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The content of bioactive substances in sea buckthorn and the functional potential of its waste

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Abstract

Recently the sea buckthorn became one of cultivated species. Research in the food industry aims to capitalize on sea buckthorn in a wide range of products due to the benefits it may brings to the human body. The recovery and use of sea buckthorn waste is also valuable regarding the nutritional value. Sea buckthorn contains various types of nutrients and bioactive substances, such as vitamins, carotenoids, flavonoids, polyunsaturated fatty acids , free amino acids, minerals and more. Sea buckthorn fruits can produce juices, jams, oils, food pigments, tea, and its waste may be valorized in sea buckthorn flour which is used as a bioactive ingredient other food products. This paper presents aspects such as: identification of sea buckthorn products and the waste which can be transformed in new functional ingredients.

Keywords: sea buckthorn, waste, bioactive, functional product

1. Introduction

Research on the cultivation and use of sea buckthorn (*Hippophae rhamnoides* L.) is the subject of research in the food industry, human and veterinary medicine, agriculture, horticulture, animal husbandry and landscape architecture. It was intended that the plants, fruits and waste from the processing could be used in multiple forms for food purposes. At the base of the scientific name is a legend, the name being given by Charles Linne, the species appears in 1753 in "Specie Plantarum" at number 1023. Sea buckthorn is already used in a wide range of foods, we will describe the known ones and the improvements it brings. Sea buckthorn contains various types of nutrients and bioactive substances, such as vitamins, carotenoids, flavonoids, polyunsaturated fatty acids, free amino acids, elemental components and more [38,39].

The sea buckthorn products now on the European market, some on a large scale, some on a small scale, are: Sea buckthorn juice, Jellies, Liqueurs, sweets, vitamin C tablets, sea buckthorn oil, beer, wine, tea, food pigment, jam, sea buckthorn cookies, medicines, cosmetics, shampoos, pet supplements.

He presence of valuable chemicals and nutritionally important constituents in sea buckthorn berries, and from the scientific knowledge of their importance, it is clear that sea buckthorn berry is one of the most important sources of these constituents, and should be used as alternative nutritional sources in the commercial market. Similarly in depth investigation on the effect of processing on the total nutrient content of sea buckthorn berries species growing in different agro-ecological regions needs to be carried out [3].

2.The content of bioactive substances in Sea Buckthorn

2.1.Phenolic Compounds

The whole plant of sea buckthorn-berries, roots, leaves, steams and branches -contain various kinds of phenolic, including flavonoides, phenolic acids, and hydrolysable tanins [16]. The concentration of phenolic compounds differs depending on the part of the plant or fruit. A total of 15 phenolic compounds, classified into 4 categories (flavones, phenolic acids, flavonol-monoglycosides, and flavonol-diglycosides), were identified by Guo et al.

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Only in the free fractions of all sea buckthorn subspecies, using the RP-HPLC tehnique [19]. Flavonoids and phenolic compounds more than 60 flavonoids and 10 phenolic acids were founded in Sea Boukthorn [50,51]. Flavonoids ar the most common polyphenols found in food, especially their glycosides, which form the largest group of antioxidants found in nature [10]. Their concentration in sea buckthorn berries is several times higher than the content recorder in other high-flavonoid plants such as hawthorn, cornelian cherry, whild grown European black-bery, blacktorn or dog rose, mulberry, pomegranate, red raspberries, end blueberry [12]. A recent studi of sea bucktorn berries from Poland reported a flavonoid content from 4,63 to 8,93 mg/g DW [48]. Fruits, over 98% of flavonoids were flavonols; and isorhamnetin derivatives were dominant (from 66% to 72% of total flavonols), followed by quercetin derivatives (from 25% to 32% of total flavonols) [49]. Flavonol glycosides form the most concentrated class of phenolic compounds in sea buckthorn [44, 33]. They are found mainly in gycosylated forms of the aglycones of isorhamnetin, quercitin, myricetin, and kaempferol [12,33]. Regarding the phenolic acid content of sea buckthorn fruit, Zadernowski et al. described that the salicylic acid is the dominating phenolic acid in sea buckthorn berries [56]. In addition to flavonoids and phenolic acid, Hippophae species contain tanins. Tanins in sea Buckthorn are divided into two grupsȘ hydrolysable and condensed tannins. Gallo- and ellagitannins of monomeric type are the most abundant subgrups of hydrolysable tannins and includes stachyurin, casuarinin, casuarictin, hippophaenin B, strictinin, and isostrictinin [22,28]. Condensed (procianidins), while the other group consist of (+)-gallocatechin or (-)-epichatechin units (procianidins), while the other group consist of (+)-gallocatechin or (-) epigallocatechin units (prodelphinidins) [40, 42]. They are present in higher concentrations in sea buckthorn seeds, roots, flowers, green berries, and stems [31].

2.2. Ascorbic Acid

Ascorbic acid (vitamin C) is the most important therapeutic element in sea buckthorn fruit, as it acts as an antioxidant and supports the integrity of the cell membrane [25,26]. In *H. rhamnoides*, extensive variation of vitamin C were found between different shrubs, populations, and subspecies.

The most stand-out trait of Sea Buckthorn is high content of vitamin C. Beveridge et al. (1999) [4] reviewed vitamin C values from 360 to as high as 1676 mg/100 g of berry, whereas Tiitinen et al. (2006b) [47] reported values from 128 to 1300 mg/100 ml of berry juice, which is clearly higher than the concentration naturally found in naturally vitamin C rich fruits, such as lemons, oranges [11] or even kiwis [13]. The highest concentrations are only comparable with exotic fruits like acerola [6]. Thus, Sea Buckthorn emerges as a great source of vitamin C after considering that one of the lowest values found in literature is 80.58 mg of vitamin C/100 g of fresh berries [46]. Nevertheless, vitamin C is rapidly degraded under certain processing conditions. Light, temperature, pH, enzymes, metallic catalyzers, and oxygen are parameters that can severely accelerate vitamin C degradation [20,41]. The starting concentration of vitamin C in the raw product is a major factor affecting the final concentration of this vitamin after processing. The high concentration values reported for Sea Buckthorn allows obtaining high vitamin C products even after processing. This is of great importance since a lot of products have difficulties in conserving adequate vitamin C levels after processing. The ascorbic acid content in sea buckthorn berries is 5 to 100 times higher than most other fruit or vegetable crops independently of Hippophae species [8]. The vitamin C content in sea buckthorn was found to be 20 times higher than of hawthorn, 3 times higher than in kiwi, 6 times higher than in citrus, 80 times higher than in tomatoes, and 200 times higher than apples [55].

2.3. Lipids and Fatty Acids

The composition of sea buckthorn seed and pulp oils varies depending on the subspecies, origin, crop care activities, fruit harvesting time, and extraction method [17,51]. Morphologically, sea buckthotn berries consist of seeds 23%, pulp 68%, and sckin 8% [17]. The main constituents of neutral lipids in sea buckthorn are cerides (esters of C20-C26 fatty acids whith aliphatic alcohols), concentrated in the peel of the fruit and in the seed, C23-C29 hydrocarbons (most of the surface layer of the peel) and phytosterols (70-100% β-sitosterol, α—and β-amyrins, erytrodiol and other constituents of the unsaponifiable lipid fraction of seeds) [23].

Sea buckthorn seed oils contain mainly the following acids: linoleic, α-linolenic, oleic, palmitic, and stearic, whith small amounts or traces of vaccenic, palmitoleic, arachidic, eicosanoic, myristic, pentadecanoic, and margaric acid. A notable feature of sea buckthorn seed oils is the extremely low level of palmitoleic acid (0,1-0,5%). Large relative deviations were observed for oleic acid (13-21%) and linoleic acid (33-43%) concentrations. Unlike pulp oils, seed oils had higher amounts of polyunsaturated fatty acids (65-72%) and lower amounts of monounsaturated fatty acids (16-21,5%) and saturated fatty acids (11-16%), respectively [14]. The high content of palmitoleic acid, unusual for a vegetable oil, distinguishes the oil from sea buckthotn pulp/peel from those from sea buckthorn seeds [37].

2.4. Carbohydrates and Fibers

In addition, the sugar content varies depending on the origin, population, and genetic background of the plant [35]. The catbohydrates contained in sea buckthorn berries are mostly glucose and fructose, with small amounts of xylose, mannitol, sorbitol, xylitol [35], ethyl glucose end saccharose [47]. As sea buchthorn berries have a low sugar content and a high titratable acidity, an important factor in improving the flovor of sea buckthorn berries is a high sugar/acid ratio [24,58]. The seeds are source of highly unsaturated oil, containing saponifiable and unsaponifiable matter. Phytosterols are the major constituents of the unsaponifiable fraction of sea buckthorn, which are capable of lowering plasma cholesterol upon consumption by humans. [14,51]. Furthermore, due to its constituents, the oil from fruits and seeds has been tested in various pathological conditions [3] (such as liver diseases, inflammation, disorders of the gastrointestinal system, eczema, wounds, inflammation, burns, lupus erythematosus, and chronic dermatoses. Oil from seed or pulp absorbs ultraviolet light and promote healthy skin [18].

The polysaccharides of sea buckthorn berries are especially non-starchy type of polysaccharides, composed of cellulose, hemicelluloses, pectin, and hydrocolloids that are together with lignin the major constituents of dietary fiber [8]. Pilat et al. reported only sea buckthorn seeds contain starch, a dietary polysaccharide whith high digestibility in the human small intestine, in an amount of 49 g/kg dry weight [60].

Both peel and pulp contain pectin, in much smaller quantities of 5 g/kg dry weight and 15 g/kg dry weight, respectively. The content of raw fiber in seeds was 130 g/kg dry weight, in peel 66g/kg dry weight, and pulp 47 g/kg dry weight [60].

2.5. Proteins and Amino Acids

Distribution of protein in sea bucktorn berry varies widely in particular parts, the sea buckthorn seeds being considered a unique protein surse [8]. Comparing to other berry varietes, the berries of sea buckthorn are caracterized by a relatively high content of protein [54]. A total of 18 out of 22 known amino acids have been found in seabuckthorn fruit [32,57], half ofwhich are essential since they play a critical role in various processeswithin our bodies such as energy production, building cells andmuscles, fat loss, and mood and brain functions. Sea buckthorn juice isrich in various free amino acids [3]. In addition, the protein levels in sea bucktorn juice are quite high for a fruit juice and this in reflected in the fact that sea buckthorn juice is a cloudy or opalescent product. The source of opalescence in most juice is duet o the presence of cellular debries, but largely duet o the precence of cell membranes that contain considerable proteins and give a stable turbidity to the juice [27].

The total protein content reported for various species of sea buckthorn were 46-129g/kg dry weight (India variety)and 93 g/kg dry weight (Polish variety) [29,56]. Asparagine was also found quantitatively predominant in sea bucktorn in other more recent studies [26]. Aspartic acid as the predominant free amino acid in sea buckthorn berries followed by proline, and thereonine [57].

2.6. Carotenoids

Various carotenoids are the main substances present in large quantities in the pulp of sea buckthorn fruits [24,36], acting as an antioxidant and helping to syntesize and epithelialize collagen [25]. The different carotenoids generally increased in concentration during ripening and comprised from 120 to 1425 µg/g to 1425 µg/g of DW of total carotenoids (1.5-18.5 mg/100 g of FW) depending on cultivar, harvest time, and year [2].

Pop et al. reported a total carotenoid content of a Romanian *H. rhamnoides* variety of 860 mg/kg dry weight of berries, identifying zeaxanthin dipalmitte and other zeaxanthin ester, β-carotene, non-conjugated zeaxanthin, lycopene and β-cryptoxanthin palmitate as dominant carotenoids [36]. The carotenoid content is one of the key characteristics by which sea buckthorn oi lis traded commercially. Carotenoids in oil vary widely depending on the source of the oil from 0,5 to 21,4 g/kg [27].

3. Industrial sea buckthorn fruit products

3.1. Juice sea bucktorn

Sea buckthorn juice is one of the imperative product obtained from the sea buckthorn berries, is now commercially very important. The juice provides a nutritious beverage, high in suspended solids, and very high in vitamins especially in vitamin C and carotenoids. It contains different kinds of nutrients and bioactive substances including vitamins, fatty acids, free amino acids and elemental components. These components vary substantially among individuals, populations, origins or subspecies [53]. The sea buckthorn juice is yellow in color; the high amount of carotene is responsible for this yellow coloration. The presence of some of the other pigments also contributes to the color. Granules or clumps are embedded in the juice, which are actually yellow-brown in color [4,5]. The oil droplets also contribute to the yellow coloration [53]. The chemical composition of sea buckthorn berries varies with the origin, climate and method of extraction.

3.2. Sea buckthorn jam

Selvamuthukumaran and co-workers studied obtaining sea buckthorn jam with a strong antioxidant effect. They were used to make frozen sea buckthorn jam, commercial grade food sucrose, baking soda and carrageenan. Thus they obtained a stable product. The ingredients, viz. sugar and carrageenan were chosen as independent variables, while sensory attributes, i.e. taste and consistency as dependent variables. Effects of various independent variables on chosen response show that the ingredient sugar had more prominent effect on taste score and carrageenan on consistency score, respectively. The optimum conditions to yield maximum scores of taste and consistency of jam were sugar of 85 gm and carrageenan of 3.4 gm per 100 gm of recipe. Jam contains more natural antioxidants with good texture when compared to commercial products. Shelf stability of jam shows that significant changes in nutritional constituents were observed except acidity and pH during the entire storage period. The microbial population of stored sample was found to be non detectable and product showed a stability of 8-months at room temperature [43].

3.3. Oil sea buckthorn

Zielińska and Nowak studied obtaining sea buckthorn oil. Vegetable oils are obtained by mechanical extraction or cold pressing of various parts of plants, most often: seeds, fruits, and drupels. Chemically, these oils are compounds of the ester-linked glycerol and higher fatty acids with long aliphatic chain hydrocarbons (min. C14:0). Vegetable oils have a variety of properties, depending on their percentage of saturation. This article describes sea-buckthorn oil, which is extracted from the well characterized fruit and seeds of sea buckthorn. The plant has a large number of active ingredients the properties of which are successfully used in the cosmetic industry and in medicine. Valuable substances contained in sea-buckthorn oil play an important role in the proper functioning of the human body and give skin a beautiful and healthy appearance. A balanced composition of fatty acids give the number of vitamins or their range in this oil and explains its frequent use in cosmetic products for the care of dry, flaky or rapidly aging skin. Moreover, its unique unsaturated fatty acids, such as palmitooleic acid (omega-7) and gamma-linolenic acid (omega-6), give sea-buckthorn oil skin regeneration and repair properties. Sea-buckthorn oil also improves blood circulation, facilitates oxygenation of the skin, removes excess toxins from the body and easily penetrates through the epidermis. Because inside the skin the gamma-linolenic acid is converted to prostaglandins, sea-buckthorn oil protects against infections, prevents allergies, eliminates inflammation and inhibits the aging process. With close to 200 properties, sea-buckthorn oil is a valuable addition to health and beauty products [59].

4. Functional potential of its waste

Numerous studies have shown that waste from fruit processing has a high content of bioactive compounds with high antioxidant capacity [1,15], with a beneficial role on human healt [9,34].

International scientific research has focused on the characterization of fruit by-products and their further incorporation for the development of functional foods and beverages [50]. Choosing the most appropriate extraction method for obtaining bioactive compounds from agri-food by-products is a broad topic of discussion. On the one hand, we are looking for ways to increase the amount of valuable nutrients and biocomposites while optimizing the extraction parameters in order to minimize the negative impact on the obtained extract, and on the other hand, we aim to reduce costs and processing time. Additionally, a constant challenge is finding the best method to ensure a low impact on the environment and consumer health, reduce energy costs, and use safe solvents. The chosen extraction method is characterized by parameters such as the type of solvent, its pH, the solid–liquid ratio, the process temperature, and the contact area between the solid and the solvent. In turn, these variables affect the energy consumption, the quantity of solvent used and its recovery capacity, the extraction yield, and other factors, which have been increasingly studied through the optimization of parameters and comparison between techniques for different target compounds and their matrix (Leichtweis et al. 2021; Kumar et al. 2021).

Another way to capitalize on sea buckthorn grains is to dry the residue obtained by extracting the juice, drying it and grinding it, thus obtaining sea buckthorn flour, which can be used to obtain new functional products. Following the research carried out by Stoin D., he indicated that the addition of 10% dry sea buckthorn in the dough of cookies was observed to improve the sensory and nutritional qualities [44].

Sturza R. demonstrated hows the impact of biologically active substances on structural and mechanical, physicochemical, microbiological properties as well as the antioxidant activity of products under the conditions of in vitro gastric digestion. It has been demonstrated that the sea buckthorn flour increases the porosity of pastries, reduces the wet gluten amount and this contributes to moisture loss. The organoleptic assessment indicates that the addition of 2 % sea buckthorn flour improves the appearance, the color and the consistency of pastries. Microbiological analysis showed that samples with added sea buckthorn flour exhibit microbiological stability due to the sea buckthorn chemical composition.

The antiradical activity DPPH• in conditions of in vitro gastric digestion of the samples with added sea buckthorn flour increases in a positive way, indicating a clearly positive effect on health [45].

Conclusions

Research on sea buckthorn fruit has developed worldwide due to its health benefits, easy processing in the food industry and recovery of by-products and waste. It was found that the waste obtained after processing has significant amounts of bioactive ingredients that can be recovered. Trends in the food industry are focused on the safe handling of waste and its subsequent processing to obtain new functional products or their use in traditional products to bring a nutritious contribution. Sea buckthorn flour can be used successfully in bakery products, in an optimal amount so as not to negatively influence the sensory qualities of the products and to be accepted by the consumer.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

References

1. Alabiden Tlais, A.Z.; Fiorino, G.M.; Polo, A.; Filannino, P.; Di Cagno, R. High-Value Compounds in Fruit, Vegetable and Cereal Byproducts: An Overview of Potential Sustainable Reuse and Exploitation. *Molecules* 2020, 25, 2987.
2. Andersson C. S., Olsson M.E., Johansson E., Rumpunen K., Carotenoids in Sea Buckthorn (Hippophae rhamnoides L) Berries during Ripening and Use of Pheophytin a as a Maturity Marker, Agric. Food Chem., 2009, 57,1, 250-258
3. Bal M.V. , Meda V., Naik, S.N.., Satya, S., Sea buckthorn berries: A potential source of valuable nutrients for nutraceuticals and cosmoceuticals, *Food Research International*, 2008, 44(7):1718-1727.
4. Beveridge, T. and J.E. Harrison, Microscopic structural components of sea buckthorn (H. rhamnoides. L) 2001. Lebensmittel-Wissenschaft und-Technologie 34(7):458-461 DOI: 10.1006/fstl.2001.0791
5. Beveridge, T., Li, T. S., Oomah, B. D., & Smith, A. (1999). SB products: Manufacture and composition. Journal of Agriculture and Food Chemistry, 47(9), 3480–3488.

6. Cefali, L. C., de Oliveira Maia, L., Stahlschimidt, R., Ataide, J. A., Tambourgi, E. B., Rosa, P. C. P., & Mazzola, P. G. (2018). Vitamin C in Acerola and red plum extracts: Quantification via HPLC, in vitro antioxidant activity, and stability of their gel and emulsion formulations. Journal of AOAC International, 101(5), 1461–1465.
7. Cenkowski, S., Yakimishen, R., Przybylski, R., & Muir, W. E. (2006). Quality of extracted SB seed and pulp oil. Canadian Biosystems Engineering / Le Genie Des Biosystems Au Canada, 48, 9–16.
8. Ciesarová Z., Murkovic M., Cejpek K., Kreps F., Tobolková B., Koplík R., Belajová E., Kukurová K., Daško Ľ., Panovská Z., et al. Why is sea buckthorn (*Hippophae rhamnoides* L.) so exceptional? A review. *Food Res. Int.* 2020;**133**:109170. doi: 10.1016/j.foodres.2020.109170.
9. Chaouch, M.A.; Benvenuti, S. The Role of Fruit by-Products as Bioactive Compounds for Intestinal Health. *Foods* 2020, 9, 1716.
10. Cheng J., Kondo K., Suzuki Y., Ikeda Y., Meng X., Umemura K. Inhibitory effects of total flavones of *Hippophae rhamnoides* L. on thrombosis in mouse femoral artery and in vitro platelet aggregation. *Life Sci.* 2003;**72**:2263–2271. doi: 10.1016/S0024-3205(03)00114-0.
11. Christaki, E. (2012). Hippophae Rhamnoides L. (SB): A potential source of nutraceuticals. Food and Public Health, 2(3), 69–72.
12. Cosmulescu S., Trandafir I., Nour V. Phenolic acids and flavonoids profiles of extracts from edible wild fruits and their antioxidant properties. *Int. J. Food Prop.* 2017;**20**:3124–3134. doi: 10.1080/10942912.2016.1274906.
13. Dumbravă, D. G., Moldovan, C., Raba, D.-N., Popa, M. V., & Drugă, M. (2016). Evaluation of antioxidant activity, polyphenols and vitamin C content of some exotic fruits. Journal of Pharmacy and BioAllied Sciences, 22(1), 13–16.
14. Dulf F.V. Fatty acids in berry lipids of six sea buckthorn (*Hippophae rhamnoides* L., subspecies carpatica) cultivars grown in Romania. *Chem. Cent. J.* 2012;**6**:106. doi: 10.1186/1752-153X-6-106.
15. Fan, Y.; Li, X.; Ding, L.; Zhou, W.; Xu, G.; Wang, Y.; Zhang, Y.; Ni, Q. Accelerated Solvent Extraction of Antioxidant Compounds from Gardeniae Fructus and Its Acetylcholinesterase Inhibitory and PC12 Cell Protective Activities. *Foods* 2021, 10, 2805.
16. Fatima T., Nazir A., Naseer B., Hussain S.Z. Seabuckthorn (*Hippophae rhamnoides*): A repository of phytochemicals. *Int. J. Pharm. Sci. Res.* 2018;**3**:9–12.
17. Garcia V.L. The omega 7 as a health strategy for the skin and mucous membranes. *EC Nutr.* 2019;**14**:484–489.
18. Geetha S, Asheesh G. Medicinal and therapeutic potential of Sea buckthorn (Hippophae rhamnoides L). , *J Ethnopharmacol*.,2011,; 138: 268-278
19. Guo R., Guo X., Li T., Fu X., Liu R.H. Comparative assessment of phytochemical profiles, antioxidant and antiproliferative activities of Sea buckthorn (*Hippophaë rhamnoides* L.) berries. *Food Chem.* 2017;**221**:997–1003. doi: 10.1016/j.foodchem.2016.11.063.
20. Gutzeit, D., Baleanu, G., Winterhalter, P., & Jerz, G. (2008). Vitamin C content in SB berries (Hippopha?? Rhamnoides L. ssp. rhamnoides) and related products: A kinetic study on storage stability and the determination of processing effects. Journal of Food Science, 73(9), C615–C620.
21. Jaroszewska A., Biel W., Telesiński A. Effect of mycorrhization and variety on the chemical composition and antioxidant activity of sea buckthorn berries. *J. Elem.* 2018;**23** doi: 10.5601/jelem.2017.22.3.1434.
22. Ji M., Gong X., Li X., Wang C., Li M. Advanced research on the antioxidant activity and mechanism of polyphenols from hippophae species-a review. *Molecules.* 2020;**25**:917. doi: 10.3390/molecules25040917.
23. Kallio H., Yang B., Peippo P., Tahvonen R., Pan R. Triacylglycerols, glycerophospholipids, tocopherols, and tocotrienols in berries and seeds of two subspecies (ssp. sinensis and mongolica) of sea buckthorn (*Hippophaë rhamnoides*) *J. Agric. Food Chem.* 2002;**50**:3004–3009. doi: 10.1021/jf011556o.
24. Kallio H., Yang B., Peippo P. Effects of different origins and harvesting time on vitamin C, tocopherols, and tocotrienols in sea buckthorn (*Hippophaë rhamnoides*) berries. *J. Agric. Food Chem.* 2002;**50**:6136–6142. doi: 10.1021/jf020421v.
25. Kuhkheil A., Naghdi Badi H., Mehrafarin A., Abdossi V. Chemical constituents of sea buckthorn (*Hippophae rhamnoides* L.) fruit in populations of central Alborz Mountains in Iran. *Res. J. Pharmacogn.* 2014;**4**:1–12.
26. Larmo P.S., Yang B., Hyssälä J., Kallio H.P., Erkkola R. Effects of sea buckthorn oil intake on vaginal atrophy in postmenopausal women: A randomized, double-blind, placebo-controlled study. *Maturitas.* 2014;**79**:316–321. doi: 10.1016/j.maturitas.2014.07.010.
27. Li T.S.C., Beveridge T.H.J. *Sea Buckthorn (Hippophae rhamnoides L.): Production and Utilization.* NRC Research Press; Ottawa, ON, Canada: 2003. Sea Buckthorn (*Hippophae rhamnoides* L.): Production and Utilization.
28. Ma X., Moilanen J., Laaksonen O., Yang W., Tenhu E., Yang B. Phenolic compounds and antioxidant activities of tea-type infusions processed from sea buckthorn (*Hippophaë rhamnoides*) leaves. *Food Chem.* 2019;**272**:1–11. doi: 10.1016/j.foodchem.2018.08.006.
29. Malinowska P., Olas B. Sea buckthorn—Valuable plant for health. *Kosmos.* 2016;**2**:285–292.

30. Marsiñach M.S., Cuenca A.P. The impact of sea buckthorn oil fatty acids on human health. *Lipids Health Dis.* 2019;**18** doi: 10.1186/s12944-019-1065-9.
31. Michel T., Destandau E., Le Floch G., Lucchesi M.E., Elfakir C. Antimicrobial, antioxidant and phytochemical investigations of sea buckthorn (Hippophaë rhamnoides L.) leaf, stem, root and seed. *Food Chem*. 2012;131:754–760. doi: 10.1016/j.foodchem.2011.09.029.
32. Mironov, V. A. . Chemical composition of Hippophaė rhamnoides of differentpopulations of the USSR. Proceedings of the first international symposium on seabuckthorn (H. rhamnoides L.), (1989), October 19–23, Xi'an, China (pp. 67−70).
33. Olas B. Sea buckthorn as a source of important bioactive compounds in cardiovascular diseases. *Food Chem. Toxicol.* 2016;**97**:199–204. doi: 10.1016/j.fct.2016.09.008.
34. Othman, S.B.; Joudu, I.; Bhat, R. Bioactives from Agri-Food Wastes: Present Insights and Future Challenges. *Molecules* 2020, 25, 510. Foods 2022, 11, 462
35. Pallavee K., Ashwani M. Sea Buckthorn Juice: Nutritional Therapeutic Properties and Economic Considerations. *Int. J. Pharmacogn. Phytochem. Res.* 2017;**9** doi: 10.25258/phyto.v9i6.8194.
36. Pop E.A., Diaconeasa Z.M., Fetea F., Bunea A., Dulf F., Pintea A., Socaciu C. Carotenoids, Tocopherols and Antioxidant Activity of Lipophilic Extracts from Sea Buckthorn Berries (*Hippophae rhamnoides*), Apricot Pulp and Apricot Kernel (Prunus armeniaca) *Bull. Univ. Agric. Sci. Vet. Med. Cluj-Napoca. Food Sci. Technol.* 2015;**72**:169–176. doi: 10.15835/buasvmcn-fst:11425.
37. Ranjith A., Sarin Kumar K., Venugopalan V.V., Arumughan C., Sawhney R.C., Singh V. Fatty acids, tocols, and carotenoids in pulp oil of three sea buckthorn species (*Hippophae rhamnoides*, H. salicifolia, and H. tibetana) grown in the Indian Himalayas. *JAOCS J. Am. Oil Chem. Soc.* 2006;**83**:359–364. doi: 10.1007/s11746-006-1213-z.
38. Ruan C., Li D. Community characteristics of Hippophae rhamnoides forest and water and nutrient condition of the woodland in Loess Hilly Region. Chin. J. Appl. Ecol. 2002;13:1061–1064.
39. Ruan C.J., Rumpunen K., Nybom H. Advances in improvement of quality and resistance in a multipurpose crop: Sea buckthorn. Crit. Rev. Biotechnol. 2013;33:126–144. doi: 10.3109/07388551.2012.676024
40. Salminen J.P., Karonen M. Chemical ecology of tannins and other phenolics: We need a change in approach. *Funct. Ecol.* 2011;**25**:325–338. doi: 10.1111/j.1365-2435.2010.01826.x.
41. Santos, P. H. S., & Silva, M. A. (2008). Retention of vitamin C in drying processes of fruits and vegetables - a review. Drying Technology, 26(12), 1421–1437.
42. Salminen J.P., Karonen M. Chemical ecology of tannins and other phenolics: We need a change in approach. Funct. Ecol. 2011;25:325–338. doi: 10.1111/j.1365-2435.2010.01826.x.
43. Selvamuthukumaran, M., Khanum, F., Nagar, S., Processing seabuckthorn fruit for antioxidant rich jam deveopment and shelf stability assessment, 2014, *Chemistry*, DOI: 10.1186/s12944-017-0469-7
44. Stoian D., Dogaru D.-V., Poiana M.-A, Bordean D., Cocan I., Use of sea buckthorn bioactive potential in obtaining of farinaceous functional product, *Journal of Agroalimentary Processes and Tecnologies*, 2014, 20(4), 396-403;
45. Sturza, R., Ghendov-Mosanu, A.A., Deseatnicov, O.I., Suhodol, F.N, Use of sea bucktorn fruits in the pastry manufacturing, (2016), Scientific Study & Research Chemistry & Chemical Engineering, Biotechnology, *Food Industry* , 17 (1), pp. 035 – 043.
46. Teleszko, M., Wojdyło, A., Rudzińska, M., Oszmiański, J., & Golis, T., Analysis of lipophilic and hydrophilic bioactive compounds content in SB (Hippophae rhamnoides L.) berries. *Journal of Agricultural and Food Chemistry*, 2015, 63(16), 4120–4129.
47. Tiitinen K., Vahvaselkä M., Hakala M., Laakso S., Kallio H. Malolactic fermentation in sea buckthorn (Hippophaë rhamnoides L.) juice processing. *Eur. Food Res. Technol*. 2006;222:686–691. doi: 10.1007/s00217-005-0163-2.
48. Tkacz K., Wojdyło A., Turkiewicz I.P., Ferreres F., Moreno D.A., Nowicka P. UPLC-PDA-Q/TOF-MS profiling of phenolic and carotenoid compounds and their influence on anticholinergic potential for AChE and BuChE inhibition and on-line antioxidant activity of selected *Hippophaë rhamnoides* L. cultivars. *Food Chem.* 2020;309:125766. doi: 10.1016/j.foodchem.2019.125766.
49. Tkacz K., Wojdyło A., Turkiewicz I.P., Bobak Ł., Nowicka P. Anti-Oxidant and Anti-Enzymatic Activities of Sea Buckthorn (*Hippophae rhamnoides* L.) Fruits Modulated by Chemical Components. *Antioxidants.* 2019;8:618. doi: 10.3390/antiox8120618.
50. Trigo, J.P.; Alexandre, E.M.C.; Saraiva, J.A.; Pintado, M.E. High value-added compounds from fruit and vegetable by-products— Characterization, bioactivities, and application in the development of novel food products. Crit. Rev. *Food Sci. Nutr.* 2020, 60, 1388–1416
51. Yang B, Karlsson R, Oksman P, Kallio H. Phytosterols in sea buckthorn (Hippophaë rhamnoides L.) berries: identification and effects of different origins and harvesting times. *J Agric Food Chem*.2011, 49(11):5620-5629

52. Yang B., Kallio H. Composition and physiological effects of sea buckthorn (Hippophaë) lipids. *Trends Food Sci. Technol.* 2002;**13**:160–167. doi: 10.1016/S0924-2244(02)00136-X.
53. Zeb A., Chemical and Nutritional Constituents of Sea Bucktorn Juice, *Pakistan Jurnal of Nutrition*, 2004, DOI:10.3923/pjn.2004.99.106.
54. Xiao-Hua L., Ling-Xue K., Hong-Zhang L. Advances on Effective Compositions of Seabuckthorn. *J. Jilin Agric. Univ.* 2007;**29**:162–167.
55. Xing J., Yang B., Dong Y., Wang B., Wang J., Kallio H.P. Effects of sea buckthorn (*Hippophaë rhamnoides* L.) seed and pulp oils on experimental models of gastric ulcer in rats. *Fitoterapia.* 2002;**73**:644–650. doi: 10.1016/S0367-326X(02)00221-6.
56. Zadernowski R., Naczk M., Czaplicki S., Rubinskiene M., Szałkiewicz M. Composition of phenolic acids in sea buckthorn (*Hippophae rhamnoides* L.) berries. *JAOCS J. Am. Oil Chem. Soc.* 2005;**82**:175–179. doi: 10.1007/s11746-005-5169-1.
57. Zhang, L.; Chena, J.; Liaob, H.; Lia, C.; Chena, M. Anti-inflammatory effect of lipophilic grape seed proanthocyanidin in RAW 264.7 cells and a zebrafish model. *J. Funct. Foods* 2020, 75, 104217.
58. Zheng J., Kallio H., Linderborg K., Yang B. Sugars, sugar alcohols, fruit acids, and ascorbic acid in wild Chinese sea buckthorn (*Hippophaë rhamnoides* ssp. sinensis) with special reference to influence of latitude and altitude. *Food Res. Int.* 2011;**44**:2018–2026. doi: 10.1016/j.foodres.2010.10.007.
59. Zielinska, A. and Nowak, I., Abundance of active ingredients in sea-buckthorn oil, *Lipids Healt Dis.*, 2017, PMC5438513, doi: 10.1186/s12944-017-0469-7.
60. Piłat B., Bieniek A., Zadernowski R. Chemical composition of individual morphological parts of the sea buckthorn fruit (Hippophae rhamnoides, L.). In: Kauppinen S., Petruneva E., editors. Proceedings of the Producing Sea Buckthorn of High Quality: Proceedings of the 3rd European Workshop on Sea Buckthorn; Helsinki, Finland. 10–14 October 2014; pp. 79–82