istotnie przy $p \leq 0,05$

Table 2. Dry matter in tubers of Jerusalem artichoke cultivars, %
Tabela 2. Sucha masa bulw topinamburu badanych odmian, %

Cultivars – Odmiana	Dry matter – Sucha masa
Albik	24.65 ± 0.79 [a]
Rubik	20.23 ± 1.24 [c]
Sauliai	21.93 ± 0.07 [b]
Nr. 05-1	22.59 ± 1.54 [b]
Nr 05-7	22.23 ± 0.32 [b]

Means followed by the same letter are not significantly different at $P \leq 0.05$
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According to the micro- and macroelements content of the raw material accumulation can predict a positive or adverse effects on human health. Four macro- and 11 microelements were determined in oil pumpkins seeds and Jerusalem artichoke tubers. The elements featuring the greatest content and being the most important in human nutrition are discussed below.

Calcium is present in human bones and teeth [FAO/WHO 2004, Galan et al. 2002]. The highest content of Ca 896,18 mg kg^{-1} was found in seeds of cv. 'Miranda'. Content of Ca in seeds of cvs. ‘Golosemiannaja’ and ‘Danaja’ was significantly lower (tab. 3). Analysis of Ca in Jerusalem artichoke tubers showed that the greatest content was characteristic in tubers of cv. ‘Sauliai’ (1603 mg kg^{-1}). Tubers of other cultivars showed similar content of the element (tab. 4).

Table 3. Macroelements content in seeds of oil pumpkin cultivars, mg kg^{-1} d.m.
Tabela 3. Zawartość makroelementów w nasionach dyni oleistej badanych odmian, mg kg^{-1} s.m.

Macroelement Makroelement	Cultivar – Odmiana				
	Herakles	Golosemiannaja	Miranda	Danaja	Olga
Ca	452.73 ± 18.17^{c}	456.98 ± 50.51^{c}	896.18 ± 108.05^{a}	468.60 ± 69.25^{c}	510.00 ± 47.15^{b}
Mg	4665.01 ± 326.60^{b}	4649.87 ± 557.39^{b}	4749.09 ± 363.30^{b}	4575.75 ± 468.50^{b}	5097.00 ± 344.1^{a}
K	103.55 ± 12.11^{b}	95.09 ± 11.45^{c}	120.58 ± 12.53^{a}	102.15 ± 10.87^{b}	105.40 ± 13.50^{b}
Na	2.88 ± 0.58^{a}	2.88 ± 0.58^{a}	2.99 ± 0.84^{a}	1.71 ± 0.83^{b}	3.01 ± 0.89^{a}

Means followed by the same letter are not significantly different at $P \leq 0.05$
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Almost all human tissues contain a small amount of magnesium. Magnesium is essential part of many enzymes responsible for transfer of energy. Cereals and vegetables contribute for more than half daily rates of Mg [FAO/WHO 2004]. Seeds of oil pumpkin of cv. ‘Olga’ showed significantly higher content of the Mg compared to seeds of the other four pumpkin cultivars (tab. 3). In the case of Jerusalem artichoke tubers of cvs. ‘Albik’, ‘Rubik’ and ‘Sauliai’ showed higher content of the element (864.41 879.69 and 734.24 mg kg^{-1} d.m., respectively) (tab. 4).

Potassium plays an important role in muscle contraction and nerve transmission, also in maintaining the body's proper, electrolyte and pH balance. When potassium is deficient in the diet, activity of both muscles and nerves can become compromised [Kang et al. 2007]. The ratio of natrium and potassium is very important to human body. The diet that is high in natrium and low in potassium can negatively impact potassium status. Many health experts recommend taking in at least free times more potassium than natrium [Adrogué and Madias 2007].

The higher accumulation of K was determinate in seeds of pumpkin cv. ‘Miranda’, whereas significantly lower for seed of ‘Golosemiannnaja’ (120.58 and 95.09 mg kg^{-1}, respectively) (tab. 3). According results in various cultivars of Jerusalem artichoke the highest amount of K was accumulated in cv. ‘Albik’ tubers and the lowest – in ‘Rubik’ tubers (31.26 and 29.98 mg kg^{-1}, respectively) (tab. 4).

Content of sodium in the crops was very low compared to contents of magnesium and calcium. The lowest content of Na was identified in seeds of cvs. ‘Danaja’, as well as in Jerusalem artichoke tubers of ‘Sauliai’, lines No. 05-1 and No. 5-7 (tab. 3 and 4).

Table 4. Macroelements content in tubers of Jerusalem artichoke cultivars, mg kg^{-1} d.m.
Tabela 4. Zawartość makroelementów w bulwach topinamburu badanych odmian, mg kg^{-1} s.m.

Macroelement Makroelement	Cultivar – Odmiana				
	Albik	Rubik	Sauliai	Nr. 05-1	Nr. 05-7
Ca	1442.31 ± 197.10^b	1421.40 ± 40.45^b	1603.98 ± 90.90^a	1346.48 ± 18.13^b	1339.32 ± 60.84^b
Mg	864.41 ± 214.50^a	879.69 ± 130.52^a	734.24 ± 127.20^a	703,26 ± 123.03^b	676.08 ± 127.84^b
K	34.24 ± 0.42^a	29.98 ± 0.71^b	32.80 ± 0.55^a	32.84 ± 1.12^a	31.26 ± 0.7^b
Na	23.60 ± 5.27^a	16.73 ± 0.50^a	12.30 ± 2.14^b	11.16 ± 1.12^b	10.26 ± 1.89^b

Means followed by the same letter are not significantly different at P ≤ 0.05
Średnie oznaczone tymi samymi literami nie różnią się istotnie przy p ≤ 0,05

Iron is an important microelement because serves as carrier of oxygen in haemoglobin and is a part of important enzyme systems in various tissues [FAO/WHO 2004]. Significantly higher content of Fe was characteristic to seeds of cvs. 'Miranda' compare with the over cultivars (tab. 5). There is significant difference between various cultivars of Jerusalem artichoke tubers. The biggest amount of this element has been determinated in tubers of breeding line No. 05-7, the lowest – in No. 05-1 (77.12 and 36.84 mg kg^{-1}, respectively) (tab. 6).

Table 5. Microelements content in seeds of oil pumpkin cultivars, mg kg^{-1} d.m.
Tabela 5. Zawartość mikroelementów w nasionach dyni oleistej badanych odmian, mg kg^{-1} s.m.

Microelement Mikroelement	Cultivar – Odmiana				
	Herakles	Golosemiannaja	Miranda	Danaja	Olga
Fe	100.19 ± 13.87^b	99.17 ± 16.73^b	112.87 ± 12.71^a	100.99 ± 8.50^b	105.00 ± 14.17^b
Mn	41.42 ± 1.75^b	43.80 ± 1.70^a	43.76 ± 0.34^a	40.69 ± 1.19^b	39.00 ± 1.42^c
B	11.77 ± 1.09^b	11.26 ± 1.05^c	11.44 ± 0.62^b	12.60 ± 0.84^a	12.00 ± 0.93^b
Cu	11.59 ± 0.58^a	11.63 ± 0.52^a	9.36 ± 0.91^b	11.31 ± 0.97^a	11.00 ± 0.72^a
Cr	0.28 ± 0.06^a	0.11 ± 0.06^b	0.21 ± 0.07^b	0.01 ± 0.00^c	0.11 ± 0.08^b
Se	0.01 ± 0.00^c	0.04 ± 0.01^b	0.09 ± 0.01^a	0.09 ± 0.03^a	0.04 ± 0.01^b
V	0.01 ± 0.00^b	0.01 ± 0.00^b	0.03 ± 0.01^a	0.01 ± 0.00^b	0.02 ± 0.01^b
Zn	65.45 ± 0.64^a	64.42 ± 1.91^a	54.81 ± 2.31^b	55.65 ± 3.41^b	39.00 ± 2.41^c
Al	7.53 ± 1.91^b	6.68 ± 1.28^c	8.83 ± 1.49^a	5.63 ± 1.36^c	8.40 ± 1.51^a
Ni	1.83 ± 0.24^b	1.66 ± 0.49^c	2.44 ± 0.36^a	2.26 ± 0.54^b	2.01 ± 0.42^b
Pb	0.01 ± 0.00^a	0.01 ± 0.00^a	0.02 ± 0.01^a	0.01 ± 0.00^a	0.01 ± 0.00^a

Means followed by the same letter are not significantly different at P ≤ 0.05
Średnie oznaczone tymi samymi literami nie różnią się istotnie przy p ≤ 0,05

Manganese is an essential element for enzymes, which are involved in carbohydrate, fat and protein metabolism, formation of connective tissue, bone growth and reproduction function [Galan et al. 2002, Kang et al. 2007]. Considerably highest amount of Mn accumulated in oil pumpkin seeds of cvs. 'Golosemiannnaja' and 'Miranda' (43.80 and 43.76 mg kg^{-1}, respectively) (tab. 5). The lowest amount of this element was determinate in 'Olga' seeds (39 mg kg^{-1}). Similarly the content of Mn was accumulated in all cultivars of Jerusalem artichoke tubers and varied from 2.41 to 3.84 mg kg^{-1} (tab. 6).

Selenium is an integral component of different enzymes, participates in antioxidant protection of cells and plays other important functions, but is present in a very narrow concentration range. Outside this concentration range deficiency or toxicity occurs [Pyrzyńska 2009, Sager 2006, Al-Saleh et al. 2006]. Recommended daily intake of Se for adults is 25 µg for women and 33 µg for men [FAO/WHO 2004]. Accordiour data's high accumulation of Se was characteristic for seeds of pumpkin cvs. 'Miranda' and 'Danaja' (0.09 mg kg^{-1}), whereas significantly lower for seeds of cvs. 'Golosemiannaja' and 'Olga' (0.04 mg kg^{-1}) (tab. 5). Among Jerusalem artichoke cultivars Se content was identified only in tubers of cv. 'Rubik' and in breeding lines No. 05-1 (0.02 and 0.01 mg kg^{-1} respectively) (tab. 6).

Table 6. Microelements content in tubers of Jerusalem artichoke cultivars, mg kg^{-1} d.m.
Tabela 6. Zawartość mikroelementów w bulwach topinamburu badanych odmian, mg kg^{-1} s.m.

Microelement Mikroelement	Cultivar – Odmiana				
	Albik	Rubik	Sauliai	Nr. 05-1	Nr. 05-7
Fe	68.65 ± 7.96^{b}	66.88 ± 2.39^{b}	61.15 ± 14.36^{b}	36.84 ± 11.78^{c}	77.12 ± 6.09^{a}
Mn	3.25 ± 1.19^{a}	3.15 ± 0.28^{a}	3.22 ± 0.68^{a}	2.41 ± 0.67^{a}	3.84 ±1.21^{a}
B	9.11 ± 0.17^{b}	9.79 ± 1.23^{a}	8.74 ± 0.94^{b}	8.38 ± 0.77^{b}	7.37 ± 0.93^{c}
Cu	3.27 ± 0.35^{a}	3.59 ± 0.33^{a}	4.09 ± 0.97^{a}	3.19 ± 0.10^{a}	3.61 ± 0.40^{a}
Cr	3.27 ± 0.35^{a}	3.59 ± 0.33^{a}	4.09 ± 0.97^{a}	3.19 ± 0.10^{a}	3.61 ± 0.40^{a}
Se	0.00 ± 0.00^{b}	0.02 ± 0.01^{a}	0.00 ± 0.00^{b}	0.01 ± 0.01^{b}	0.00 ± 0.00^{b}
V	0.23 ± 0.02^{a}	0.22 ± 0.04^{b}	0.22 ± 0.02^{b}	0.14 ± 0.02^{c}	0.21 ± 0.03^{b}
Zn	9.27 ± 2.93^{a}	8.60 ± 1.09^{a}	8.55 ± 1.85^{a}	7.91 ± 1.45^{a}	8.85 ± 1.91^{a}
Al	79.66 ± 6.06^{a}	76.18 ± 2.35^{a}	65.92 ± 15.44^{a}	38.05 ± 12.70^{b}	80.13 ± 11.14^{a}
Ni	0.64 ± 0.19^{a}	0.70 ± 0.02^{a}	0.58 ± 0.29^{a}	0.32 ± 0.13^{b}	0.56 ± 0.29^{a}
Pb	0.06 ± 0.03^{a}	0.04 ± 0.00^{a}	0.03 ± 0.01^{a}	0.02 ± 0.01^{a}	0.04 ± 0.00^{a}

Means followed by the same letter are not significantly different at $P \leq 0.05$
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Heavy metals and their compounds are generally mean higher levels of dangerous to humans, plants and animals that may have both acute and chronic impacts [Onianwa et al. 2001]. The effects of heavy metals to the health can be complex: they can cause poisoning, have carcinogenic, mutagenic, teratogenic, embryotoxic effects. However, heavy metals as other elements are necessary for the human body, but most importantly, not to exceed the permissible limits of metals concentrations [Kang et al. 2007, Watts 1995]. In our study were to investigate microelements such as AL, Ni and Pb, but the amount of them does not exceed the limits specified in the Lithuanian hygiene norms [Lithuanian Hygiene Standard HN 54:2008].

There were reported close links between low amount of zinc and increased risk of cancer [Song et al. 2009]. But zinc is an important element in numerous proteins and plays an essential role in several cell functions [FAO/WHO 2004]. Our results showed that seeds of cvs. 'Herakles' and 'Golosemiannaja' accumulated the highest amount of

Zn compared to seeds of other oil pumpkin cultivars (tab. 5). Tubers of all Jerusalem artichoke cultivars accumulated similar amount of the element in all cultivars and varied from 7.91 to 9.27 mg kg^{-1} (tab. 6).

Some foods, such as tea and cereal crops, contain aluminium, but the greater amount of Al in food comes from additives. Al is naturally present in varying amounts in most foodstuffs and its level in plant crops is influenced by geographical region [Kathleen and Gura Pharm 2010]. Oil pumpkin seeds accumulated considerably low amount of Al (tab. 5). Significantly the lowest content of Al has been identified for oil pumpkin seeds of cvs. 'Golosemiannaja' and 'Danaja' (6.68 and 5.63 mg kg^{-1}, respectively) (tab. 6). According our research all tubers cultivars of Jerusalem artichoke accumulated significant amount and varied from 65.92 to 80.13 mg kg^{-1}, except tubers of breeding line No. 05-7 38.0 mg kg^{-1}.

CONCLUSIONS

1. The amount of dry matter was characterized by different cultivars of pumpkin oil seeds and Jerusalem artichoke. The highest amount of dry matter was estimated in 'Herakles', 'Danaja', 'Olga' and in tubers of cv. 'Albik'.
2. The highest level of Ca, K, Fe, Mn, Se, Al was accumulated in pumpkin oil seeds cv. 'Miranda' and Mg, Na in cv. 'Olga'.
3. The highest amount of Ca, Mg, Se was identified in Jerusalem artichoke tubers of cv. 'Rubik' and K, Na, Zn in cv. 'Albik' tubers. Mn and Zn in different cultivars of Jerusalem artichoke tubers was accumulated similarly.

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ZAWARTOŚĆ NIEKTÓRYCH PIERWIASTKÓW W WYBRANYCH ALTERNATYWNYCH ROŚLINACH OGRODNICZYCH UPRAWIANYCH METODĄ EKOLOGICZNĄ NA LITWIE

Streszczenie. Nasiona dyni oleistej (*Cucurbita pepo* L. var. *Styriaca*) i bulwy topinamburu (*Helianthus tuberosus* L.) stanowią alternatywny produkt dla tradycyjnie spożywanych warzyw. Zawierają one szereg cennych składników pod względem aktywności biologicznej. Celem trzyletnich badań było określenie zawartości mikro- i makroelementów w nasionach dyni oleistej i bulwach topinamburu uprawianych ekologicznie na Litwie. Wybrane do doświadczenia odmiany dyni były następujące – 'Miranda', 'Herakles', 'Golosemiannaja', 'Danaja', 'Olga', a topinamburu – 'Albik', 'Rubik', 'Sauliai' oraz linie hodowlane nr 05-1 i nr 05-7. Zawartość makro i mikroelementów określano za pomocą spektrometru masowego. Wyniki wskazują, że zawartość suchej masy była najwyższa w nasionach dyni 'Herakles', 'Danaja', 'Olga', a w bulwach topinamburu 'Albik'. Najwięcej Ca, K, Fe, Mn, Se akumulowały nasiona dyni oleistej 'Miranda', a Mg, Na – 'Olga'. Największą zawartość Ca, Mg, Se identyfikowano w bulwach topinamburu 'Rubik', a K, Na, – 'Albik'. Zawartość Mn i Zn w wybranych do doświadczeń bulwach odmian topinamburu prawie się nie różniła.

Słowa kluczowe: składniki mineralne, sucha masa, nasiona dyni oleistej, bulwy topinamburu

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