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ORIGINAL PAPER

CONTENT OF SELECTED MINERALS IN THE FRUIT OF SASKATOON BERRY (*AMELANCHIER ALNIFOLIA* NUTT.) GENOTYPES GROWN IN CENTRAL POLAND*

Dagmara Migut[1], Józef Gorzelany[1], Stanisław Pluta[3], Grzegorz Zaguła[2]

[1] Department of Agro and Food Production Engineering
[2] Department of Bioenergetics and Food Science
University of Rzeszów, Poland
[3] Department of Horticultural Crop Breeding
Research Institute of Horticulture, Skierniewice, Poland

Abstract

The study presents concentrations of various minerals in the fruit of four genotypes of Saskatoon berry (*Amelanchier alnifolia*) cultivated in central Poland. The fruit samples of two Polish clones (no. 5/6 and type S) and two Canadian cultivars (cvs.): Martin and Smoky, were used for examinations conducted in 2015-2016. Each year, the fruits used for the study were harvested manually at the optimal ripening phase, and immediately after harvest they were cooled, placed and stored in a freezer (-20°C) until the analysis of the composition was carried out. The above fruit genotypes were examined for the content of selected minerals on an ICP-OES Thermo iCAP Dual 6500 spectrometer, using a 3-point calibration curve for each element and optical adjustment based on internal models provided by yttrium and ytterbium ions. The Saskatoon berry fruit examined were found to have a high content of micro- and macroelements. Out of the elements determined, the highest values were recorded for the content of potassium, but phosphorus, magnesium and calcium were also pleniful. The iron and zinc content was lower than in the literature data. As for heavy metals, no presence of lead, cadmium and chromium was detected, and the berries contained only small amounts of nickel, molybdenum and copper. The findings showed that climate conditions during the years when the experiment was conducted affected the content of these minerals in analyzed fruit samples. Fruit of the testes Saskatoon berry genotypes may provide new functional food material to be used in the food industry and in production of dietary supplements.

Keywords: Saskatoon berry, microelements, macroelements.

Dagmara Migut, M.Sc. Eng., Department of Agro and Food Production Engineering, University of Rzeszow, Zelwerowicza Street 4, 35-601 Rzeszow, Poland. e-mail: migutdagmara@gmail.com
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INTRODUCTION

The Saskatoon berry (*Amelanchier alnifolia* Nutt.) is a plant in the family of Rosaceae, native to Canadian prairies and northern plains in the United States of America (Mazza, Cottrell 2008). There are many cultivars of this plant species, mainly grown in Canada and the USA, the most popular are Smoky, Honeywood, Thiessen, Northline and Martin (Hu et al. 2005, St-Pierre et al. 2005, Ozga et al. 2006, 2007, Mazza, Cottrell 2008, Rop et al. 2013, Lachowicz et al. 2017*a*)

The small fruit of the Saskatoon berry used for food related purposes, contains significant amounts of flavonoids (Jin et al. 2015) and other valuable antioxidants (Hu et al. 2005, Lavola et al. 2012). The Saskatoon berry fruit range in the diameter from 5 to 15 mm, and vary in colour from red to dark purple. Raw fruit are edible. They have a faint but sweet taste, resembling that of the northern highbush blueberry (*Vaccinium corymbosum*), with strong almond undertone added by the flavour of the seeds. These fruit contain numerous bioactive compounds, such as phenolic acids, flavonols, carotenoids, anthocyanins, pectins, as well as vitamins, e.g. tocopherol, pyridoxine, riboflavin, ascorbic acid, thiamine, carotene, and pantothenic acid, which play an important role in preventing chronic disorders, e.g. cancer, cardiovascular disorders, or neurodegenerative diseases (Mazza 1982, Green, Mazza 1986, Mazza 2005, Kwok et al. 2004, Bakowska-Barczak, Kołodziejczyk 2008, Rop et al. 2012, Gherbi 2011, Jurikova et al. 2013, Diaconeasa et al. 2015, Skrovankova et al. 2015). They also contain phosphorus, potassium, calcium, magnesium, zinc, manganese, copper, sodium, aluminium and iron, which is the main microelement in the fruit (Mazza 1982, Glew et al. 2007). These elements are responsible for a number of processes taking place in the human body. Some of them are components of bones and teeth, and play key roles in various physiological and biochemical processes, such as electrolyte balance, metabolism, oxygen binding or hormonal functions (Nile, Park 2014, Pereira 2016). The nutritional value of the Saskatoon berry is comparable to that of northern highbush blueberry. However, cultivation of the former species is considerably easier, because of its lower soil and climate related requirements (Pruski et al. 1991, Mazza 2005, Seeram 2008).

For years Poland has been among leading producers and exporters of fruit and semi-finished products (concentrates and frozen foods) obtained from berry-producing plants, such as strawberry, red and black currant, raspberry, black chokeberry and northern highbush blueberry. The related data show that production of these fruits is consistently growing in our country (Central Statistical Office 2017). Cultivation of new species of fruit plants, such as the Saskatoon berry, may provide an opportunity for improving profitability and competitive strength of the interested growers. The fruit of the Saskatoon berry can be used in food industry: in production of beverages, jam, jellies and liqueurs, in baked goods, or as an addition for icecream or yoghurts. They also go well together with other fruit, particularly those with sour taste. The increasing interest in the Saskatoon berry cultivation is also linked with the natural hardiness of the plant, as a result of which it can be grown successfully in the soils and climate predominant in Poland. Besides, the fruit of Saskatoon berry may easily and effectively be collected with fruit harvesters, the same that are used for collecting currants, gooseberries and black chokeberries. The small scale of the Saskatoon berry cultivation, observed currently in our country, has a tendency for increasing production of the fruit in the future (Żurawicz et al. 2014, Lachowicz et al. 2017*b*, Piecko et al. 2017).

This study was designed to determine the content of minerals in fruit of four genotypes of the Saskatoon berry cultivated in central Poland; for this purpose an ICP-OES Thermo iCAP Dual 6500 spectrometer was used.

MATERIALS AND METHODS

The research material comprised fruit of four genotypes of the Saskatoon berry: two Polish selected clones (5/6 and type S) from the breeding program realized at the Research Institute of Horticulture (INHORT) in Skierniewice and two Canadian cultivars (Martin and Smoky). Fruit samples were collected from shrubs grown along an experimental path established in 2011 at the Experimental Orchard in Dąbrowice, owned by the INHORT and located in central Poland (51°55′24″N, 020°5′58″E). The field was prepared according to agronomic recommendations for shrub crop (blackcurrant or chokeberry) cultivation by commercial growers in Poland. The fruit were picked manually at the optimum time during their maturation, in two consecutive years (2015 and 2016). Directly after harvesting, fresh fruit were chilled and stored in a freezer (at the temp. of -20°C) until the tests were to be carried out.

Rational mineral fertilization was applied according to the results of the chemical analysis of the soil samples. During the growing seasons, the crop cultivation practice included mainly weeding, soil cultivation, irrigation and integrated plant protection treatments.

Data on the weather conditions in the years 2015-2016 were obtained from the meteorological station – Metos-Compact (Pessl Instruments), located at the Experimental Orchard in Dąbrowice, where the field experiment was located (Table 1).

Winter 2014/2015 was relatively mild, with little snowfall. No frost damage was noted and the conditions of overwintering small fruit crops were good. The spring period of 2015 was characterized by warm and sunny weather, without frosts. Rainfall in the spring was not abundant, lower than the multiyear average. Summer was extremely hot and dry, with maximum temperatures reaching and exceeding 30°C. Autumn was warm and long.

Table 1

Weather conditions at the Experimental Orchard in Dąbrowice in 2015-2016

Year	Month	Temperature (°C)			Total precipitation (mm)
		maximum	minimum	mean	
2015	January	11.6	-11.4	1.3	35.4
	February	8.3	-6.4	0.8	9.6
	March	17.6	-6.7	4.8	39.0
	April	24.5	-3.2	8.2	44.4
	May	26.3	0.9	13.1	34.6
	June	30.1	2.8	16.7	34.6
	July	36.2	6.4	19.5	48.4
	August	37.9	3.8	21.6	6.2
	September	35.9	0.4	14.8	22.6
	October	23.6	-9.9	7.0	52.0
	November	15.7	-7.2	5.5	36.4
	December	14.0	-10.0	5.0	21.4
2016	January	10.5	-17.9	-3.0	14.0
	February	11.8	-3.5	4.2	28.4
	March	15.3	-5.9	4.0	21.0
	April	25.1	-2.2	9.2	19.6
	May	30.3	1.7	15.0	37.4
	June	34.2	2.8	18.6	98.6
	July	34.0	6.7	19.1	81.6
	August	34.2	5.0	18.3	34.2
	September	34.2	-2.6	15.3	7.4
	October	22.9	-2.4	7.2	60.4
	November	14.4	-6.7	3.1	28.8
	December	9.8	-8.3	1.3	39.4

Such weather conditions were favourable for the growth and yield of studied plants, as they were irrigated with a drip system.

It was another mild winter 2015/2016, with no snow cover. The overwintering of fruit plants was generally good. No significant frost losses were observed in these crops. Spring plant growth in 2016, same as in 2015, started quite early. However, there were spring chills (especially night drops in temperature), causing mild and local spring frosts. In the spring and summer months, more precipitation was recorded, and temperatures were similar to those of long-term averages. The weather course in the growing season of 2016 was favourable for the growth and yield of plants evaluated in the field experiment.

Determination of mineral content by ICP-OES analysis

The fruit samples of the four Saskatoon berry genotypes were subjected to mineralization under high pressure, in HNO_3 65%, super pure. 5 gram samples were weighed and placed in Teflon vessels, which were then filled with 8 ml of nitric acid and sealed tightly. For each group of nine samples, during the microwave dissolution process, the rotor of the digestion system was additionally filled with a blank sample comprising 8 ml of nitric acid alone. The samples were digested for one hour, with the applied algorithm of temperature increase as specified for biological samples, not exceeding 200°C. This procedure was carried out using an Ethos One microwave digestion system (Milestone, Sorisole, Italy). The vessels were opened after the mineralization process had been completed and the samples with acid had been brought to room temperature. The samples were cooled down to room temperature and supplemented with water to the volume of 50 ml. The detection threshold obtained for each element was not lower than 0.01 mg kg^{-1} (with the assumed detection capacity of the measuring apparatus at a level exceeding 1ppb). The measurements were performed on an ICP-OES spectrometer, Thermo iCAP Dual 6500 (Thermo Scientific, Waltham, USA) with horizontal plasma, and the capacity of detection along and across plasma flame (Radial and Axial). Before measuring each batch, the equipment was calibrated with the use of certified Merck models, with concentrations of 10000 ppm for Ca, Fe, K, Mg, P and 1000 ppm for Al, Ba, Cd, Cu, Na, Pb. The measurement result for each element was compensated to account for the measurement of elements in the blank sample.

In each case, a 3-point calibration curve was used for each element, with optics correction applying the method of internal models, in the form of yttrium and ytterbium ions at the concentrations of 2 mg l^{-1} and 5 mg l^{-1}, respectively. The analytic methods were validated with two independent tests. Certified Reference Material (NIST - 1515) was used and the recovery obtained for specific elements. In order to identify the relevant measurement lines and avoid possible interferences, the method of adding a model with known concentration was applied (Table 2).

Table 2

The lengths of measurement lines and the obtained recovery for the specific elements in question

Element	Measurement line (nm)	Recovery according to CRM* (%)	Recovery according to Known Addition Method (%)
Al	167.079	98	100
Ba	455.503	101	99
Ca	393.366	97	99
Cd	214.438	102	98
Cu	324.754	102	101
Fe	259.940	100	99
K	766.490	99	100
Mg	279.553	101	97
Na	589.592	98	100
P	177.495	98	99
Pb	220.353	97	99

* Certified Reference Material

Statistical analysis

Statistical analyses were conducted using Statistica 12 (Stat-Soft, Kraków, Poland). One-way analysis of variance (ANOVA) was performed with the confidence level assumed at $\alpha = 0.05$; *post hoc* analyses were performed using the Tukey's test.

RESULTS AND DISCUSSION

The mean content of the selected minerals identified in the fruit samples of the four Saskatoon berry genotypes (Martin, Smoky, clone 5/6 and clone type S) is presented in Table 3. The results obtained in our studies showed significant differences among the tested macro- and microelements of these genotypes and in both years of investigations. A detailed analysis of our results indicated that the content of some elements (Al, Ca, K, Mg, Mn, Na, P, S and Zn) in analyzed fruit samples depended on the climate conditions in the years of the research (2015-2016). Generally, the content of these macro- and microelements in fruit of the tested genotypes was higher in 2016 than in 2015.

Our results showed that the highest content of an element in analyzed fruits of the four Saskatoon genotypes was determined for potassium (K). Its average content of the four genotypes ranged from 175.1 to 2034.0 mg kg^{-1} with the highest value found for the cv. Smoky. These results exceed those reported in the literature, e.g. Mazza (2005) obtained the average potassium content of 1620.0 mg kg^{-1} in fruit of the Saskatoon berry cultivars in Canada.

The average phosphorus (P) content in the analyzed fruit ranged from 392.0 to 484.0 mg kg^{-1} with significant differences observed between the tested genotypes. Similar values were obtained by Rop et al. (2012) in the Czech Republic. In their study, the values of the analyzed macroelement also differed significantly depending on the tested genotype. The highest average potassium content was determined in fruit of clone type S.

Calcium (Ca) as another important element in the human body, and its average content in the analyzed fruit of the Saskatoon berry differed significantly, ranging from 477.0 to 676.0 mg kg^{-1}, relative to a genotype and year of evaluation. The highest amount of Ca was found in fruit of the clone type S. According to Mazza (2005), the average content of this macroelement was 420.0 mg kg^{-1} for the tested Saskatoon genotypes in Canada, whereas almost twice as much calcium was reported by Rop et al. (2012) from the Czech Republic.

The average magnesium (Mg) content identified in fruit samples of the tested genotypes in both years ranged from 288.0 to 371.0 mg kg^{-1}, with the highest value found for cv. Smoky. Our results of the magnesium content determinations were significantly higher compared to those recorded in the literature (Rop et al. 2012).

Table 3

Mean values and standard deviations for the minerals in the fruit of the selected Saskatoon berry genotypes in 2015 and 2016 (mg kg^{-1} fresh mass)

Minerals	Smoky		Martin		Klon typ S		Klon 5/6	
	2015	2016	2015	2016	2015	2016	2015	2016
Macroelements								
Ca	485.0±1.2^{b}	673.0±5.2^{c}	310.0±1.7^{a}	644.0±4.4^{c}	659.0±2.8^{c}	692.0±4.2^{c}	574.0±4.2^{b}	538.0±4.1^{b}
$\bar{x}$±SD	579.0±132.9		477.0±236.2		676.0±23.3		556.0±25.5	
K	1628.0±3.9^{b}	2440.0±12.4^{d}	1419.0±5.9^{a}	2375.0±10.5^{d}	1988.0±8.1^{c}	1888.0±4.9^{c}	2026.0±15.6^{c}	1475.0±11.1^{a}
$\bar{x}$±SD	2034.0±574.2		1897.0±676.0		1938.0±70.7		1751.0±389.6	
Mg	312.0±0.7^{b}	430.0±3.5^{d}	212.0±1.2^{a}	366.0±4.0^{c}	351.0±2.4^{c}	367.0±2.3^{c}	319.0±2.7^{b}	290.0±2.7^{b}
$\bar{x}$±SD	371.0±83.4		288.0±110.2		359.0±11.3		305.0±20.5	
Na	1.8±0.1^{b}	2.1±0.1^{b}	5.1±0.2^{c}	0.6±0.1^{a}	8.0±0.3^{d}	0.9±0.1^{a}	4.2±0.2^{c}	0.3±0.1^{a}
$\bar{x}$±SD	2.0±0.2		2.9±3.2		4.5±5.0		2.3±2.8	
P	361.0±0.5^{b}	468.0±1.0^{c}	323.0±0.2^{a}	531.0±3.4^{d}	494.0±0.7^{c}	473.0±1.9^{c}	403.0±0.7^{b}	381.0±0.7^{b}
$\bar{x}$±SD	415.0±75.07		427.0±147.1		484.0±14.8		392.0±15.6	
S	113.0±0.4^{a}	173.0±0.2^{c}	120.0±0.2^{a}	185.0±0.3^{c}	140.0±0.5^{b}	159.0±0.7^{b}	151.0±0.2^{b}	136.0±0.2^{b}
$\bar{x}$±SD	140.0±42.4		150.0±42.8		146.0±7.7		140.0±13.8	
Microelements								
Cr	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}
$\bar{x}$±SD	0.0±0.0		0.0±0.0		0.0±0.0		0.0±0.0	
Cu	0.4±0.0^{a}	0.5±0.0^{a}	0.4±0.0^{a}	0.7±0.0^{a}	0.4±0.0^{a}	0.5±0.0^{a}	0.4±0.0^{a}	0.5±0.0^{a}
$\bar{x}$±SD	0.5±0.1		0.6±0.2		0.5±0.1		00.5±0.1	
Fe	7.0±0.8^{a}	8.9±0.6^{a}	6.0±0.9^{a}	7.1±0.5^{a}	7.1±0.9^{a}	7.0±0.5^{a}	7.2±0.7^{a}	7.3±0.7^{a}
$\bar{x}$±SD	8.0±1.3		6.7±0.8		7.1±0.1		7.3±0.1	
Mn	6.2±0.0^{b}	8.8±0.0^{c}	4.8±0.0^{a}	11.0±0.1^{d}	6.8±0.3^{b}	7.1±0.1^{b}	6.6±0.0^{b}	8.5±0.1^{c}
$\bar{x}$±SD	7.5±1.8		4.8±3.4		7.0±0.2		7.6±1.3	
Mo	0.1±0.0^{a}	0.1±0.0^{a}	0.0±0.0^{a}	0.7±0.0^{b}	0.1±0.0^{a}	0.1±0.0^{a}	0.1±0.0^{a}	0.1±0.0^{a}
$\bar{x}$±SD	0.1±0.0		0.4±0.5		0.0 ± 0.0		0.1±0.0	
Zn	3.7±0.0^{b}	4.3±4.6^{b}	0.5±0.3^{a}	4.8±0.0^{b}	0.5±0.0^{a}	5.9±0.0^{c}	0.6±0.0^{a}	3.3±0.0^{b}
$\bar{x}$±SD	4.0±0.4		2.7±3.0		3.2±3.8		2.0±2.0	
Heavy metals								
Al	3.4 ± 0.1^{c}*	3.4±0.1^{c}	2.4±0.1^{b}	1.3±0.2^{a}	2.8±0.1^{b}	4.2±0.1^{d}	1.5±0.1^{a}	1.7±0.0^{a}
$\bar{x}$±SD	0.34±0.0		1.9±0.8		3.5±1.0		1.6±0.1	
Cd	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}
$\bar{x}$±SD	0.0±0.0		0.0±0.0		0.0±0.0		0.0±0.0	
Pb	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}	0.0±0.0^{a}
$\bar{x}$±SD	0.0±0.0		0.0±0.0		0.0±0.0		0.0±0.0	
Sr	0.6±0.0^{a}	1.2±0.0^{a}	0.7±0.5^{a}	1.0±0.0^{a}	9.0±0.0^{c}	2.9±2.0^{b}	1.0±0.0^{a}	1.0±0.0^{a}
$\bar{x}$±SD	9.0±4.0		0.9±0.2		6.0±4.3		1.0±0.0	

* *a-e* mean ± SD; various letters within the same line show significant differences ($P < 0.05$).

Sodium (Na) ions are the major group of extracellular cations, essential for the maintenance of the functional potential of cell membranes. The average sodium content in the fruit samples varied from 2.0 to 4.5 mg kg^{-1}, with significant differences between the analyzed Saskatoon berry genotypes. The highest content of this element was found in clone type S. Our results were significantly lower than reported in the literature for five cultivars of the Saskatoon berry: from 5.0 to 25.0 mg kg^{-1} (Mazza 1982, Rop et al. 2012, Jurikova et al. 2013).

The average content of sulphur (S) in the fruit samples harvested in 2015 did not differ significantly, ranging from 113.0 mg kg^{-1} (cv. Smoky) to 151.0 mg kg^{-1} (clone 5/6). In 2016, significantly higher content of this element was identified, namely from 136.0 mg kg^{-1} (clone type S) to 185.0 mg kg^{-1} (cv. Martin) on average. These results were higher to those reported in the literature for the tested Saskatoon genotypes (Mazza, 1982, Mazza and Davidson, 1993).

It is a well-known fact that iron (Fe) is the main microelement in fruit (Glew et al. 2007). The average iron content in fruit samples ranged from 6.7 to 8.0 mg kg^{-1}, with no significant differences observed between four tested genotypes. Compared to the results reported by other researchers (Mazza 1979, 2005), our findings showed a lower content of iron in the fruit of the Saskatoon berry genotypes.

The average amount of copper (Cu) for four genotypes and in both years was from 0.5 to 0.6 mg kg^{-1}. There were no significant differences in the content of this microelement in fruits of the tested genotypes. In the first year of the study, the Cu content was 0.4 mg kg^{-1} for all genotypes on average. In 2016, a slightly higher content of this element was identified: from to 0.5 mg kg^{-1} (cv. Smoky, clones no 5/6 and type S) to 0.7 mg kg^{-1} (cv. Martin). These results were lower of those reported in the literature for the tested Saskatoon berry cultivars in Canada and the Czech Republic (Mazza 1982, Mazza, Davidson 1993, Mazza 2005, Rop et al. 2012).

The average content of zinc (Zn) ranged from 2.0 to 4.0 mg kg^{-1}, with significant differences between the tested genotypes. The highest content of zinc was determined in fruits of cv. Smoky. Higher content of this element was recorded in the fruit of the tested genotypes in 2016 than in 2015. Our results were significantly lower than those reported in the literature (Mazza, Davidson 1993, Mazza 2005, Rop et al. 2012).

Regarding the elements hazardous to human health, such as Al, Ag, Cd, Hg and Pb, some of the results of their determinations are described and presented in the Table 3.No presence of lead, cadmium or chromium was detected in fruit samples of the tested Saskatoon genotypes. Only small amounts of nickel and molybdenum were identified.

The differences in the macro- and microelements between average results obtained for the four genotypes and their average content in the two investigated years could have been influenced by a genotype, agronomic practices and environmental growth conditions, such as soil fertility, temperature and humidity (St-Pierre et al. 2005, Żurawicz et al. 2014).

CONCLUSIONS

The Saskatoon berry is a new fruit crop, which has not been grown commercially in Poland yet. It seems to have the potential for increasing its fruit production and processing. The present findings can be used to promote this specific fruit crop and its cultivation by our fruit growers, and to stimulate research into properties of new genetic material.

The Saskatoon berry fruit and its food products are a good source of nutrients needed for the proper functioning of the human body. This fruit is found to have high content of macroelements (potassium, calcium, phosphorus, magnesium and sulphur), while the content of the remaining elements is below 10.0 mg kg^{-1}. The Saskatoon berry fruit can be used effectively in the production of dietary supplements.

Among other elements analyzed, including heavy metals, lead, cadmium and chromium were not detected in fruit samples of the tested genotypes. Only nickel and molybdenum were identified, but their content did not exceed critical levels. From this point of view, the Saskatoon berry does not pose health hazard to people.

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