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ORIGINAL PAPER

VARIABILITY OF MINERALS CONTENT AS A FACTOR LIMITING HEALTH PROPERTIES OF BIRCH SAPS*

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Abstract

In this study, the content of minerals in silver birch (*Betula pendula* Roth.) tree saps was tested using atomic absorption spectrometry to evaluate the intraspecies variability. The mean values of zinc (2.79 - 4.49 mg dm^{-3}), sodium (0.66 - 2.76 mg dm^{-3}) and copper (0.02 - 0.19 mg dm^{-3}) for tree saps collected from particular locations did not differ significantly. The mean calcium (77.83 mg dm^{-3}) and magnesium (13.38 mg dm^{-3}) content in the sap from trees growing in a farmyard was significantly higher than in sap from other sites, where calcium ranged between 25.85 and 41.04 mg dm^{-3} and magnesium varied from 5.98 to 8.00 mg dm^{-3}. Based on the results of tree sap analyses, it can be claimed that mineral content detected in birch saps is low when compared to the dietary standards (RDA, AI), although saps from individual trees can have a copper and zinc content, owing to which birch sap can be considered as a potentially valuable source of these two minerals. However, the prospective health-promoting benefits related to the high content of zinc and copper are not explicit. According to our study, this mineral content is highly variable, both between particular trees in a single location and between distant locations. For example, in the case of copper, one liter of sap collected from neighbouring trees can contain from zero to several dozen percent of the Recommended Dietary Allowances, making it impossible to identity specific nutritional benefits.

Keywords: birch tree saps, intraspecies variability, minerals.

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INTRODUCTION

Birch trees (*Betula* sp.) contribute to many valuable products. In the highly-developed wood industry of the Scandinavian countries, wood of several birch tree species is used. *Betula pendula* Roth. plays a crucial role in afforestment of unproductive areas and as ornamental trees in parks of Central and Northern Europe (Rastogi et al. 2015). Beside this, birch sap use is also very important. Birch sap, slightly less popular than maple sap, is most frequently collected in Central and Northern Europe and East Asia. Its composition has been examined in Germany (Essiamah 1980), South Korea (Yoon et al. 1992, Jiang et al. 2001, Jeong et al. 2012, 2013), Romania (Peev et al. 2010), Lithuania (Viškelis, Rubinskienė 2011), Latvia (Kūka et al. 2013), Finland (Kallio et al. 1985, Kallio, Ahtonen 1987*a*,*b*, Ahtonen, Kallio 1989) and in Poland (Bilek et al. 2015*a*, *b*, Bilek et al. 2016*a*,*b*). Saps most frequently analyzed are those from *B. pendula* Roth. (Essiamah 1980, Jiang et al. 2001, Peev et al. 2010, Viškelis, Rubinskienė 2011, Kūka et al. 2013) and *B. pubescens* Ehrh. (Kallio et al. 1985, Kallio, Ahtonen 1987*a*,*b*, Ahtonen, Kallio 1989), while saps from *B. platyphylla* var. *japonica* Sukaczev (Jeong et al. 2012, 2013), *B. populifolia* Marsh. (Kok et al. 1978), *B. costata* Trautv., *B. schmidtii* Regel, *B. davurica Pallas* and *B. ermanii* Cham. (Yoon et al. 1992) are examined less often.

The interest in tree saps in the said countries stems from the health-promoting properties ascribed to them centuries ago by traditional medicine. According to folklore, birch sap was an effective cure e.g. in complaints of kidneys, stomach, and liver, in gallstones, anaemia and scurvy, in infectious diseases and infestation with intestinal parasites, in cases of the weakened immune system, as well as in skin diseases (Svanberg et al. 2010, Zyranova et al. 2010, Papp et al. 2014). Birch saps are also recommended for external use in cosmetics, e.g. to strengthen hair and facilitate its growth, to fight skin rashes and cause freckle fading (Rastogi et al. 2015). For this reason, when examining birch sap, attention is drawn primarily to the parameters determining its health-promoting value, that is minerals (Viškelis, Rubinskienė 2011, Jeong et al. 2012, 2013, Kūka et al. 2013, Bilek et al. 2015*a*, 2016*a*), free amino acids and peptides (Ahtonen, Kallio 1989, Jiang et al. 2001, Kūka et al. 2013), anti-oxidative potential and phenolic compounds (Viškelis, Rubinskienė 2011, Kūka et al. 2013, Bilek et al. 2015*b*), vitamins (Viškelis, Rubinskienė 2011, Kūka et al. 2013), and organic acids (Kallio, Ahtonen 1987*a*, Ahtonen, Kallio 1989).

Opinions expressed by consumers of tree saps, including bottled tree saps, and also the information provided by popular science and scientific publications consistently suggest that the most important components responsible for health properties of tree saps are minerals (Viškelis, Rubinskienė 2011, Kūka et al. 2013, Bilek et al. 2015*a*, 2016*a*). At the same time, our previous studies have shown that the chemical composition of tree saps varies, both within and between species. Admittedly, these were studies on a small number of individuals from each species (Bilek et al. 2015*a*,*b*, 2016*a*,*b*). Meanwhile, this diversity must be reflected in health and nutritional benefits associated with the consumption of tree saps. Accordingly, we can expect that the variation in the chemical composition will cause completely different nutritional benefits of tree saps collected from different individuals, to the extent that tree saps of selected individuals may be useless for the consumer in terms of their mineral content. Therefore, out aim was to assess the content of minerals in sap collected from twenty individuals of birches in an area where they are still tapped and used. The content of minerals was compared to the dietary standards in Poland.

MATERIAL AND METHODS

Sampling

Tree saps of silver birch (*Betula pendula* Roth.) were collected in winter 2014, from 24 to 28 February, in South-East Poland, the Subcarpathian Province (*województwo podkarpackie*), in the agricultural commune of Niwiska (Niwiska 444, 50.228810, 21.639209), situated far from any industrial plants or busy roads, and having a nearly 50% forest cover. The collection, performed with consent of owners of the land parcels where the trees grew, took place under high ambient pressure and without any precipitation. During the collection, the mean daytime temperatures were 10°C and did not fall below -1°C at night. The saps were collected from 10.00 a.m. to 2.00 p.m. Four groups of trees, five trees in each, were selected (Figure 1). Theygrew in the following locations: unproductive land about 50 m from farmland and 20 m from a quiet country road, temporarily used for cattle grazing (Site A), land about 10-20 meters from a busy farm with a small watercourse collecting wastewater from the farm (Site B), woods - several hundred meters from roads and farm buildings (Site C), and land in the immediate vicinity of farmland, about 30 m from a quiet country road (Site D). Each tree selected for sap tapping had a diameter exceeding 25 cm, according to the published recommendations (Larochelle et al. 1998). The sample collection protocol is generally based on local tradition (own, unpublished information, interviews with the inhabitants of Niwiska). Trees were cut with a small ax at the height of about 50 cm, and then a steel tube was firmly inserted at the base of the cut. In this study, tree sap was collected in a sterile centrifuge tube (50 ml volume). After collecting birch sap, which usually took a few minutes, the tubes were closed instantly.

Right after collection, tree sap samples were frozen at -20ºC and, once a whole batch was collected, transported to a laboratory accredited by the Polish Centre for Accreditation, i.e. Malopolska Centre of Food Monitoring of the University of Agriculture in Kraków, where the samples were thawed

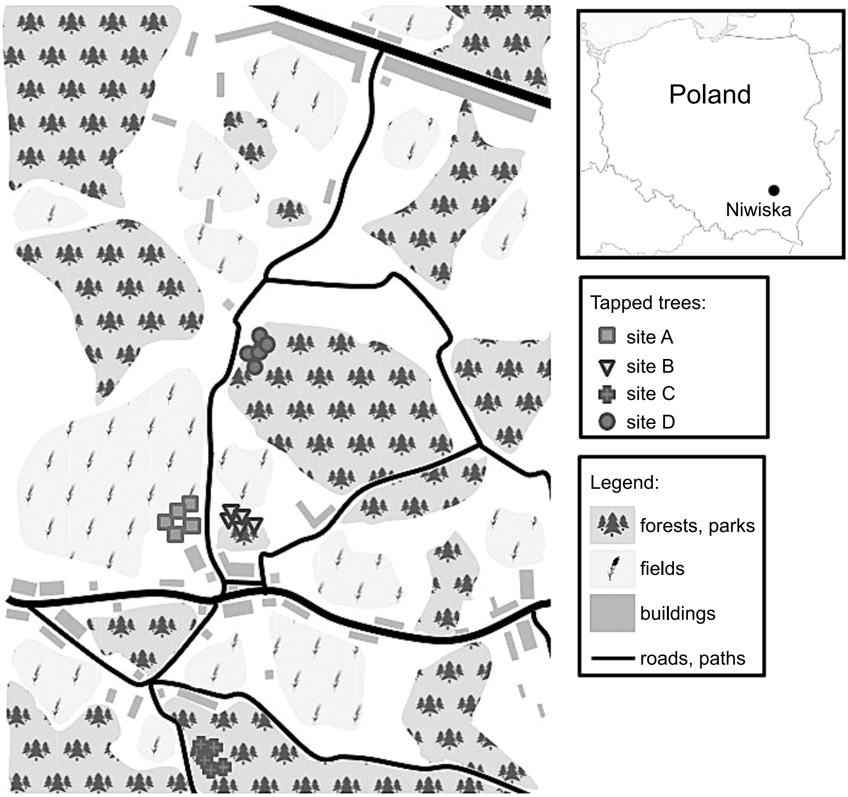

Fig. 1. Places of tapping birch saps: site A – unproductive land, temporarily used for cattle grazing, site B – land close to a busy farm with a small watercourse collecting wastewater from the farm, site C – woods several hundred meters from roads and farm buildings, site D – land in immediate vicinity of farmland

and analyzed, according to the certificate of accreditation PCA-AB 1369 dated 15.10.2012, in which the validation parameters are described.

Determination of minerals using atomic absorption spectrometry

A MARS Xpress microwave closed system (CEM, Matthews, North Carolina, USA) was used. About 2 g of each sample was digested with 0.010 dm^{-3} of nitric acid (65%, Suprapur, Merck KGaA, Germany) in a microwave digestion system and diluted to 0.025 dm^{-3} with double deionized water. A blank digest was obtained in the same way. Instrumental parameters and settings were: 5 min for 600 W at 100°C, 5 min for 1200 W at 180°C, 15 min for 1200 W at 200°C and 5 min vent.

The mineral content was determined by atomic absorption spectrometry. Standard solutions were prepared from 1000 mg dm^{-3} stock solution (CertiPUR, Merck KGaA, Germany) of sodium, potassium, calcium, magnesium, zinc and copper by dilution with double deionized water (Milli-Q Millipore

18.2 MΩ cm^{-3} resistivity). Nitric acid (65%) Suprapur reagent was purchased from Merck KGaA (Germany). All the plastic and glassware were cleaned by soaking in diluted HNO_3 (1:9) and rinsed with deionized water prior to use.

A Varian AA240FS (Varian, Mulgrave, Victoria, Australia) atomic absorption spectrometer equipped with single element hollow cathode lamps and an air-acetylene burner was used for the determination of the content of calcium, magnesium, sodium, potassium and zinc. The instrumental parameters were the ones recommended by the manufacturer. The air-acetylene flame in FAAS measurements consisted of an acetylene flow was 2 dm^{-3} min^{-1} and aqn air flow of 13.5 dm^{-3} min^{-1}. A spectral slit width of 0.5 nm was selected to isolate the Ca, Mg, Na and K line. Calcium was analyzed at a wavelength of 422.7 nm, magnesium at a wavelength of 285.2 nm, sodium at a wavelength of 589.0 and potassium at a wavelength of 766.5 nm. Zinc was analyzed at 213.9 nm with a slit width of 1.0 nm. Determination of copper was performed using an atomic absorption spectrometer Varian AA240Z (Varian, Mulgrave, Victoria, Australia) with the Zeeman background correction equipped with a Varian GTA-120 electrothermal atomizer linked with an automatic sample dispenser. For the determination of copper by GFAAS, 20 µl of each sample was injected into a graphite tube. A three-stage heating program was executed. In the first stage, the sample was dried at a temperature of 95°C and then at 120°C. In the ashing stage, the temperature was increased to 900°C. Finally, the sample was atomized by rapidly increasing the temperature to 2300°C. At this temperature, the graphite tube was cleaned. In GFAAS measurements, an argon flow was 0.3 dm^{-3} min^{-1}. Copper was analyzed at 327.4 nm with the addition of 5 µL of magnesium-palladium matrix modifier. Argon was used as the inert gas.

Determination of the content of minerals was carried out in duplicate, and the average results were calculated as mg of the element per liter of birch sap.

Statistical analysis

Statistical analysis was carried out using one-way analysis of variance (*one-way* ANOVA). The distinguishing factor was the tree location. The *post-hoc* Tukey's Honestly Significant Difference test for equinumerous assays was used to determine statistically significant differences. All calculations and diagrams were made using Statistica ver. 12.0 software. Differences with the significance of $a = 0.05$ were considered statistically significant.

Nutritional standards

The results were refered to the Polish nutritional standards for electrolytes (i.e. sodium and potassium) and mineral components (i.e. copper, zinc, calcium and magnesium) (Jarosz 2012). It was examined to what extent one liter of birch saps satisfied the Recommended Dietary Allowance as well as Adequate Intake for adult women.

RESULTS AND DISCUSSION

The values obtained for the parameters examined, that is the content of sodium, potassium, magnesium, calcium, copper and zinc, are presented in table 1 as means of results from five trees. The mean values of zinc, sodium and copper for tree saps collected from particular locations did not differ significantly. For potassium, calcium and magnesium, however, the statistical analysis revealed significant differences between saps tapped from trees in particular locations. The mean potassium content in saps collected from trees in the wood (Site C) was significantly lower than the mean potassium content in birch saps from the farmyard trees (Site B). The mean calcium and

Table 1

The mean content of minerals in tested saps

Mineral	Localization	Mean ± SD	ANOVA
Ca (mg dm^{-3})	A	33.67 ± 7.82	*a*
	B	77.83 ± 23.50	*b*
	C	41.04 ± 23.80	*a*
	D	25.85 ± 16.70	*a*
Cu (mg dm^{-3})	A	0.03 ± 0.03	*a*
	B	0.02 ± 0.01	*a*
	C	0.17 ± 0.26	*a*
	D	0.19 ± 0.30	*a*
K (mg dm^{-3})	A	105.1 ± 33.00	*a, b*
	B	120.7 ± 31.80	*b*
	C	61.01 ± 15.90	*a*
	D	91.87 ± 37.40	*a, b*
Mg (mg dm^{-3})	A	7.58 ± 0.85	*a*
	B	13.38 ± 4.75	*b*
	C	5.97 ± 1.11	*a*
	D	8.00 ± 2.95	*a*
Na (mg dm^{-3})	A	2.76 ± 3.21	*a*
	B	1.15 ± 0.83	*a*
	C	1.29 ± 2.51	*a*
	D	0.66 ±0.92	*a*
Zn (mg dm^{-3})	A	4.49 ± 3.49	*a*
	B	3.97 ± 3.74	*a*
	C	4.14 ± 2.69	*a*
	D	2.79 ± 1.09	*a*

A – unproductive land, temporarily used for cattle grazing, B – land close to a busy farm with a small watercourse collecting wastewater from the farm, C – woods several hundred meters from roads and farm buildings, D – land in immediate vicinity of farmland
a, *b* – the different letters denote the statistically significant differences between experimental groups ($p < 0.05$)

magnesium content was significantly higher in samples collected from the farmyard trees (Site B) than in birch sap collected from the other locations (Sites: A, B, D) – Table 1.

Tree saps often have diverse content of minerals. In previous studies, the predominant minerals in birch saps were potassium, calcium, magnesium, zinc and copper (VIŠKELIS, RUBINSKIENĖ 2011, JEONG et al. 2012, 2013). This trend was also confirmed by our tests (Table 1), althoug the mineral content detected in birch saps compared to the dietary standards for the Polish population proved to be low (JAROSZ 2012) – Figures 2-6. Saps from individual trees only had a high high content of copper and zinc, owing to which birch saps can be considered as a potentially valuable source of these two minerals (JAROSZ 2012) – Figures 3, 6.

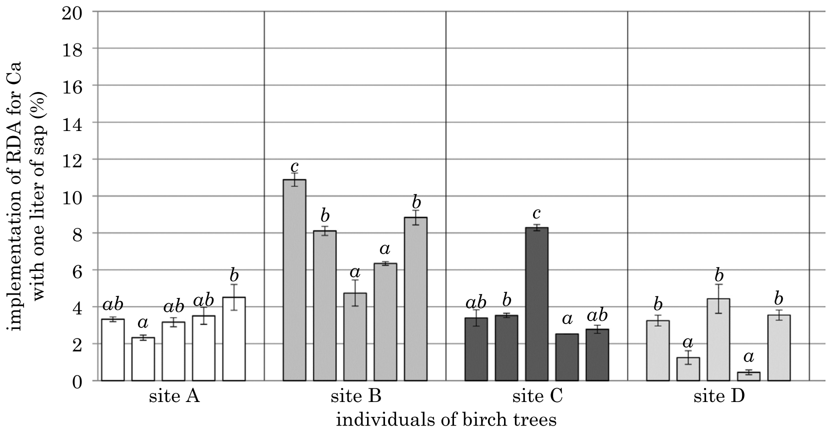

Fig. 2. Coverage of Recommended Dietary Allowance for calcium with one liter of birch saps examined for adult women: *a*, *b*, *c* – the different letters denote the statistically significant differences between experimental groups ($p < 0.05$), sites A, B, C, D – see Fig. 1

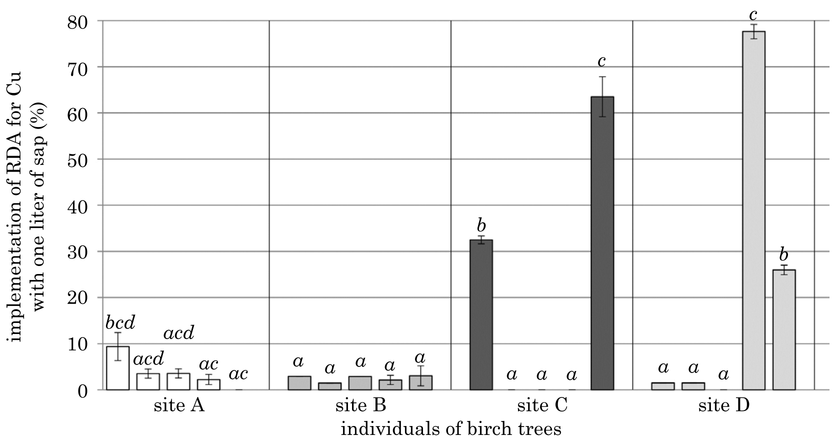

Fig. 3. Coverage of Recommended Dietary Allowance for copper with one liter of birch saps examined for adult women: *a*, *b*, *c*, *d* – the different letters denote the statistically significant differences between experimental groups ($p < 0.05$), sites A, B, C, D – see Fig. 1

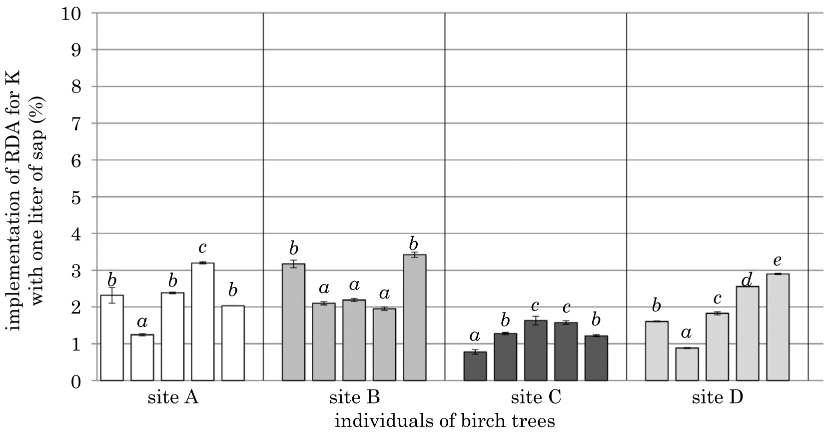

Fig. 4. Coverage of Adequate Intake for potassium with one liter of birch saps examined for adult women: *a*, *b*, *c*, *d*, *e* – the different letters denote the statistically significant differences between experimental groups ($p < 0.05$), sites A, B, C, D – see Fig. 1

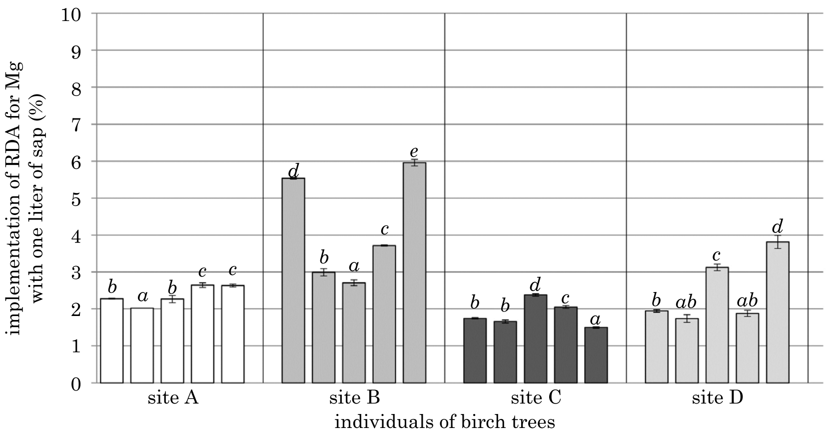

Fig. 5. Coverage of Recommended Dietary Allowance for magnesium with one liter of birch saps examined for adult women: *a*, *b*, *c*, *d*, *e* – the different letters denote the statistically significant differences between experimental groups ($p < 0.05$), sites A, B, C, D – see Fig. 1

High content of zinc and copper in the studied birch saps is responsible for the health-promoting activity, declared in the consumers' accounts and ethnobiology data (Zyranova et al. 2010, Svanberg et al. 2012, Papp et al. 2014, Rastogi et al. 2015), ie. the application in colds and to improve the condition of hair. Zinc is responsible e.g. for the immunological defense of the human body as well as for production and efficiency of many hormones. Copper participates in the creation of collagen cross-links and elastin, in the synthesis of skin and hair pigments, and in the retention of keratin structure (Osredkar, Sustar 2011).

However, prospective health-promoting benefits of birch sap related to the high content of zinc and copper are not explicit. According to our study,

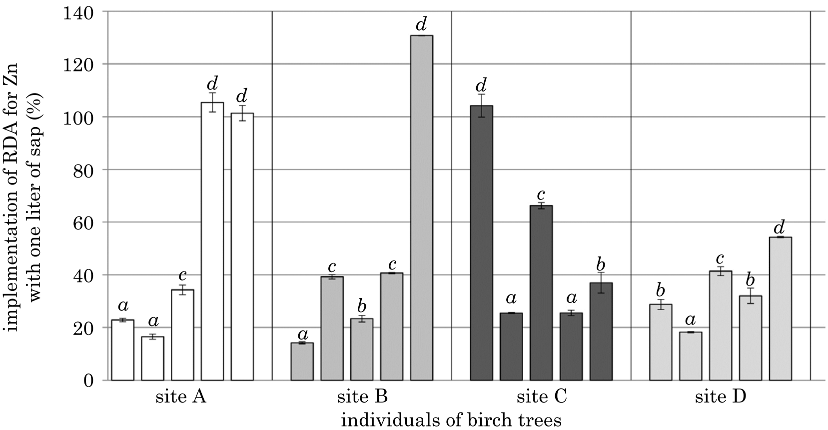

Fig. 6. Coverage of Recommended Dietary Allowance for zinc with one liter of each of the birch saps examined for adult women: *a*, *b*, *c*, *d* – the different letters denote the statistically significant differences between experimental groups ($p < 0.05$), sites A, B, C, D – see Fig. 1

the mineral content is highly variable both between particular trees in a single location (Figures 2-6) and between distant locations. For example, one liter of sap collected from neighbouring trees in a single location can cover from zero to several dozen percent of the Recommended Dietary Allowances set up for copper (JAROSZ 2012) – Figure 3. High variability of the content of selected minerals between different locations is further confrimed by comparing the present analytical results for birch saps collected from the silver birch locations at a distance of over a dozen (Werynia) and several dozen (Pietrusza Wola) kilometers. For example, the mean calcium concentration was 5.52 mg dm^{-3} (±3.14, n = 5) in Werynia, 17.3 mg dm^{-3} (±9.6, n = 5) in Pietrusza Wola and 41.0 at site C in Niwiska (±22.5, n = 5) (BILEK et al. 2015*a*).

The health-promoting potential of birch saps is therefore controversial. The content of minerals is variable, hence the nutritional value of saps collected from many trees can be negligible. However, it should be noted that our previous research did not demonstrate that birch tree saps contained toxic components, e.g. nitrates, common unfavorable elements of plant products (BILEK et al. 2015*b*, 2016*b*).

Further examinations are needed in order to determine what dates of collection and locations (e.g. the parameters of soil and soil water) as well as properties of particular trees (e.g. age, insolation, health) would ensure tree saps with an optimum content of minerals.

CONCLUSIONS

1. Birch saps can be a valuable nutritional source of selected minerals, e.g. copper and zinc, while being a poor nutritional source of calcium, magnesium and potassium.

2. The mineral content of tree saps is highly variable, both between particular trees in a single location as well as between distant locations.

3. The nutritional value of saps collected from many trees can be negligible, but combining tree saps obtained from several trees can help in getting a product with the averaged and better health parameters.

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