A study on mineral composition of *Aronia melanocarpa* as a functional food with potential therapeutic properties

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Summary
In order to estimate the role of certain bioelements present in *Aronia melanocarpa* (Michx.) Elliot, commonly known as black chokeberry, in human health, this study determined the content of essential macro- and microelements in berries, juice and in the dried pomace. In all the analysed samples, the element with the highest content was potassium (approximately 4 000 $mg \cdot kg^{-1}$), then calcium (approximately 1 200 $mg \cdot kg^{-1}$), magnesium (approximately 500 $mg \cdot kg^{-1}$), and the element with the smallest content was sodium (approximately 250 $mg \cdot kg^{-1}$). Thanks to the positive effect of these macroelements on the cardiovascular, locomotor and immune systems, consumption of black chokeberry berries and black chokeberry-based products can improve the overall health. The results of this study show that, with a daily consumption of 100 g berries, all daily body needs for certain microelements can be satisfied, for example for Cr, Mn, B and Sr. The determined contents of Fe, Cu and Zn in the analysed samples show that black chokeberry berries and various black chokeberry-based products (juice, flour and dry matter) are a good source of these microelements. The results of this study showed that organic *Aronia melanocarpa* berries can be used as a functional food with potential therapeutic properties.

Keywords
Aronia melanocarpa; essential bioelements; functional food; therapeutic properties

In recent decades, the modern way of life has led to changes in many habits of human behaviour, among which changes in human diet are especially significant. The accelerated pace of work and life means that the traditional diets are increasingly being replaced by "fast" and ready-made food, which can have a bad effect on human health. This way of nutrition, when used for a long period of time, can lead to various health problems caused by obesity, such as cardiovascular diseases, diabetes, elevated low-density lipoprotein (LDL) levels or arthritis. In order to improve our general well-being, it is important to replace this kind of diet, at least in part, with fresh fruits and vegetables, or by products based on these foods. It has been scientifically proven that regular use of fruits and vegetables in human nutrition can improve the general well-being of a person and also reduce the harmful effects of cardiovascular and many other chronic non-infectious diseases [1–5]. Fruits and vegetables, as a rich source of antioxidants, vitamins (vitamin C, α-tocopherol, β-carotene), as well as some phytochemicals (lycopene, flavonoids, anthocyanins), have an important role in functional and therapeutic nutrition [6]. Intake of these nutrients from natural plant sources is far more beneficial to human health than the use of synthetic products. There is a growing trend of organic production of fruits and vegetables due to the increasing demand for natural products. Among the most popular fruits are the so-called superfruits, such as berries (blueberries, raspberries, blackberries, chokeberries, cherries or blackthorns), grapes, rosehips, which contain a range of health-promoting compounds, including vitamins, minerals, fatty acids and antioxidants. *Aronia* has recently become more common as a berry fruit in the functional food market due to its health benefits. This plant species can be consumed fresh, used to prepare functional beverages

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(juice, tea, enriched water or wine), jams, spreads, fruit preserves, as well as a raw material in the food, cosmetics and pharmaceutical industries [7].

Aronia is native to North America, although it is now grown throughout Europe. The genus *Aronia* (family *Rosaceae*, subfamily *Maloideae*) includes three species of deciduous shrubs: *Aronia melanocarpa* or black chokeberry, *Aronia arbutifolia* or red chokeberry and *Aronia purnifolia* or purple chokeberry, the latter being a hybrid of the two former species. Of these types of chokeberry, *A. melanocarpa* is the most widely used. The black colour of its fruit comes from the high concentration of anthocyanins. Several studies showed that chokeberry, compared to other types of black berries, has a higher content of phenolic compounds, such as phenolic acids, proanthocyanidins, anthocyanins, flavonols and flavanones [8]. The presence of polyphenolic compounds in *Aronia* berries can have positive effects on elevated high blood pressure [9] and on lipid metabolism, reducing the level of triglycerides, total and LDL cholesterol [10], while it can also have a positive effect on neurological health, memory and learning [11].

In addition to organic components, also mineral substances, macro- and microelements, play a very important role in the growth, development and normal functioning of the human body, as well as in the prevention and alleviation of the symptoms of certain diseases. Living cells depend on minerals for proper structure and function. Minerals are necessary for the formation of blood and bones, the proper composition of body fluids, healthy nerve function, and proper operation of the cardiovascular system, among others central and peripheral nervous system, and building the immune system. Because all enzyme activities involve minerals, they are essential for the proper utilization of vitamins and other nutrients [12].

Based on the general literature review, it can be said that a small number of authors have dealt with the determination of the content of bioelements in fruit and black chokeberry-based products. In studies that studied black chokeberry, there are no data on the therapeutic and functional significance of black chokeberry, regarding its mineral composition. Because of that, the aim of this study was to evaluate the possible therapeutic and functional effects of black chokeberry based on determining the content of certain biometals in the black chokeberry berries and its juice, as well as in the dried pomace. The content of mineral components in the examined samples was determined using a highly sensitive and selective analytical technique of inductively coupled plasma with optical emission spectroscopy (ICP-OES).

MATERIALS AND METHODS

Samples and samples preparation

Fresh black chokeberry berries, juice and dried pomace were used as samples. The samples of mature *Aronia* berries were collected from the commercial plantation at Gornja Velika Vrbnica, from the slopes of mountain Goč in the western part of Republic of Serbia. The plants were organically grown as no pesticides or herbicides were applied. With this method of production, berries with very good sensory characteristics were obtained. The berries had a smooth surface, no damage, uniform colour and size, pleasant smell and a sour-bitter taste. The size of the fruits was 0.5–1 cm, weight 0.7–1 g, with approximately 5–8 seeds in each fruit. *Aronia melanocarpa* plant was identified and documented in voucher specimen collection (No 02260012) at the Institute for Medicinal Plants Research in Belgrade (Serbia).

Samples of black chokeberry berries and dried pomace for mineral components determination were prepared by wet digestion method [13]. A portion of each sample (2 g) was weighed accurately and transferred to acid-washed porcelain crucible, heated gradually, maintained at 250 °C for 2 h and ignited at 450 °C for a period of 12 h in a muffle furnace. The ashes were treated with 5 ml of 65% HNO_3 and 1 ml of 30% H_2O_2, evaporated to dryness on a steam bath and returned to the furnace at 450 °C for 1 h. The obtained ash was digested with 5 ml of 65% HNO_3 and filtered through No. 541 paper filter (Whatman, Maidstone, United Kingdom) into a 50 ml volumetric flask.

Juice was obtained by squeezing the fresh undamaged, selected black chokeberry berries on electric juicer. The juice of the black chokeberry was thick with a consistent texture, dark red colour, with sour and bitter taste. Juice density was determined by pycnometry [14] and the relative juice density was determined as 1.176 $g \cdot ml^{-1}$. Portions of 3 ml of the analysed samples of aronia juice were treated with a mixture of HNO_3 and HCl (1 : 1.5, v/v), and heated at a temperature of 60–80 °C for 2 h, in order to achieve their complete mineralization [13].

Chemicals

The following chemicals were used for preparation and analysis of tested samples: nitric acid, hydrochloric acid and hydrogen peroxide (Merck, Darmstadt, Germany). Inductively coupled plasma (ICP) multi-element standard solution (Ultra Scientific, North Kingstown, Rhode Island, USA) of 20.00 ± 0.10 $mg \cdot l^{-1}$ was used as a stock solution for calibration.

Instrumentation

All analyses for mineral content determination were carried out ICP optical emission spectrometer iCAP 6000 (Thermo Scientific, Waltham, Massachusetts, USA) with Echelle optical design and a charge injection device (CID) solid state detector. The instrument was operated in conditions given in Tab. 1.

Statistical analysis

All measurements were carried out in triplicate and presented as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) for statistical evaluation of results was used, followed by LSD post-hoc test to assess differences between the sample groups' means, for each bioelement separately. The p values of < 0.05 were considered significant. For statistical calculations, statistical package of software SPSS 20 (IBM, Armonk, New York, USA) was used.

Tab. 1. Operational parameters for inductively coupled plasma optical emission spectrometry measurements.

Parameter	Value
Flush pump rate	1.67 Hz
Analysis pump rate	0.83 Hz
Radio frequency power	1 150 W
Nebulizer gas flow	0.7 l·min^{-1}
Coolant gas flow	12 l·min^{-1}
Auxiliary gas flow	0.5 l·min^{-1}
Plasma view	Axial

RESULTS AND DISCUSSION

The determined contents of macro- and microelements in the samples of black chokeberry of organic origin (berries, juice and dried pomace) are shown in Tab. 2 and Tab. 3. These represent the basis for assessing therapeutic and functional significance of the samples. The results obtained, by applying appropriate statistical tests, showed that there was a statistically significant difference in the content of each detected mineral separately between adequate type of tested samples groups at a level of $p < 0.05$. The results are presented as the mass of the determined element expressed in milligrams per kilogram of the sample, given that the recommended daily dose for the intake of aronia berries is 100 g.

The results of this study (Tab. 2, Tab. 3) indicate that black chokeberry berries, as well as black chokeberry-based products, are rich in macro- and microelements. Based on the results shown in Tab. 2, it can be concluded that among the analysed macroelements Ca, K, Mg and Na, there was a highest content of K in all samples, followed by Ca and Mg, while Na was present at the lowest content. Given that the recommended daily K intake is approximately 3 000 mg (Tab. 4), the determined contents of this element of 5 110 mg (berries), 3 920 mg (dried pomace) and 3 776 mg (juice) per kilogram showed that these samples are a good source of K, which is necessary for the normal functioning of the organism. K is the main cation of extracellular fluids and it has an important role in the transmission of nerve impulses and muscle contraction. It is also necessary for proper functioning of the cardiovascular system because it regulates blood pressure and water balance in the organism [15]. Considering the biological significance of K, as well as the fact that consuming fresh black chokeberry berries and juice compensates for about 17 % of the body's total daily needs for K, the use of these foods can have a therapeutic effect in alleviating cardiovascular problems.

Comparing the values of potassium content in fresh berries and cold-pressed juice (Tab. 2) with those determined in our previous study where

Tab. 2. The content of macroelements in samples.

Content [mg·kg^{-1}]	Berries	Dried pomace	Juice
Ca	1 240 ± 32 ^{a}	2 180 ± 26 ^{a}	163.2 ± 1.7 ^{a}
K	5 110 ± 61 ^{a}	3 920 ± 17 ^{a}	3 776 ± 22 ^{a}
Mg	609 ± 4.1 ^{a}	663 ± 3.1 ^{a}	246.2 ± 1.6 ^{a}
Na	493 ± 3.6 ^{a}	225 ± 2.4 ^{a}	22.9 ± 0.9 ^{a}

Values represent mean ± standard deviation. Statitistical significance of inter-sample difference analysed by ANOVA followed by LSD test for each macroelement separately (a – $p < 0.0001$).

Tab. 3. The content of microelements in samples.

Content [mg·kg^{-1}]	Berries	Dried pomace	Juice
B	14.5 ± 0.18 ^{a}	16.7 ± 0.21 ^{a}	10.99 ± 0.27 ^{a}
Cr	0.547 ± 0.06 ^{a}	0.857 ± 0.02 ^{a}	0.688 ± 0.03 ^{a}
Cu	2.22 ± 0.07 ^{a}	8.26 ± 0.13 ^{a}	5.25 ± 0.05 ^{a}
Fe	14.8 ± 0.21 ^{a}	21.8 ± 0.11 ^{a}	1.77 ± 0.24 ^{a}
Mn	18.7 ± 0.37 ^{b}	19.1 ± 0.17 ^{b}	3.51 ± 0.69 ^{a}
Ni	2.84 ± 0.25 ^{a}	2.26 ± 0.13 ^{a}	1.02 ± 0.02 ^{a}
Se	nd	nd	nd
Sr	7.35 ± 0.32 ^{a}	15.3 ± 0.13 ^{a}	0.407 ± 0.02 ^{a}
Zn	3.87 ± 0.03 ^{a}	9.42 ± 0.04 ^{a}	0.955 ± 0.02 ^{a}

Values represent mean ± standard deviation. Statitistical significance of inter-sample difference analysed by ANOVA followed by LSD test for each microelement separately (a – $p < 0.0001$, b – $p < 0.001$).
nd – not detected.

Tab. 4. Recommended daily intake of certain macro- and microelements [37–42].

Element	Recommended daily intake [mg·d^{-1}]		
	Children (4–8 years)	Women	Men
Ca	700–1000	800–1300	800–1300
K	2000–2300	2300–2600	2500–3400
Mg	80–240	320–360	400–420
Na	800–1000	1200–1500	1200–1500
B	0.85–1.06	0.92–1.03	1.29–1.42
Cr	0.11–0.015	0.021–0.025	0.025–0.035
Cu	0.34–0.44	0.70–0.90	0.70–0.90
Fe	7–10	8–18	8–11
Mn	1.2–1.5	1.6–1.8	1.9–2.3
Ni	0.08–0.1	0.10–0.11	0.13–0.15
Se	0.02–0.03	0.04–0.055	0.04–0.055
Sr	–	–	1–3
Zn	3–5	7.3–8	8.5–11

dried berries and pasteurized juice were analysed (approximately 3 840 mg·kg^{-1} and 1 495 mg·kg^{-1}, respectively) [16], it can be concluded that fresh berries and juice are a better source of K, which should also make them therapeutically more effective. The more efficient therapeutic effect of fresh cold-squeezed juice, compared to pasteurized juice, was confirmed in the study of Chrubastik et al. [8]. It showed degradation of certain biologically important components of aronia due to the exposure of the juice to elevated temperature.

The dried pomace, which remains after squeezing black chokeberry juice, with K content of 3 920 mg·kg^{-1}, can serve as a supplement to various food products, which can be used as a functional food when enriched with this mineral. Studies by Tanaka and Tanaka [17] showed that aronia fruits and products contain dietary fibre at 562 g·kg^{-1}, primarily cellulose, hemicellulose and lignin, which have a positive effect on the digestive system. Therefore, the use of black chokeberry as a functional food is recommended.

Apart from potassium, other minerals that are present can also significantly contribute to the functional and therapeutic effects of black chokeberry and black chokeberry-based products. Ca and Mg are minerals that have a very important role in the human body, where they primarily participate in the production and maintenance of bone tissue quality, the process of energy creation, transmission of nerve impulses and muscle contractions [15]. Lack of Ca and Mg in the human body can lead to osteoporosis, osteomalacia, arthritis and muscle weakness [15]. In addition to the intake of these minerals in the required amounts, the intake of boron as a trace element is necessary in order to prevent diseases caused by Ca and Mg deficiency because B interacts with Ca, Mg and vitamin D. Boron is also effective in treating arthritis, by increasing the efficiency of Ca uptake in bones, joints and cartilage [18]. Also, B reduces the loss of Ca, Mg and P, which increases their biological role in bone metabolism. In addition to the necessary physical activity, a healthy diet, with the intake of these minerals in sufficient quantities, is also needed for a properly functioning musculoskeletal system. Consumption of black chokeberry juice or other black chokeberry-based products (jam, tea, wine, pastries) can provide approximately 16 % of the recommended daily intake of Ca and Mg (Tab. 4). In order to better absorb Ca from the preparations based on black chokeberry, it is recommended to increase the intake of milk components such as proteins, phosphopeptides and lactose, while bioavailability of Mg can be improved by proteins, triglycerides and non-digestible carbohydrates [19, 20]. Phytates and oxalates, present in certain foods, are the main components that reduce bioavailability of Ca and Mg [19]. Boron, as a microelement, plays a very important role in the human body, however, there are only a few studies that deal with its health effects. A diet enriched with fresh black chokeberry berries and products based on this plant species, in a portion of 100 g (about 1.4 mg of boron), can fully compensate for the total daily needs of the human body for this element (Tab. 4).

Strontium, as a microelement, shows similar biological activity as macroelements Ca and Mg. Sr has a great tendency to bind to bone tissue, increasing its strength, which is especially pronounced in tooth enamel [21]. Also, like Ca, Sr has a very important role in preventing the occurrence and development of osteoporosis [22]. Given the biological importance of Sr, as well as the fact that the recommended daily intake of Sr, for adults, ranges from 0.98 mg to 2.2 mg (Tab. 4), consumption of fresh black chokeberry berries, with a total content of this element of approximately 7.35 mg·kg^{-1}, can have a significant therapeutic effect in maintaining a properly functioning skeletal system. The dried pomace contains a significant amount of Sr, 15.3 mg·kg^{-1}, by grinding of which raw materials for the needs of food, cosmetic, decorative and pharmaceutical industries can be obtained. Consumption of products enriched with this raw material may have positive effects on human health.

The modern way of life includes many stressful situations that can lead to apathy, depression, anxiety or other diseases, which, along with

an inappropriate diet and insufficient physical activity, can significantly damage the immune system in humans. A strong immune system is the basis of a healthy life, therefore, a sufficient intake of vitamins and minerals is necessary to strengthen the immune system, such as vitamin D, C, A, B-group vitamins, together with Zn, Cu, Se, Fe and Mg. A good way to get the necessary vitamins and minerals is through foods rich in these nutrients. Along with other foods used in human nutrition, berries, such as organic black chokeberry analysed in this study, are a good source of essential minerals (Tab. 2, Tab. 3). Based on the literature [23–25], it can be said that the analysed black chokeberry samples from the Republic of Serbia, compared to other berries (blueberries, raspberries, blackberries and strawberries), which are used in human nutrition, the former contain significantly more minerals. Thus, for example, the content of microelements in this study was more than 10-fold higher compared to the content of these minerals in other fruit berries [23]. The contents of Cu and Fe in this work were approximately twice as high compared to the contents of these two microelements in another study [24]. Only the in the case of Zn, the content determined in the present study was similar to the content of this micronutrient in a study of other authors [25]. For all of the above, the use of fresh black chokeberry berries, juice and other products based on this plant species has increased in the human diet significantly in the last two years, due to COVID-19 pandemic, in order to strengthen the human immune system.

The results of this study showed that consuming fresh black chokeberry berries can provide approximately 3 % of Zn and approximately 17 % of Cu, considering the total recommended daily intake for these elements. The dried pomace contains approximately 10 mg per kilogram of Cu and Zn. The total intake of Cu and Zn, as essential nutrients, is significantly increased by consuming biscuits, pastries and bread enriched with flour obtained from dried pomace, black chokeberry juice or various jams and spreads based on black chokeberry. Consumption of these foods, with potential therapeutic and functional effects, in human nutrition, can contribute to improvement of general health, while strengthening the immune system. The importance of Zn in the immune system is a consequence of its role in cell growth, division and maturation, cell membrane stabilization, as well as in DNA and RNA synthesis. Zn plays a role in these functions as an activator or an integral component of a large number of enzymes. In order to improve bioavailability of Zn from black chokeberry or foods rich in Zn for the human body, it is necessary to take into account the intake of phytate, oxalic acid and tannins, because they inhibit the absorption of Zn. On the other hand, picylonic acid, vitamin B6, citrates and certain amino acids (glycine, histidine, lysine and cysteine) have positive effects on Zn availability [26].

Copper, as an essential biometal, has an important role in the process of erythropoiesis, maturation and signal-mediated activity of immune cells, it participates in accelerating metabolism and strengthening tissue respiration, contributes to iron resorption in the digestive tract and catalyses hemoglobin biosynthesis, helping to incorporate heme iron [27]. Proteins and polybasic amino acids play an important role in improving bioavailability of Cu, while hemicellulose, fructose as well as some cations (Zn^{2+}, Fe^{2+}, Sn^{2+} and Mo^{2+}) reduce absorption of this mineral [28].

In addition to Cu and Zn, Fe also plays an important role in the human immune system when it comes to maintaining and improving general health. The main role of Fe, as an integral part of hemoglobin in red blood cells, is the transfer of oxygen from the lungs to the tissues of all organs in the body. Also, Fe is necessary for DNA synthesis, it serves as a transport medium for electrons in the cell and it is an integral part of important systemic enzymes in various tissues. Low Fe in the human body leads to anemia, while excessive intake of this element leads to hemosiderosis, as well as Cu deficiency. Cu is an element that plays a very important role in Fe metabolism, therefore, its deficiency in the organism can lead to various types of anemia [29, 30]. The plant species analysed in this study, in addition to previously mentioned health benefits, can also be used to compensate for iron deficiency in the body caused by disorders of metabolism of this element. Fresh black chokeberry berries contain approximately 15 $mg \cdot kg^{-1}$ of Fe, which represents approximately 10 % of the daily requirements for this nutrient, while approximately 22 $mg \cdot kg^{-1}$ of Fe, was detected in the flour from the dry residue. Based on the Fe content in the tested samples, fresh black chokeberry berries and flour from the dry residue can be a good raw material for enriching food with this bioelement. In order to improve bioavailability of Fe from black chokeberry and products based on this plant species, it is recommended to combine them with foods of natural origin rich in vitamin C, (hips, apples, strawberries, cherries, broccoli, peppers, etc.), given that polyphenols as inhibitors of Fe bioavailability are present at high content in chokeberry fruit [8, 31]. As the content of vitamin C in foods is reduced by heat treatment

[19], it is recommended to obtain juice by cold squeezing. In addition to polyphenols, inhibitors of Fe bioavailability are also phytates, caffeine and calcium [26]. Due to their inhibitory effect on Fe absorption, foods rich in these compounds, such as cereals, coffee, tea, milk and dairy products, should not be consumed together with black chokeberry and black chokeberry-based preparations.

Poor immune response of the organism, insufficient physical activity, as well as reduced intake of foods rich in natural fibres, vitamins and minerals, can lead to various health problems. The most common cause of cardiovascular and other chronic non-infectious diseases is obesity, which occurs as a consequence of disorders of lipid and carbohydrate metabolism. In addition to Cu, Zn and Fe, Cr and Mg also have an important role in lipid and carbohydrate metabolism.

Chromium is a bioelement that has a function in maintaining a normal concentration of glucose in the blood. Together with vitamin B3 and the amino acid glutathione, it is a part of the glucose tolerance factor, which improves glycoregulation, i. e. binding of insulin to its receptors, which enhances the effect of insulin. The study of NGALA et al. [32] showed that low levels of Cr in the organism led to elevated blood sugar, total cholesterol and triglycerides, but also to a decrease in high-density lipoprotein (HDL) levels and a decrease in insulin sensitivity. Since Zn and Mb reduce bioavailability of Cr, it is necessary to avoid consuming foods rich in these microelements together with black chokeberry and products based on this plant species [33]. The results of this study show that black chokeberry and black chokeberry-based products (juice and dried pomace flour) are a good source of Cr, and that they can be used to reduce blood sugar levels, as well as to lower total cholesterol and triglycerides. At the same time, consuming these foods should increase the concentration of HDL, as well as increase insulin sensitivity. Therefore, a daily intake of 100 g of black chokeberry berries can compensate for almost 100 % of the body‘s total needs for this element (Tab. 4).

Manganese has an important role in the metabolism of lipids and lipoproteins. It is also involved in the pathogenesis of atherosclerosis and numerous other cardiovascular diseases. The study by FRIEDMAN et al. [34] showed that serum cholesterol and HDL significantly reduced deficiency of Mn, while serum triglycerides and phospholipids increased Mn deficiency. It is known that Mn from meat and fish is much better absorbed than Mg from vegetables, while casein from milk reduces its bioavailability. Also, Fe has an inhibitory effect on bioavailability of Mn [35]. Since the lack of Mg in the human body, along with other risk factors (obesity, insufficient physical activity, diabetes, stressful situations, smoking), can lead to various forms of heart problems, it is advisable to consume foods rich in Mn. Black chokeberry and flour of dried pomace analysed in this study contain Mn at approximately 20 $mg \cdot kg^{-1}$, which corresponds to the recommended daily requirements for this element. Therefore, they can be used for therapeutic purposes.

The bioelement Se has a role in maintaining the body‘s resistance to various diseases by increasing the production and efficiency of leukocytes, and it protects them from the effects of free radicals that are formed during infections [36]. This mineral was not detected in black chokeberry samples analysed in this study, under defined conditions of the applied analytical technique.

The results of this study showed that, based on the content of mineral components, black chokeberry berries, juice and dried pomace, have a potential of various health benefits, which may qualify them to be a food of choice in the area of health-promoting, organically produced foods. In addition to the interest of certain population groups in consuming black chokeberry and products based on it, the increase in consumption preferences can be influenced by using modern, better designed packaging for berries, juice and other black chokeberry-based products. Also, incorporation of black chokeberry berries into candies or chocolates can increase the consumption of this fruit. This can be achieved also by highlighting the composition in the label on the packaging of juices and products that contain black chokeberry. In order to increase the consumption of these foods, because of their health benefits, these products should be made more accessible to the younger and older population, as well as to people with impaired health and those who are interested in a healthy lifestyle. Thus, it would be desirable to offer these products in a space where young people spend time, such as schools, colleges, libraries, canteens, cafeterias, fast food stores, and to healthcare users. The products could be consumed as a snack or as a meal.

CONCLUSIONS

Based on the results obtained in this study, it can be concluded that *Aronia melanocarpa* is a good source of some macroelements (Ca, K, Mg and Na) and some microelements (B, Cr, Cu, Fe,

Mn, Ni, Se, Sr and Zn). The content of macroelements, in fresh berries, ranged from 0.5 $g \cdot kg^{-1}$ to 5 $g \cdot kg^{-1}$, while the content of microelements ranged from 0.5 $mg \cdot kg^{-1}$ to approximately 19 $mg \cdot kg^{-1}$. The juice obtained by cold squeezing of black chokeberry fruit and the dried pomace also appear to be a good source of macroelements (0.02–3.7 $g \cdot kg^{-1}$ and 0.2–3.9 $g \cdot kg^{-1}$, respectively) as well as of microelements (approximately 0.4–11 $mg \cdot kg^{-1}$ and approximately 0.9–22 $mg \cdot kg^{-1}$, respectively). Bearing in mind that certain essential micro- and macroelements have a beneficial effect on human health (alleviation of cardiovascular problems, strengthening of the immune system, compensation of iron deficiency, prevention and alleviation of problems caused by osteoporosis, maintenance of normal locomotor system function), and that the analysed samples are rich in bioelements, it can be said, that black chokeberry and black chokeberry-based products can be used for therapeutic purposes or as a functional food. In order to make better use of bioelements from fresh black chokeberry berries as well as products based on this plant species, it is necessary to take into account the intake of other foods that contain components that could reduce bioavailability of these nutrients.

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