Journal of Elementology ISSN 1644-2296

Vaitkevičienė N., Jarienė E., Danilčenko H., Kulaitienė J., Mažeika R., Hallmann E., Blinstrubienė A. 2019.
Comparison of mineral and fatty acid composition of wild and cultivated sea buckthorn berries from Lithuania.
J. Elem., 24(3): 1101-1113. DOI: 10.5601/jelem.2019.24.1.1759

RECEIVED: 21 October 2018
ACCEPTED: 14 April 2019

ORIGINAL PAPER

COMPARISON OF MINERAL AND FATTY ACID COMPOSITION OF WILD AND CULTIVATED SEA BUCKTHORN BERRIES FROM LITHUANIA

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Abstract

Sea buckthorn (*Hippophae rhamnoides* L.) is an ancient plant with recently rediscovered nutritional and medicinal values. This research was carried in 2016-2017 in order to investigate and compare the mineral composition and fatty acid of sea buckthorn berries growing in the wild and cultivated in Lithuania. The content of essential elements (N, K, Mg, Ca, Fe, Zn, Se, Ni, and Cu), toxic heavy metals (Pb and Cd) and fatty acid composition was determined. The results showed that the main minerals identified were N and K. Cultivated berries had significantly more N (5.62%), P (14.00%), Ca (33.33%), Fe (7.09%), Mg (12.11%) and B (19.76%) than wild berries. In the whole berry, the dominant fatty acid classes were monounsaturated fatty acids (MUFAs), followed by polyunsaturated fatty acids (PUFAs) and saturated fatty acids (SFAs). The total MUFA content was significantly higher in wild berries than in cultivated ones, while PUFA and SFA levels were higher in cultivated berries. Based on these results, we conclude that berries of cultivated sea buckthorn can be a rich alternative source of PUFAs, such as linoleic and γ-linolenic acids, as well as some mineral elements (N, P, Ca, Fe, Mg). However, wild berries were found to be a good source of MUFAs (especially palmitoleic and vaccenic acids) and Cu. The high variation between different wild and cultivated sea buckthorns shows the potential for the selection and breeding of raw material for variously defined purposes.

Keywords: *Hippophaė rhamnoides* L, cultivated berry, wild berry, fatty acids, linoleic acid, omega-3, macro-microelements.

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INTRODUCTION

Sea buckthorn, which belongs to the family *Elaeagnaceae*, is a shrub or a small tree, approximately 3-4 metres high, with yellow flowers and orange berries (Michel et al. 2012). It is currently cultivated throughout the world for its valuable berries, which can be used for many purposes (Nowakowska et al. 2017*a*).

Berries of sea buckthorn have attracted considerable attention of researchers and consumers, mainly owing to their high nutritional and medicinal values (Bal et al. 2011). They are rich in organic acids, amino acids, vitamins (C, B_1, B_2, A, K, E), and have a high number of biologically active compounds (Bal et al. 2011, Burčová et al. 2017). Sea buckthorn berries contain multiple minerals. According to the literature, there are at least 24 mineral elements present in these berries, e.g., N, P, Ca, Fe, Mn, B, Si and others. Many of the components found in sea buckthorn are known to have beneficial effects on health, and are necessary for the proper functioning of the human organism (Krejcarová et al. 2015).

Another health-related aspect of sea buckthorn berries is their essential fatty acid composition, which humans cannot synthesize and must obtain from food. Essential fatty acids are necessary for the formation of healthy cell membranes and the proper development and functioning of the brain and nervous system (Pawlosky et al. 1996). Acids, especially polyunsaturated fatty acids (PUFAs), have an important influence on the prevention of coronary heart disease (Ander et al. 2003). A number of studies have indicated that soil from sea buckthron berries possesses important immunostimulant, antiulcer and cholesterol lowering effects (Geetha et al. 2005, Dulf 2012). Oil can be obtained from whole berries, pulp or seeds.

The chemical composition of sea buckhorn berries depends on many factors, of which the most important include the subspecies to which the plant belongs, its origin, the geographical/climatic conditions of the area where it grows, the time of harvesting, and the methods used for processing berries (Bal et al. 2011). In addition, the position of a berry on a tree can determine its nutrient and water status and its exposure to various environmental factors (sunlight, pests and diseases) (Yang et al. 2011). However, more research is needed to gain better understanding of the genetics, physiology and biochemistry of sea buckthorn grown in the wild or cultivated in different regions.

The increasing dietary intake of sea buckthorn berries represents an opportunity to improve the human population's health, and to develop value-added products that emphasize the functional properties of these berries, which can further stimulate local consumption. Considering the above, the objective of this study is to investigate and compare the mineral composition and fatty acid of sea buckthorn berries grown in the wild and cultivated in Lithuania.

MATERIAL AND METHODS

Plant materials

In this study, one wild (*Hippophae rhamnoides* ssp. *rhamnoides*) and one sea buckthorn cultivar Shcherbinka were grown in the same area in the Mažeikiai district of Lithuania (latitude 56°21′00′N, longitude 22 15′22′E). The wild berries were collected from natural growth sites, and berries of the cultivar Shcherbinka were obtained from a farmer in 2016 and 2017. Agrochemical characteristics of the native and cultivated soils are described in Table 1.

Table 1

Agrochemical characteristics of native and cultivated soils

Soil	pH_{KCL}	Total N	Available P	Available K
		(mg kg^{-1})		
Native	5.79	45.89	142.58	181.74
Cultivated	5.38	39.63	172.51	188.74

All berries were picked at a commercial maturity stage, in September, and 40 berries were used in each replicate. Analyses were performed in triplicate. Once the samples were collected, they were dried in an oven at 50°C for 24 h. The dried samples were ground in a laboratory mill (Grindomix GM 200, Retsch GmbH, Haan, Germany), and stored in airtight plastic bags in a dark and dry place until analysis (for one week).

Soil chemical analysis

Soil sampling for evaluation of the soil agrochemical characteristics was carried out in 2016 and 2017, in spring before leaves on the sea buckthorn plants emerged. The soil samples were taken using a sampling auger from randomly selected 5 points in each treatment replicate, from the surface soil layer of 0-20 cm in depth. The samples were air-dried, crushed in a porcelain mortar and sieved through a 2 mm sieve, after which they were analysed for: soil pH by the potentiometric method using a pH-meter in 1 N KCl extract (LST ISO 10390:2005), total nitrogen (N) mg kg^{-1} by the Kjeldal method (ISO 11261), availables phosphorus (P) mg kg^{-1} and potassium (K) mg kg^{-1} by the Egner-Riehm-Domingo (A-L) method (GOST 26208-91).

Lipid extraction using the Folch method

Extraction of lipids for fatty acid analysis was performed with chloroform/methanol (2:1 v/v) as described by FOLCH et al. (1957). A one-gram dried berry sample was mixed with 40 ml of a chloroform/methanol mixture and homogenized using a disperser T 18 (IKA®-Werke GmbH&Co. KG, Germany). After filtration, 20 ml of 0.74% potassium chloride solution was added, and the sample was left to stand for 10-12 h to allow complete stratification. The bottom layer was then collected with a syringe into a 15 ml test-tube and evaporated in a vacuum thermostat at 50°C. Methylation of the samples was performed using sodium methoxide and 25 wt % solution in methanol, then 5 ml sodium methoxide was added and the sample was stirred. After 1 h, 7 ml hydrochloric acid, 6 ml hexane and 2 ml water were added. The top layer was then transferred into a new test tube and evaporated.

Determination of fatty acid composition in total lipid extract of whole berries

Whole berry lipids were converted into their fatty acid methyl esters (FAMEs) and analysed. FAMEs were prepared using the procedure of Liu (1994). The FAMEs were analysed using a gas liquid chromatograph (GC-2010 Plus SHIMADZU) fitted with a flame ionization detector. The separation of methyl esters of the fatty acids was accomplished using a Restek capillary column Rt-2560 (100 m; 0.25 mm ID; 0.25 µm df; Restek, Bellefonte, PA, USA). The rate of flow of the carrier gas (nitrogen) was 0.79 ml min^{-1}, and the injection volume was 1.0 µl. The FAMEs were identified by comparing their retention times with those of the following authentic standard mixtures: Supelco 37 composition, FAME mix, trans FAME mix K110, and linoleic acid methyl ester isomer mix. The relative content of each fatty acid in a sample was expressed as a relative percentage of the sum of all the fatty acids.

Determination of macronutrients, essential trace elements and toxic heavy metals

The standard methods were used for the quantification of the following elements and heavy metals in the sea buckhorn berries dry matter: nitrogen (N) was assessed using the Kjeldahl method (LST EN 5983-1:2005); phosphorus (F), calcium (Ca), magnesium (Mg), potassium (K), iron (Fe), zinc (Zn), copper (Cu), boron (B) and molybdenum (Mn) were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES). The procedures were performed according to the standard method (LST EN 15510:2017). Cadmium (Cd), nickel (Ni), selenium (Se) and lead (Pb) were determined by graphite furnace atomic absorption spectrometry (GFAAS) after pressure digestion. Details on instrumental operating conditions and measurement parameters are given in standard (LST EN 14083:2003).

Statistical analysis

All data were statistically processed using a one-way analysis of variance (ANOVA) method from the software package Statistica (Statistica 10; StatSoft, Inc., Tulsa, OK, USA). Data were expressed as arithmetic means and standard deviations (mean ± S.D.). The statistical significance of differences between the means was estimated by the Fisher's LSD test ($p < 0.05$).

RESULTS AND DISCUSSION

Macronutrients and essential trace elements of berries

Imbalance of essential minerals disturbs the normal functioning of the human organism, which can cause several pathological conditions. Considering the importance of trace elements, we investigated the content of some minerals along with a few heavy metals in native (wild) naturally growing and cultivated sea buckthorn berries. The concentrations of these elements in the samples are summarized in Table 2.

Nitrogen was the predominant macroelement in the berries of both types of samples. According to our results, berries from the cultivar Shcherbinka had significantly higher levels (by 5.62%) of N (Table 2). Ercisli et al. (2007) also found that out of all the mineral elements they investigated, the content of N was higher in the berries of sea buckthorn that had grown wild in Turkey (range between 19.40 and 21.81 g kg^{-1} DM). Our results showed

Table 2

Macronutrients, essential trace elements and toxic heavy metals in whole berries from wild and cultivated types of sea buckthorn

Elements	Sea buckthorn	
	wild	cultivar Shcherbinka
	Macroelements (g kg^{-1} DM)	
Nitrogen (N)	17.61 ± 0.08*b*	18.60 ± 0.28*a*
Potassium (K)	9.820 ± 0.28*a*	10.30 ± 0.42*a*
Phosphorus (P)	1.501 ± 0.04*b*	1.710 ± 0.06*a*
Calcium (Ca)	0.638 ± 0.03*b*	0.844 ± 0.07*a*
Magnesium (Mg)	0.602 ± 0.03*a*	0.701 ± 0.03*a*
	Essential trace elements (mg kg^{-1} DM)	
Iron (Fe)	33.71 ± 0.42*b*	36.10 ± 0.38*a*
Copper (Cu)	4.250 ± 0.09*a*	3.100 ± 0.28*b*
Manganese (Mn)	10.90 ± 0.27*b*	12.22 ± 0.13*a*
Zinc (Zn)	9.501 ± 0.85*a*	9.357 ± 0.20*a*
Boron (B)	13.61 ± 0.14*b*	16.30 ± 0.28*a*
Selenium (Se)	LD	LD
Nickel (Ni)	0.492 ± 0.04*a*	0.411 ± 0.03*b*
	Toxic heavy metals (mg kg^{-1} DM)	
Cadmium (Cd)	0.023 ± 0.001*b*	0.045 ± 0.003*a*
Lead (Pb)	0.034 ± 0.003*a*	0.038 ± 0.003*a*

Average mean±standard deviation (n=3); the differences between the means marked by different letters (*a*, *b*) in the row are significant at $p \leq 0.05$; LD – limit of detection (< 0.60 mg kg^{-1}).

that the K content in the wild berries and cultured berries was 9.82 g kg^{-1} DM and 10.30 g kg^{-1} DM, respectively (Table 2). While the content of this element in both samples was similar, it was not found to be significantly different. In an earlier study (Nowakowska et al. 2017*b*) found that the K content of wild sea buckthorn berries ranged from 5.63 to 11.44 g kg^{-1}, and in cultivated berries (cv. Hergo), it was 14.82 g kg^{-1}. P is an essential mineral, primarily needed for the growth and repair of body cells and tissues. Our analysis indicated that the cultivated berries (1.71 g kg^{-1} DM) accumulated significantly higher P content than wild berries (1.50 g kg^{-1} DM) – Table 2. Our results agree with the findings of Nowakowska et al. (2017*b*), who reported P content ranging between 1.08 kg^{-1} and 1.74 g kg^{-1} in wild berries and 2.15 g kg^{-1} in berries of the cultivar Hergo. Sea buckthorn berries are also high in macroelements such as Ca and Mg. The Ca content in the wild berries and cultured berries was 0.64 g kg^{-1} DM and 0.84 g kg^{-1} DM, respectively (Table 2). Significant differences in the content of this element were identified between these samples. The levels of Mg in the berries analysed in our experiment were very similar. In another study, Zeb (2004) found that the Ca and Mg content of sea buckthorn berries was between 0.27 and 3.12 and 0.47 and 2.22 g kg^{-1}, respectively, which supports our present findings. Sabir et al. (2005) found Ca levels in the range 0.70-1.25 g kg^{-1} from berries grown in Pakistan, which is slightly higher than that in our study. However, our results for the content of Ca and Mg are higher than those found by Cioroi et al. (2017). According to many authors, the content of macronutrients in sea buckthorn berries depended on the quantity of these elements in the soil, and in a specific growing site. Soil pH also plays an important role in the mineral availability. Soil with low pH provides a higher content of elements to the plant than soil with neutral or slightly basic pH (Cioroi et al. 2017, Nowakowska et al. 2017*b*). Furthermore, differences in the composition of berries from native and cultivar sea buckthorn might be due to genetic differences and/or the adaptation of plants to the local environment (Yang et al. 2011).

Sea buckthorn also provides other microelements including Fe, Cu, Mn, Zn, B, Ni and Se, all of which have been found to possess nutraceutical potential (Sarpong et al. 2014). These minerals are essential to the healthy functioning of the human body. However, levels of these elements above permissible levels can cause various health problems. Among microelements, higher levels of Fe, Mn and B were detected in the cultivated berries, which had 7.09% more Fe, 12.11% more Mn and 19.76% more B than wild berries ($p < 0.05$) – Table 2. Recommended reference intakes of microelements are 14 mg/day Fe, 2 mg/day Mn and 10 mg/day Zn (EU Regulation 1169/2011). However, an especially high mean level of Cu (4.25 mg kg^{-1} DM) was found in wild berries; this level exceeded the level in berries from cultivated sea buckthorn plants by 37.10%. Therefore, wild berries can be a rich alternative source of Cu. The current reference nutrient intake for Cu is 1 mg/day for adults (EU Regulation 1169/2011). Therefore, 235 g of dry wild berries satisfies this demand. The wild grown sea buckthorn also had a significant higher concentration of Ni than cultivated berries. The content of Zn in the berry samples was very similar and was not found to be significantly different. The measured Se content in tested berries was below the limit of detection (< 0.60 mg kg^{-1}). According to a recent study, in the majority of cases, cultivated sea buckthorn berries contained higher levels of the tested micronutrients (Nowakowska et al. 2017*b*), which supports our present findings. Yang, Kallio (2001) reported that the Finnish and Chinese sea buckthorn berries contained Ca (0.27-1.48 g kg^{-1}), Mg (0.40-0.79 g kg^{-1}), Fe (22.0-282.0 mg kg^{-1}), Zn (8.8-27.0 mg kg^{-1}) and Cu (3.8-12.0 mg kg^{-1}). In addition to soil parameters, the uptake of these elements depends on interactions between individual elements, i.e. antagonistic and synergistic interactions between N, K, P, Mg, Fe and Zn (Rietra et al. 2017).

Toxic heavy metals in berries

Under normal conditions, plants contain low levels of heavy metals such as Pb, and Cd. The increase in the content of these elements in both the atmosphere and the soil also raises the content of these elements in plants. The content of Cd and Pb in tested berries was variable (Table 2). Similar levels of Pb were detected in both wild growing (0.034 mg kg^{-1} DM or 0.006 mg kg^{-1} FW**)** and cultivated (0.038 mg kg^{-1} DM or 0.007 mg kg^{-1} FW**)** plants. The allowable Pb content in small fruits is set by the European Commission (2006) at 0.20 mg kg^{-1} FW. The cultivated berries had higher Cd content (0.045 mg kg^{-1} DM or 0.008 mg kg^{-1} FW**)** than the wild berries (0.023 mg kg^{-1} DM or 0.004 mg kg^{-1} FW). These values did not exceed the maximum allowable concentrations (0.05 mg kg^{-1} FW) imposed by the European Commission (2006). These differences could be due to the natural content of these elements in the soil, as well as to contamination of both soil and air. Heavy metal bioavailability also depends on a plant species and its ability to absorb metals (Ercisli et al. 2007).

Fatty acid composition of berries

The fatty acid composition of the lipids extracted from wild and cultivated sea buckthorn berries is presented in Table 3. It was found that tested berries contained mostly UFAs (747.0 g kg^{-1} in wild berries and 744.3 g kg^{-1} in cultivated berries), composed primarily of MUFAs (512.7 g kg^{-1} in wild berries and 463.4 g kg^{-1} in cultivated berries) and PUFAs (234.3 g kg^{-1} in wild berries and 280.9 g kg^{-1} in cultivated berries). The total SFA content in the wild and cultured berries was 250.1 g kg^{-1} of the total fatty acid content and 253.9 g kg^{-1} of the total fatty acid content. Dulf (2012) studied the composition of fatty acids in oils from *cultivated* sea buckthorn (*Hippophae rhamnoides* L. ssp. *carpatica*) whole berries, and found values of UFAs and SFAs varying from of 612.9 to 754.2 g kg^{-1} and 245.8 to 387.2 g kg^{-1}, respectively. This result is in agreement with our results. In a previous study conducted by Xu et al. (2008), fatty acids in the whole berry and pulp oil were dominated by MUFAs (greater than 640 g kg^{-1}), followed by SFAs (approximately 300 g kg^{-1}), which is a slightly higher result than ours.

The results indicate that wild berries have a significantly higher total MUFA content than cultivated berries (Table 3). MUFAs were mainly repre-

Table 3

Fatty acid composition (weight g kg^{-1} of total fatty acid content) in whole berries of wild and cultivated sea buckthorn

Fatty acids	Sea buckthorn	
	wild	cultivar Shcherbinka
Myristic (C14:0)	2.60 ± 0.00*a*	2.00 ± 0.00*b*
Myristoleic (C14:1)	0.31 ± 0.00*b*	1.53 ± 0.22*a*
Pentadecanoic (C15:0)	0.93 ± 0.00*b*	2.23 ± 0.31*a*
Pentadecenoate (C15:1)	0.00 ± 0.00	0.60 ± 0.40*a*
Palmitic (C16:0)	227.2 ± 0.65*a*	223.1 ± 2.39*a*
Palmitoleic (C16:1 *n*-7)	185.0 ± 1.37*a*	134.6 ±0.50*b*
Hexadecenoic (C16:1 *n*-9)	0.91 ± 0.11*a*	0.80 ± 0.00*a*
Margaric (C17:0)	0.86 ± 0.16*a*	0.56 ± 0.00*b*
Margaroleic (C17:1)	0.44 ± 0.00*a*	0.71 ± 0.36*a*
Stearic (C18:0)	13.25 ± 0.33*b*	17.86 ± 0.44*a*
Oleic (C18:1 *n*-9)	255.5 ± 0.30*b*	264.1 ± 0.80*a*
Vaccenic (C18:1 *n*-7)	65.61 ± 0.30*a*	56.52 ± 1.10*b*
Linoleic (C18:2 *n*-6)	127.0 ± 2.22*b*	163.5 ± 0.16*a*
γ-linolenic (C18:3 *n*-6)	0.30 ± 0.16*a*	0.60 ± 0.25*a*
α-linolenic (C18:3 *n*-3)	100.3 ± 0.23*b*	109.8 ± 0.30*a*
Arachidic (C20:0)	2.81 ± 0.00*b*	3.72 ± 0.71*a*
Eicosenoic (C20:1 *n*-9)	2.50 ± 0.11*a*	2.73 ± 0.22*a*
Henicosanoic (C21:0)	0.73 ± 0.10*b*	1.54 ± 0.51*a*
Behenic (C22:0)	1.09 ± 0.13*b*	2.28 ± 0.24*a*
Erucic (C22:1 *n*-9)	1.06 ± 0.10*a*	1.07 ± 0.20*a*
Docosatetraenoic (C22:4 *n*-6)	3.90 ± 0.11*a*	4.41 ± 0.31*a*
Docosapentaensyre (C22:5 *n*-3)	2.53 ± 0.13*a*	2.60 ± 0.20*a*
Lignoceric (C24:0)	0.60 ± 0.00*b*	0.93 ± 0.00*a*
Nervonic (C24:1 *n*-9)	1.51 ± 0.10*a*	1.00 ± 0.22*b*
Other fatty acids	3.06 ± 0.47*a*	1.21 ± 0.29*b*
Total (g kg^{-1})	1000	1000
Sum of SFAs	250.1 ± 0.61*b*	253.9 ± 2.30*a*
Sum of UFAs	747.0 ± 1.10*a*	744.3 ± 3.33*a*
Sum of MUFAs	512.7 ± 3.53*a*	463.4 ± 0.82*b*
Sum of PUFAs	234.3 ± 1.90*b*	280.9 ± 0.50*a*
PUFAs/SFAs	0.937 ± 0.03*b*	1.106 ± 0.03*a*
Omega-6/omega-3	1.271 ± 0.02*b*	1.490 ± 0.03*a*

Average mean±standard deviation (n=3); the differences between the means marked by different letters (*a*, *b*) in the row are significant at $p \leq 0.05$; SFAs – saturated fatty acids, UFAs – unsaturated fatty acids, MUFAs – monounsaturated fatty acids, PUFAs – polyunsaturated fatty acids.

sented by oleic acid and palmitoleic acid. In wild berries, the palmitoleic acid content was significantly higher (by 37.44%) than that in cultivated berries, while significantly higher levels of oleic acid (3.37%) were found in cultivated berries. However, wild grown and cultivated samples did not show significant differences with respect to palmitoleic acid and eicosenoic acid. The next most abundant MUFA in tested samples was vaccenic acid, which was significantly higher in wild berries. Other MUFAs, including eicosenoic, nervonic, erucic, hexadecenoic, margaroleic, myristoleic and pentadecenoate (not determined in wild) acids were each <3.0 g kg^{-1} of the total fatty acid content. This study shows that cultivated sea buckthorn berries contain significantly higher levels of myristoleic acid (1.5 g kg^{-1}) and pentadecenoate acid (0.6 g kg^{-1}).

Significantly higher total content of PUFAs was detected in the berries of farm-raised plants compared to wild grown ones (Table 3). In total, there were 5 PUFAs determined in both experimental samples. Linoleic acid or omega-6 fatty acid and α-linolenic acid or omega-3 fatty acid were the predominant PUFAs found in the tested berries, and their levels were significantly higher in cultivated berries. Docosatetraenoic, docosapentaensyre and γ-linolenic acids in wild and cultivated berries contributed only 3.90 g kg^{-1} and 4.41 g kg^{-1}, 2.53 g kg^{-1} and 2.60 g kg^{-1}, and 0.30 g kg^{-1} and 0.60 g kg^{-1}, respectively, of the total fatty acid content. There were no significant differences among samples.

There were a total of 8 SFAs found in the tested samples (Table 3). The total SFAs content was significantly higher in cultivated berries (253.9 g kg^{-1}) than that in wild ones (250.1 g kg^{-1}). It was found that the dominant SFA in wild (227.2 g kg^{-1} of 250.1 g kg^{-1} total) and cultivated (223.1 g kg^{-1} of 253.9 g kg^{-1} total) berries was palmitic acid. The highest content of this fatty acid was observed in wild berries, but the difference between samples was insignificant. The proportion of stearic acid was significantly higher in cultivated berries than that in wild berries (17.86 g kg^{-1} and 13.25 g kg^{-1}, respectively). Other minor SFAs such as myristic, pentadecanoic, margaric, arachidic, henicosanoic, and behenic acids were found in trace levels only (< 4.0 g kg^{-1} of the total fatty acid content). More arachidic, pentadecanoic, henicosanoic, behenic acids, and less myristic and margaric acids were found in cultivated berry oil than that in wild berry oil ($p < 0.05$).

Similar contents of MUFA oleic (220-460 g kg^{-1}), SFA palmitic (210-370 g kg^{-1}), MUFA palmitoleic (100-250 g kg^{-1}), MUFA vaccenic (40-70 g kg^{-1}), SFA stearic (8-27 g kg^{-1}), and SFA myristic (2-6 g kg^{-1}) acids were recently reported by Dulf (2012) for oil from whole berries of six sea buckthorn cultivars grown in Romania. However, our results are lower than those reported by Fatima et al. (2012). These authors found that the content of various fatty acids in whole berry oil of sea buckthorn cultivars grown in Canadia was 310-330 g kg^{-1} for SFA palmitic acid, 280-370 g kg^{-1} for MUFA palmitoleic acid and 120-180 g kg^{-1} for PUFA linoleic acid. Yang and Kallio (2002) reported that the main fatty acids in oil from whole berries of ssp. *rhamnoides* and ssp. *sinensis* were MUFA palmitoleic (270-330 g kg^{-1}), SFA palmitic (270-280 g kg^{-1}), MUFA oleic (170 g kg^{-1}), PUFA linoleic (90-130 g kg^{-1}), and MUFA vaccenic (80-90 g kg^{-1}). However, compared to these results, the content of α-linolenic acids was found to be higher in our samples. These results confirm that oil from wild and cultivated sea buckthorn whole berries grown in Lithuania have high levels of α-linolenic acid. An explanation behind the variability in the total and individual fatty acid levels of sea buckthorn whole berries may be sought in the different extraction procedures and analytical methods used in each study. In addition, it has been suggested that fatty acid composition in berries varies according to a subspecies, origin, cultivation conditions and place, and harvest time of berries (Yang, Kallio 2002). Differences in the fatty acid composition between wild and cultivated sea buckthorn have been attributed to differences in growth caused by soil moisture and nutrition, as well as physiological stresses associated with the rate of growth.

The ratio of PUFA to SFA is frequently used in an assessment of the nutritional value of fat composition (Uylaşer, Yildiz 2013). In the present study, PUFA/SFA ratios were close to one (0.94 in wild berries and 1.11 in cultivated berries), with a significantly higher value in cultivated berries (Table 3). Kang et al. (2005) have shown that a PUFA/SFA ratio of 1.0-1.5 in the human diet can contribute to a reduction in cardiovascular diseases.

Statistically significant differences were found between the omega-6/omega-3 ratios of analysed whole berries, with higher values in cultivated berries (1.49) and lower values in wild ones (1.27) – Table 3. According to the literature, an ideal omega-6/omega-3 ratio should not exceed 4, since higher ratios are associated with an increased risk of cancer, cardiovascular, inflammatory and autoimmune diseases (Moreira et al. 2001). The ratio of omega--6/omega-3 fatty acids from whole berries found in this study was in accordance with that reported by Dulf (2012). Other authors also reported that sea buckthorn berry oil is of particular nutritional interest because its n-6/n-3 ratio is low (<2), compared to most other vegetable oils (Dubois et al. 2007).

The amount of oil that can be extruded from berries is a very important parameter. The research will be continued to obtain optimal technological parameters for extraction of oil from wild and cultivated berries.

CONCLUSION

The mineral composition and fatty acid of wild and cultivated Lithuanian sea buckthorn is reported for the first time in this paper. Cultivated sea buckthorn contains higher levels of PUFAs such as linoleic and γ-linolenic acids and of macro/microelements such as N, P, Ca, Fe, Mn, B compared to wild berries. However, wild berries have higher levels of MUFAs (palmitoleic and vaccenic acids) and Cu. Oleic and palmitic acids were the major fatty acids found in both samples in this study.

The research results of this study enable deliberate selection of type of berries for desirable micro- and macroelements or fatty acids. The results are also valuable pharmacologically, as *Hippophae rhamnoides* ssp. *rhamnoides* berries is justly called a medicinal plant containing compounds having a desirable influence on health.

ACKNOWLEDGEMENTS

The authors appreciate the help of Gabriele Zelvyte M.S, in conducting this research.

REFERENCES

Ander B.P., Dupasquier C.M.C., Prociuk M.A., Pierce G.N. 2003. *Polyunsaturated fatty acids and their effects on cardiovascular disease*. Exp. Clin. Cardiol., 8(4): 164-172.

Bal L.M., Meda V., Naik S.N., Satya S. 2011. *Sea buckthorn berries: a potential source of valuable nutrients for nutraceuticals and cosmoceuticals*. Food Res Int., 44(7): 1718-1727. DOI: 10.1016/j.foodres.2011.03.002

Burčová Z., Kreps F., Schmidt Š., Jablonský M., Ház A., Sládková A., Šurina I. 2017. *Composition of fatty acids and tocopherols in peels, seeds and leaves of sea buckthorn*. Acta Chim Slov, 10(1): 29-34. DOI: 10.1515/acs-2017-0005

Cioroi M., Chiriac E.R., Stefan C.S. 2017. *Determination of acidity, total polyphenols content, calcium, magnesium and phosphorous in sea buckthorn berries*. Rev. Chim., 68(2): 300-303.

Dubois V., Breton S., Linder M., Fanni J., Parmentier M. 2007. *Fatty acid profiles of 80 vegetable oils with regard to their nutritional potential*. Eur. J. Lipid Sci. Tech., 109(7): 710-732. DOI: 10.1002/ejlt.200700040

Dulf F.V. 2012. *Fatty acids in berry lipids of six sea buckthorn (Hippophae rhamnoides* L.*, subspecies carpatica) cultivars grown in Romania*. Chem. Cent. J., 6(1): 1-12. DOI: 10.1186/ /1752-153X-6-106

Ercisli S., Orhan E., Ozdemir O., Sengul M. 2007. *The genotypic effects on the chemical composition and antioxidant activity of sea buckthorn (Hippophae rhamnoides* L.*) berries grown in Turkey*. Sci. Hortic., 115(1): 27-33. DOI: 10.1016/j.scienta.2007.07.004

EU Regulation. No 1169/2011 of the European Parliament and of the Council of 25 October 2011 *on the provision of food information to consumers*.

European Commission. 2006. Commission Regulation (EC) No 1881/2006 of 19 December 2006. *Setting maximum levels for certain contaminants in foodstuffs*. OJEC, L364(1881): 5-24.

Fatima T., Snyder C.L., Schroeder W.R., Cram D., Datla R., Wishart D., Krishna P. 2012. *Fatty acid composition of developing sea buckthorn (Hippophae rhamnoides* L.*) berry and the transcriptome of the mature seed*. PLOS ONE, 7(4): 1-18. DOI: 10.1371/journal.pone.0034099

Folch J., Less M., Sloanc-Stanley G.H. 1957. *A simple method for isolation and purification of total lipids from animal tissues*. J. Biol. Chem., 226: 497-509.

Geetha S., Singh V., Ram M.S., Ilavazhagan G., Banerjee P.K., Sawhney R.C. 2005. *Immunomodulatory effects of seabuckthorn (Hippophae rhamnoides* L.*) against chromium (VI) induced immunosuppression*. Mol. Cell. Biochem., 278(1-2): 101-109. DOI: 10.1007/s11010- -005-7095-9

GOST 26208-91. 1993. *Soils. Determination of mobile compounds of phosphorus and potassium by Egner-Riem-Domingo method (AL-method).* Moscow, Russia.

Yang B., Kallio H. 2001. *Fatty acid composition of lipids in sea buckthorn (Hippophaė rhamnoides* L.*) berries of different origins.* J. Agric. Food Chem., 49: 1939-1947. DOI: 10.1021/ /jf001059s

Yang B., Kallio H. 2002. *Effects of harvesting time on triacylglycerols and glycerophospholipids of sea buckthorn (Hippophaë rhamnoides* L.*) berries of different origins.* J. Food Compos. Anal., 15(2): 143-157. DOI: 10.1006/jfca.2001.1041

Yang B., Zheng J., Kallio H. 2011. *Influence of origin, harvesting time and weather conditions on content of inositols and methylinositols in sea buckthorn (Hippophaë rhamnoides) berries.* Food Chem., 125(2): 388-396. DOI: 10.1016/j.foodchem.2010.09.013

ISO 11261:1997 *Soil quality – Determination of total nitrogen – modified Kjeldahl method.*

Kang M.J., Shin M.S., Park J.N., Lee S.S. 2005. *The effects of polyunsaturated:saturated fatty acids ratios and peroxidisability index values of dietary fats on serum lipid profiles and hepatic enzyme activities in rats.* B. J. Nutr., 94(4): 526-532. DOI: 10.1079/BJN20051523

Krejcarová J., Straková E., Suchý P., Herzig I., Karásková K. 2015. *Sea buckthorn (Hippophae rhamnoides* L.*) as a potential source of nutraceutics and its therapeutic possibilities – a review.* Acta Vet. Brno, 84(3): 257-268. DOI: 10.2754/avb201584030257

Liu K.S. 1994. *Preparation of fatty acid methyl esters for gas-chromatographic analysis of lipids in biological materials.* J. Am. Oil Chem. Soc., 71(11): 1179-1187. DOI: 10.1007/BF02540534

LST EN 14083:2003 *Foodstuffs – Determination of trace elements – Determination of lead, cadmium, chromium and molybdenum by graphite furnace atomic absorption spectrometry (GFAAS) after pressure digestion.*

LST EN 15510:2017 *Animal feeding stuffs: Methods of sampling and analysis - Determination of calcium, sodium, phosphorus, magnesium, potassium, iron, zinc, copper, manganese, cobalt, molybdenum and lead by ICP-AES.*

LST EN ISO 5983-1:2005 *Animal feeding stuffs – Determination of nitrogen content and calculation of crude protein content.* Part 1. *Kjeldahl method.*

LST ISO 10390:2005 S*oil quality. Determination of pH.*

Michel T., Destandau E., le Floch G., Lucchesi M.E., Elfakir C. 2012. *Antimicrobial, antioxidant and phytochemical investigations of sea buckthorn (Hippophaë rhamnoides* L.*) leaf, stem, root and seed.* Food Chem., 131(3): 754-760. DOI:10.1016/j.foodchem.2011.09.029

Moreira A.B., Visentainer J.V., de Souza N.E., Matsushita M. 2001. *Fatty acids profile and cholesterol contents of three Brazilian Brycon freshwater fishes.* J. Food Compos. Anal., 14(6): 565-574. DOI: 10.1006/jfca.2001.1025

Nowakowska M., Ochmian I., Mijowska K. 2017*a*. *Assessment of the sea buckthorn growing in urban conditions – the quality of berries and leaves.* J. Elem., 22(2): 399-409. DOI: 10.5601/ /jelem.2016.21.2.1168

Nowakowska M., Ochmian I., Mijowska K. 2017*b*. *The influence of street conditions on sea buckthorn fruit quality and content of micro- and macronutrients in berries and in soil.* J. Elem., 22(1): 235-244. DOI: 10.5601/jelem.2015.20.1.871

Pawlosky R.J., Glenn W., Norman S. 1996. *Essential fatty acid uptake and metabolism in the developing rodent brain.* Lipids, 31: 103-107. https://doi.org/10.1007/BF02637060

Rietra R.P.J., Heinen M., Dimkpa C.O., BINDRABAN P.S. 2017. *Effects of nutrient antagonism and synergism on yield and fertilizer use efficiency*. Commun. Soil Sci. Plant Anal., 48: 1895-1920. DOI: 10.1080/00103624.2017.1407429

Sabir S.M., Maqsood H., Ahmed S.D., Shah A.H., Khan M. Q. 2005. *Chemical and nutritional constituents of sea buckthorn (Hippophae rhamnoides* ssp. *turkestanica) berries from Pakistan.* Ital. J. Food Sci., 17(4): 455-462.

Sarpong K., Dartey E., Owusu-Mensah I. 2014. *Assessment of trace metal levels in commonly used vegetables sold at selected markets in Ghana.* Inst. J. Med. Plants Res., 3(4): 290-295.

UYLAŞER V., YILDIZ G. 2013. *Fatty acid profile and mineral content of commercial table olives from Turkey*. Not. Bot. Horti Agrobot. Cluj. Napoca, 41(2): 518-523. DOI: http://dx.doi.org/10.15835/nbha4129228

XU X., GAO Y., LIU G., ZHENG Y., ZHAO J. 2008. *Supercritical CO_2 extraction of whole berry oil from sea buckthorn (Hippophaë rhamnoides* var. sp*) fruit.* Food Sci. Biotechnol., 17(3): 470-474.

ZEB A. 2004. *Chemical and nutritional constituents of sea buckthorn juice.* Pak. J. Nutr., 3: 99-106. DOI: 10.3923/pjn.2004.99.106