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Sea buckthorn (*Hippophae rhamnoides* L.) as a plant for universal application

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ABSTRACT

Sea buckthorn (*Hippophae rhamnoides* L.), belonging to the oleaster family, has been used for long time in Asian folk medicine. Even today we can see increasing interest in that plant because of its variety of biologically active compounds, which are contained in its fruits, leaves and seeds. These chemical compounds determine versatile applications of sea buckthorn in various fields of human life. Due to its regenerative properties, sea buckthorn is used as a component of numerous dermocosmetics, protecting the skin from UV radiation, dryness and some diseases or signs of aging. Active substances, such as polyphenols, contained in sea buckthorn have significant properties: antimicrobial, antiviral, antifungal and anti-inflammatory. Therefore that plant is widely applied in pharmacy to produce drugs, juices, extracts and oils. These forms of products found usage in the treatment of many disease such as: cancer, liver cirrhosis, diabetes, heart disorders etc. Sea buckthorn is widely used in the food industry as well - variety of beverages and jams are made from this plant. *H. rhamnoides* can be also used as a preservative or food additive, which increases the organoleptic and nutritional properties of food. Beside of that, sea buckthorn is useful in animal nourishment. Feed enriched with *H. rhamnoides* has a positive impact on the nutrition and health of the animals, while improving their productivity. The aim of that article was to present the variety of compounds which are responsible for that plant's properties.

Keywords: Sea buckthorn, *Hippophae rhamnoides*, Siberian pineapple, Rokitnik, food industry, nutraceuticals, antioxidant, polyphenols, antibiotic substitute, anticancer

1. INTRODUCTION

Sea buckthorn (*Hippophae rhamnoides* L.) is a spiny, deciduous shrub which belongs to the oleaster family (*Elaeagnaceae* Juss.) [1]. In the natural state the plant grows in Central Asia, China, Mongolia, the Caucasus and Siberia. In Poland, sea buckthorn grows only on the Baltic coast, where it came with the Polish exiles returning from Siberian gulags at the end of the 19th century [2,3]. A characteristic feature of sea buckthorn are intense orange berries that very densely overgrow shoots [4]. These fruits have a very original aroma for which in 70% are responsible esters, such as ethyl acetate [5]. A peculiar smell of sea buckthorn is also caused by the presence of other chemical compounds: alcohols, aldehydes, ketones and terpenes [6]. Various scientists used to compare the fragrance of *H. rhamnoides* to the scent of other fruits like pineapple (sea buckthorn is also known as Siberian pineapple), strawberry, peach, mango, citrus or blueberry [6-8]. Currently, Russia, where selected more than 60 varieties of this plant, is leading in the cultivation of sea buckthorn. *H. rhamnoides* is also grown in China, Germany, Finland and Estonia on an industrial scale [2]. In Poland, small plantations are located in the Suwalki region and also in Podlasie region and south-western area of the country [9,10]. This plant is also characterized by small environmental requirements. The ability to overgrow even very poor soils sea buckthorn owes to soil bacteria *Actinomycetes frankia*, which live in symbiosis with the roots and are able to fix nitrogen from the air. With the ability to bind atmospheric nitrogen and other compounds, sea buckthorn can be successfully used in soil remediation [11,12]. This plant is also perfect for the prevention of soil erosion, because it very quickly develops an extensive root system [13].

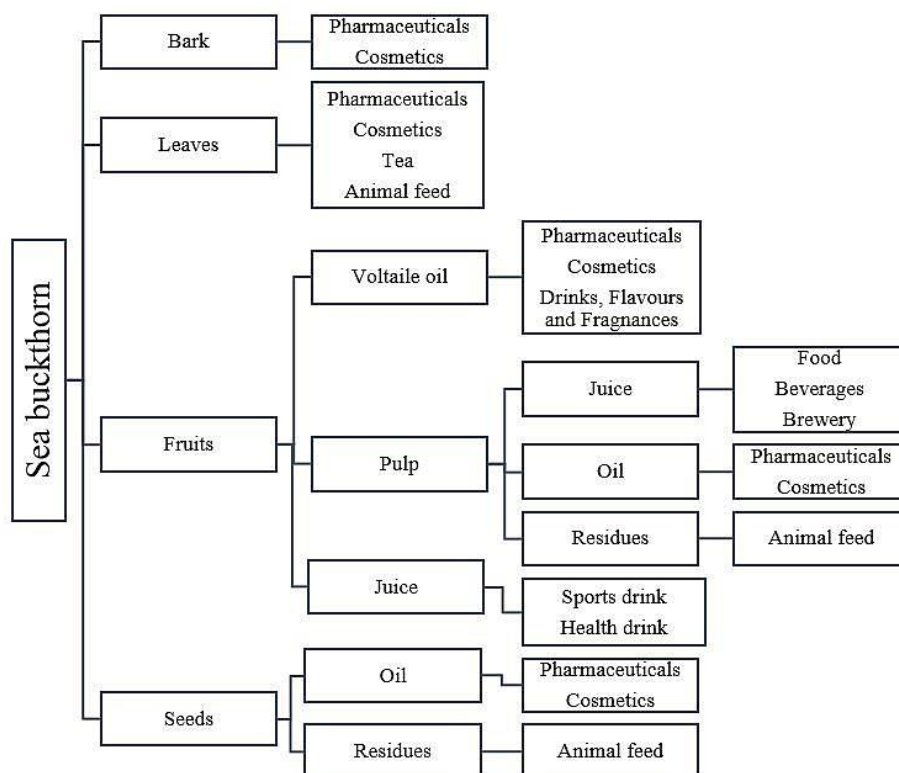


Figure 1. Potential uses of components from different parts of Sea buckthorn [17].

The positive effect of sea buckthorn on human and animal health was already known in ancient Greece. Greeks used its fruits in worm infection (*helminthiasis*) treatment in animals [14]. Young leaves and shoots were used as feed for racehorses and thus the animals quickly gained weight and it improved the condition of their hair – it became shinier. *Hippophae rhamnoides*, latin name of sea buckthorn, also comes from this application: the Greek word *hippos* means “horse” and *phos* means “to shine”. The plant was also used in Tibetan medicine, as a universal cure for many ailments and diseases like cough or diarrhea, and in Mongolian medicine, where it was used as a sedative [3].

Today, the sea buckthorn is widely used in human life due to the abundance of the biologically active compounds, to which it owes its health-promoting potential. These substances include: carotenoids, flavonoids, phospholipids, tannins, vitamins and macro- and microelements [15]. It is interesting that sea buckthorn berries don't contain ascorbate oxidase, an enzyme responsible for the degradation of ascorbic acid, and therefore products made of sea buckthorn and even dried fruits still contain large amounts of vitamin C [16]. Through this unique chemical composition, health properties, and also because of the attractive color and original flavor of the fruits, this plant is valuable material for pharmaceutical, cosmetic and food industries [8]. Potential uses of components from different parts of Sea buckthorn are shown in Figure 1.

2. SEA BUCKTHORN IN COSMETIC INDUSTRY

Especially valuable and the most widely resource from sea buckthorn used in cosmetic industry is the oil extracted from its fruits and seeds [18]. One of its most well-known properties is nourishing and regenerating effect on skin and mucous, which results in high content of fat-soluble vitamins (vitamin A and E) and nutrients (EFAs, phytosterols) [17].

Sea buckthorn oil, like all plant fats, can be divided into two groups due to their the chemical construction. The first group are esters, which can undergo alkaline hydrolysis – they are mainly triacylglycerols and they are fundamental component of vegetable oils. The second group includes substances referred as unsaponifiable fraction, that doesn't undergo alkaline hydrolysis. The unsaponifiable fraction with esters of alcohols other than glycerol create non-glyceride fraction, formed by many chemical substances with cosmetic potential such as hydrocarbons, esters, sterols, ceramides, lecithins, tocopherols and carotenoids. The composition and content of this fraction can change depending on various factors like plant variety, weather conditions or crop irrigation. The average content of unsaponifiable fraction in sea buckthorn oil is 2.5-4.0% [19].

Protection from UV radiation

Carotenoids (α -, β - and γ -Carotene) represent up to 0.6% unsaponifiable fraction of sea buckthorn oil and they are very valuable compounds for cosmetic industry. They show the ability to absorb UV radiation and can convert it into vitamin A (retinol). Sea buckthorn oil, which strongly absorbs UV-B radiation with a wavelength in the range of 290-320 nm that can cause both tanning and sunburn, can be used as a natural sunscreen [20]. However, the most important feature of carotenoids is their antiradical activity – they can capture free radicals such as singlet oxygen [20,21].

Wrinkles and skin dryness

Other most common properties of the substances present in sea buckthorn oil include their regenerative, emollient and anti-aging action. These features make the sea buckthorn products desirable for revitalizing and skin care [17]. A study carried out on 350 patients in China showed positive effects of cosmetic cream based on sea buckthorn oil. It cleared skin discoloration and freckles, smoothed out wrinkles and removed skin dryness [22]. The positive therapeutic effect of cosmetic cream with *H. rhamnoides* oil, used for many skin ailments, was confirmed by the clinical trials conducted in Shantow Tropical Diseases Hospital and Shanxi Pharmaceutical Research in Nepal. These studies also showed that the extract of sea buckthorn may accelerate metabolism and inhibit the aging process of skin, making it softer and smoother at the same time. This extract also delayed hair loss (*alopecia*) and improved hair growth [17].

Smoothing properties of sea buckthorn were confirmed also by Yang et al. (2009). After 12 weeks of supplementation with sea buckthorn oil skin of the patients became much more hydrated and its roughness reduced [23]. Schwartz et al. (2006) also described the positive effects of dietary supplements for skin containing among others sea buckthorn and zeaxanthin. The skin of persons who received supplement with sea buckthorn was moister than the skin of the control group, which received placebo (sunflower oil). Better hydration of the skin resulted in a reduction of facial lines and wrinkles caused by aging process of skin [24].

Dermatological diseases

Health potential substances contained in sea buckthorn can also prevent dermatological diseases like atopic eczema, chloasma, xeroderma or recurrent dermatitis [25,26]. Chirila et al. (2004) describe the positive effects of the cosmetic cream with extract of sea buckthorn on other ailments such as changes in skin color caused by Hashimoto's thyroiditis and vitiligo or juvenile acne. In the first case in 34-year-old woman after a 4-month use of cream, skin has been regenerated by 35-40%. In the second case, a 15-year-old young man was suffering from numerous pustules, painful nodules and deep abscesses on skin, which number decreased by 25-50% after month of using cream with sea buckthorn extract. After 4 months of treatment staphylococcal infection in the same boy was completely eliminated. There was also a 50% regeneration of the scars left after acne [27].

Burns and wounds

Results of these studies confirm the applicability of cosmetic formulations with sea buckthorn oil to accelerate the healing of wounds and burns. Especially valuable component in the treatment of these injuries is palmitic acid included in sea buckthorn oil, which is used topically to skin lesions [28]. Other compounds responsible with regeneration potential are omega-3 and omega-6 acids, carotenoids and tocopherols [29,30]. The efficacy and safety of wound treatment with oil from seed of *H. rhamnoides* has been confirmed in rats by Upadhyay et al. (2009) by use of a substance topically and orally in amount of 2.5 ml/kg of body weight. During the studies, oil has induced mitosis of cells (mitogenic activity), increased collagen biosynthesis, promoted formation of the new blood vessels, was involved in proliferation of keratinocytes and fibroblasts, and formation of granulation tissue at the injured area [31]. Oil of sea buckthorn seeds was also used to treat burns in sheep. After 14

days of treatment it was noted that epithelialization on oil lubricated areas is significantly faster than at the untreated locations [32].

3. SEA BUCKTHORN IN PHARMACY

Sea buckthorn is a plant which contains a lot of different compounds and for this reason is widely used in the treatment, what is presented in Table 1. It has antimicrobial, antiviral, antioxidant and antidiabetic properties. Its active substances have positive impact for cardiovascular system, eyes and liver functions. Moreover these compounds have neuroprotective effect and may prevent from cancer diseases [16].

Table 1. The most important biologically active compounds in sea buckthorn and their main therapeutic effect [16].

Name of compound	Therapeutic effect of compound
Tocopherols	Antioxidant activity Limitation of lipid peroxidation Pain relief
Carotenoids	Antioxidant activity Participation in the synthesis of collagen Participation in the growth of epithelial
Vitamin K	Prevention of hemorrhage Wounds healing Positive effect against ulceration
Vitamin B	Antioxidant activity Maintaining the integrity of the cell membrane
Vitamins from group B	Stimulation of cell regeneration Regeneration of neural tissue
Phytosterols	Improvement of microcirculation in the skin Anti-tumor effect Antiatherosclerotic action Prevention of the formation of ulcers Regulation of inflammatory processes
Polyphenols	Antioxidant activity Cytoprotective effect Cardioprotective effect Wounds healing
Polysaturated fatty acids (PUFA)	Immunomodulatory effect Neuroprotective effect Anti-tumor effect

Organic acids	Reducing the risk of heart attack and stroke Wounds healing Anti-tumor effect Reducing the risk of arthritis
Coumarin and triterpenes	Assisting appetite, sleep, memory and learning
Zinc	Increase of blood circulation Function of enzyme cofactor Increased use of vitamin A

Treatment of diabetes

In the case of patients with diabetes it is indicated to decrease activity of alpha-glucosidase. This enzyme has abilities to cleavage glycosidic bonds in oligosaccharides. Therefore compounds which may inhibit that enzyme are necessary to prevent postprandial hyperglycemia [33]. Sea buckthorn includes a lot of different substances with mixed properties. Flavonoids from seeds and fruits of *Hippophae rhamnoides* L. cause hypoglycemia and hypolipidemia [34].

In 2015 there have been presented results of research, which aim was to evaluate the effect of sea buckthorn extracts. The researchers used two different extracts – aqueous and methanolic - in different concentrations (from 0,0625 to 0,5 mg/ml). They wanted to estimate antidiabetic and antioxidant functions of sea buckthorn leaves. To evaluate antidiabetic activity of plant they used alpha-glucosidase inhibitory assay. The results showed that methanolic extract of leaves caused better effects connected with the values of IC50. That parameter (IC50) is the amount of analyzed sample which is required to inhibit 50% activity of an enzyme. Alpha glucosidase inhibition activity of aqueous extract (0.50 mg/ml) was lower than 50%, and in the case of methanolic extract (0.50 mg/ml) that value was about 73,67%. Value of parameter IC50 of methanolic extract was in the concentration of 0.25 mg/ml, but it was impossible to assess similar effects in the aqueous extract. These results showed that methanolic extract of sea buckthorn leaves include compounds demonstrating alpha-glucosidase inhibition activity. These biochemical particles may be used in diabetes because they can control glucose absorption [35]. There are also results of the other research based on the streptozotocin-induced diabetics rats, where used sea buckthorn leaves also showed antidiabetic activity. In that research non-diabetic and diabetic rats were compared. Diabetic rats fed by sea buckthorn had lower levels of blood glucose and cholesterol comparing to non-diabetic rats fed by the same supplement [36].

Substitute of antibiotic drugs

Nowadays researchers are strongly interested in antimicrobial properties of new substances, because of major problem with microorganisms resistance to synthetic antibiotics. Bacteria may cause infectious diseases of plants, animals and people. Nowadays medicinal plants are demanded as a source of compounds which can show the same or even better activity in comparison to common antimicrobial drugs. Sea buckthorn has leaves and seeds which show antimicrobial efficacy. Crude leafs, oil from seeds and extract from seeds have been analyzed concerning to gram-positive and gram-negative bacteria and fungal cultures.

The results were very satisfying, all of the extracts showed significant or intermediate antimicrobial activity against positive-gram bacteria (*B. subtilis*, *B. thuringiensis*). In the case of minus-gram microorganisms (*Pseudomonas fluorescens*, *Escherichia coli*, *Agrobacterium tumefaciens*, *Acinetobacter junii*) seed extract of sea buckthorn showed activity against one species of bacteria. It is probable that extracts showed higher activity against gram-positive bacteria than against gram-negative bacteria because gram-positive bacteria have peptidoglycan layer on the cell wall, which is ineffective barrier. Only two of fungi (*Mucor indicus*, *Tilletia indica*) didn't have resistance for that plant extracts. By contrast to that *Rhizopus oryzae* was invulnerable to sea buckthorn. The results of that research showed that *Hippophae salicifolia* L. - one of the sea buckthorn's species - showed the highest antimicrobial and antifungal activity in crude seed extract in comparison to crude leaves and oil from seeds. Therefore there is confidence that sea buckthorn may be used as a natural medicine and food preservative [37]. It is known that *Hippophae salicifolia* L. has higher amount of phenolic compounds in the leaves and other phenols in seeds in comparison to the other species of sea buckthorn. These active substances are responsible for antibacterial and antifungal activity. The other researchers have shown high antioxidant and antibacterial activities of crude seed extracts of sea buckthorn in various in-vitro model systems [38].

Bacteria causing different infectious diseases and illnesses can be found in food [39]. Polyphenols are responsible for antimicrobial properties of that plant, these compounds are present in fruits, leaves and bark of sea buckthorn [40]. In 2013 there have been published the results of the research based on extracts from sea buckthorn leaves. There have been prepared: SLE - sea buckthorn leaves crude extract and PRF - phenolic rich fraction. The researchers tried to measure antibacterial activity of SLE and PRF comparing to well-known antibiotic – ampicillin, what was a standard factor. Both extracts showed antibacterial properties against *E. coli*, *S. typhi*, *S. dysenteriae*, *S. pneumoniae* and *S. aureus*. The highest activity of two of these extracts was against *S. dysenteriae* but generally better effect achieved PRF than SLE – mainly because of being effective at lower concentration than SLE. These results suggested that antibacterial activity could be caused by flavonoids from SBT leaf extracts [41].

Antioxidant properties

In 2016 there has been published article about antioxidant potential of fruits from two different plants - sea buckthorn *Hippophae rhamnoides* L. and European cranberry *Vaccinium oxycoccos* L. Analyzed fruits of these plants contain polyphenols, which are responsible for positive impact for organism. In that research glycolic extracts have been used to mark antioxidant capacity with use of FRAP and ABTS methods. HPLC method was also used to measure phenolic profiles of these extracts and the results showed that sea buckthorn has better antioxidant potential comparing to European cranberry. Sea buckthorn's content of polyphenols was 60.85 mg/100 ml of extract, when that amount in the case of European cranberry was much lower and got the value of 21.39 mg/100 ml of extract [42].

Cardiovascular system protection

Hippophae rhamnoides L. is a rich source of flavonoids which show positive effect for cardiovascular system. The results of research published in 2003 indicate that these compounds may inhibit platelet aggregation by inhibition of tyrosine kinase activity. That enzyme is associated with arachidonic acid synthesis from phospholipids [43]. There was also

the other research which results showed that supplementation of sea buckthorn berry oil caused reduce of rate of aggregation reaction (% aggregation/min) [44]. In 2017 there have been published results of the other research based on evaluation of total cholesterol, triacylglycerol, LDL – cholesterol and HDL – cholesterol in serum/plasma. The effects of sea buckthorn's supplementation were calculated as weighted mean differences for net changes in these parameters. The results showed that using that plant as a food additive for people with cardiovascular problems can reduce total cholesterol, TAG and LDL-cholesterol and increase HDL – cholesterol. Therefore the authors of that research suggest that cardio-protective effect of sea buckthorn intake may be connected with flavonoids and b-sitosterol contained in that plant [45].

Hippophae rhamnoides L. is a plant, which different parts are used in traditional medicine. Diseases as a flu, cardiovascular disease, mucosal injuries and skin problems can be treated with using of that plant [20,46]. Sea buckthorn is hepatoprotective, it can improve condition of liver damaged by carbon tetrachloride [47]. Furthermore that plant is helpful in the treatment of liver cirrhosis. Probably sea buckthorn can inhibit synthesis of extracellular matrix components through the reduction of serum levels of laminin, hyaluronic acid, total bile acid and collagen [48]. Sea buckthorn has also positive impact for cardiovascular system. It can increase cardiac output, cardiac index, heart stroke index and left ventricular power index of the myocardium. Moreover it can decrease diastolic pressure of the left ventricle and the left ventricular pressure of the isovolumetric relaxation phase. Therefore it is well known that sea buckthorn improves mechanocardiography and the ischemic electrocardiogram [49]. Some researchers who published the results of research in 2008 suggest that sea buckthorn has antihypertensive effect – it can block angiotensin-2 receptor and block downstream signal pathway. It has been denominated that dose of flavones in the amount of 150 mg/kg/day shows the best effect in the treatment of hypertension, hyperinsulinemia and dyslipidemia [50].

Treatment of cancer diseases

Hippophae rhamnoides L. is a plant with significant meaning in cancer diseases treatment. That plant includes compounds, which have better activity than ascorbic acid in preventing tumor production. There was a research where Wistar rats were fed a diet with supplementation of: aminopyrine (0.2%) and NaNO₂ (0.2%) and either tap-water, sea buckthorn juice and ascorbic acid solution. The average of these rats' length of live was significantly higher (270 days) in the group fed by sea buckthorn juice than those animals given tap-water (195 days) and also ascorbic acid solution (220 days). What is more in the livers of the rats fed by sea buckthorn juice there were less carcinogenesis foci in comparison to rats from other groups. Received results suggest that supplementation of juice from *Hippophae rhamnoides* L. can impact blocking endogenous formation of N-nitroso-compounds with much more better effects than ascorbic acid or water solutions with aminopyrine (0.2%) and NaNO₂ (0.2%) [51].

Berries of *Hippophae rhamnoides* L. include a lot of vitamins: A, C and E, flavonoids, carotenes and also microelements such as: sulfur, selenium, zinc and copper. All of these compounds cause that this plant has positive impact for the treatment of many diseases. Results of the research published in 2005 show that Sea buckthorn may inhibit benzo(a)pyrene-induced forestomach and DMBA-induced skin papillomagenesis in mouse. As the authors wrote in the publication it may be caused by induction of phase II enzymes

(glutathione S-transferase and DT-diaphorase) and antioxidant enzymes (superoxide dismutase, catalase, glutathione peroxidase, and glutathione reductase) as well as DNA-binding activity of antioncogenic transcription factor - IRF-1. That factor may cause growth suppression and apoptosis induction for its anticancer effect [52]. Isorhamnetin is an O-methylated flavon-ol, from the class of flavonoids, which can be found in *Hippophae rhamnoides* L. There was a research where its cytotoxicity on human hepatocellular carcinoma cells was analyzed. The results showed that isorhamnetin may permeate the cell membrane into the cell. Its cytotoxic effect is dose-dependent and time-dependent against these carcinoma cells, with IC₅₀ equal to 74.4±1.13 µg/ml after dosing that substance for 72 hours. Flow cytometric analysis was used to determine hypodiploid cells. The obtained results showed there was some hypodiploid peak, which could be caused by cells in apoptosis and apoptotic bodies with DNA content less than 2n [53].

Eyes protection

Sea buckthorn berries are a good source of compounds which are beneficial for human health. Carotenoids are very significant substances in the group of biologically active compounds, because of their antioxidant, anti-mutagenic and antitumor properties [54]. In the wide group of carotenoids from that plant there are a lot of different substances, such as: zeaxanthin, b-cryptoxanthin, and b-carotene [55]. Zeaxanthin may be found in the retina and lens of the eye, it is responsible for the appearance of the yellow colour. Therefore it is generally known that this compound and lutein may protect the eyes from age-related deterioration and cataracts [56]. In the macula lutea of eye these substances which have protective functions preventing from foto-oxidative damage of yellow spot are collected. These compounds have that function because of their anti-oxidative role [57]. Zeaxanthin and lutein may filter blue light with high level of energy. Probably decreasing of the amount of that blue light, which can reach macula lutea, has ability to reduce oxidative stress in the retina [58]. In 2014 there were published results of the research which aim was to identify carotenoid composition: free carotenoids, carotenoid esters and chlorophyll from both sea buckthorn berries and leaves. HPLC-PAD, GC-MS and UHPLC-PAD-ESI-MS techniques were used to analyze composition of six varieties of Carpathians sea buckthorn (*Hippophae rhamnoides* L., ssp. *Carpatica*). Total content of carotenoids was higher in berries (between 53 and 97 mg/100 g dry weight) than in leaves (3.5 and 4.2 mg/100 g dry weight) of the plant. 27 compounds were found in berries, and 11 - in leaves. Zeaxanthin di-palmitate was major compound in berries, while lutein, b-carotene, violaxanthin and neoxanthin were found in higher concentrations in leaves of sea buckthorn. The results showed also that berries were the only source of the esterified carotenoids [59].

4. SEA BUCKTHORN IN FOOD INDUSTRY

Due to the richness of bioactive substances present in sea buckthorn fruits, it is now also very often used in production of functional and health food on account of constant demand increase among potential customers [60]. Sea buckthorn belongs to the most nutritious and vitamin-rich plants. The variety of minerals and amino acids contained in sea buckthorn is shown in Table 2 and Table 3. In the food industry, it may be used as a preservative or food additive or it can lift the nutritional and organoleptic value of food [61].

Juices and beverages

One of the most popular and earliest manufactured products made of sea buckthorn are juices and beverages [62]. In early 40s of 20th Century *H. rhamnoides* fruits began to be used on an industrial scale in Russia [63]. In 1943 a Swiss pharmaceutical company launched juices and syrups as a supplement to the daily diet. These nutritious, vitamin C and carotene-rich drinks are very popular in China, Germany, Scandinavia and in other Nordic countries. At the Olympic Games in Seoul in 1992, they were the official drinks of Chinese athletes [14]. Beverages made from this plant were also used in the diet of Indian soldiers – they were receiving herbal multivitamin drinks based on sea buckthorn juice during their work at very low temperatures [64]. Juices are usually obtained by centrifugation of oil fraction from the sea buckthorn fruit pulp [14].

There was also an attempt to produce fruit nectars from sea buckthorn, due to the high consumption of this kind of beverage by Polish residents. Piłat and Zadenowski (2014) developed recipes for four drinks, where apart from the juice from *H. rhamnoides*, juices of other fruits and vegetables like apples, bananas, carrots and pumpkin were also added. The content of carotenoids in nectars ranged from 1.01 to 3.75 mg/100 ml – most of them were present in the carrot-apple-sea buckthorn nectar, while the least in the banana-sea buckthorn nectar. In turn, the pumpkin-sea buckthorn nectar was characterized by the highest content of vitamin C (15.45 mg/100 ml) and the highest fat content (0.70 g/100 ml) of all products. Following the consumer assessment, it was found that the most desirable appeared to be nectar which included banana and sea buckthorn. The results of these tests can be used to launch new health-promoting products obtained from *H. rhamnoides* fruits as ingredient of the daily diet [65].

Table 2. The average content of elements in the fruits of sea buckthorn [20]

Chemical element	Average content [$\mu\text{g/ml}$]
Potassium (K)	497
Calcium (Ca)	143
Phosphorus (P)	131
Magnesium (Mg)	70,4
Sodium (Na)	76,9
Cobalt (Co)	$\leq 0,1$
Chromium (Cr)	0,178
Copper (Cu)	0,384
Manganese (Mn)	1,67
Nickel (Ni)	0,237

Strontium (Sr)	0,429
Vanadium (V)	0,0069
Iron (Fe)	7,58
Molybdenum (Mo)	0,044
Zinc (Zn)	0,763
Tin (Sn)	0,170
Selenium (Se)	9,21
Boron (B)	1,06
Bar (Ba)	0,244
Aluminum (Al)	7,88
Titanium (Ti)	0,407
Lithium (Li)	0,203
Cadmium (Cd)	<0,05
Arsenic (As)	<0,5
Lead (Pb)	0,551

Table 3. Amino acids content in the fruits of sea buckthorn [20]

Amino acid	Content [mg/100g]	Amino acid	Content [mg/100g]
Asparagine	426,6	Glutamine	19,4
Proline	45,2	Isoleucine	17,4
Threonine	36,8	Glycine	16,7
Serine	28,1	Histidine	13,7
Lysine	27,2	Tyrosine	13,4
Valine	21,8	Arginine	11,3
Alanine	21,2	Cysteine	3,3
Phenyloalanine	20,0	Methionine	2,3

Jams and jellies

Despite the sour and exotic taste, sea buckthorn berries can be used for the production of jams and jellies. Its pungent flavor can be neutralized by mixing the juice or pulp of sea buckthorn and other fruits with a much milder taste in different proportions [66].

Research conducted by Marszałek et al. (2014) has shown that sea buckthorn, due to the high content of biologically active compounds, is a valuable material for the production of jams. During the study a variety of flavors was prepared, by mixing sea buckthorn berries with other fruits like apples, gooseberries, raspberries and strawberries, which also gave jams different colors (from orange to dark red). Sensory analysis revealed that sea buckthorn jams with addition of gooseberries and raspberries got the highest ratings. The greatest health potential characterized sea buckthorn-strawberry jams, because of their highest content of vitamin C and phenols.

The highest amount of carotenoids was found in sea buckthorn-raspberry jam. During the research, aside from jams sweetened with sugar, produced in the traditional way, jams with energy value reduced to approx. 70% were also developed. Due to the larger content of fruits and less amount of sugar, jams sweetened with special sweetener blends are more desirable by consumers and much more nutritious and healthy [60].

Dietary supplements and food additives

On the food market, products made of sea buckthorn with the addition of its oil play an important role. Oils from the seeds and fruit pulp have nutritional properties, which differ from each other according to various processing methods [64]. Content of some biologically active compounds from sea buckthorn oil is shown in Table 4. Sea buckthorn oils can be found in composition of certain dietary supplements, for example those that improve condition of the mucous membranes. These supplements are attractive to consumers because they are natural source of many pro-health substances like carotenoids, EFA and phytosterols [17].

Unfortunately, there are also cases of adulteration of food supplements based on sea buckthorn oil. For this purpose, sunflower oil is used. Addition of β -carotene gives the product similar hue to orange color of original sea buckthorn oil [67].

Oil from *H. rhamnoides* combined with other vegetable oil can also be used to expand and diversify the offer of currently available cold-pressed oils. Research carried out by Pacholek et al. (2004) have shown that the linseed oil blends containing 5% sea buckthorn oil received high score in consumer opinion due to the greatest desirability of color and taste. Mixtures with a higher oil sea buckthorn oil content were lower rated. The addition of oil from sea buckthorn berries resulted in a decrease of oxidative stability of linseed oil, which is correlated with lower durability, so it is worth remembering when creating new products [68].

Furthermore, in Finland sea buckthorn is used as a nutritional ingredient of baby food [69]. The remains of the juice are a good functional supplement for products of mechanically deboned meat (MDM) and hand deboned meat (HDM) due to inhibition of decomposition of fatty acids contained therein and enrichment of meat by plant-derived polyphenols, which are beneficial for human health. Studies has been shown that 2% addition of powdered berries does not cause deterioration of the organoleptic characteristics of products made from MDM as taste, smell and texture [70].

Table 4. The average content of the selected biologically active compounds in sea buckthorn oil obtained from the seeds and pulp [71-73].

Chemical compound	Seed oil	Pulp oil
Vitamin E	207 mg/100g	171 mg/100g
Vitamin K	110-230 mg/100g	54-59 mg/100g
Carotenoids (total)	10-50 mg/100g	130 mg/100g
Organic acids (total)	11 mg/100g	38 mg/100g
Sterols (total)	1094 mg/100g	721 mg/100g
Unsaturated fatty acids (total)	87%	67%
• Palmitoleic acid	<0,5%	33%
• Oleic acid	18%	15%
• Linoleic acid	38%	10%
• α -linoleic acid	28%	8%
Saturated fatty acids (total)	12%	33%
• Palmitic acid	8%	28%

Milk products

Sea buckthorn may be exploited as an additive to dairy products like kefir, yoghurt or cheese as well. Studies conducted by Liszka et al. (2014) have shown that the addition of sea buckthorn berries pulp resulted in a significant increase of antioxidant properties of fermented milk drinks and additionally increased acidity of tested products. Kefir with sea buckthorn was characterized by higher number of the mesophilic streptococci and lower level of lactobacilli, while any important impact of pulp on the level of yoghurt microflora was not recorded [74]. *H. rhamnoides* berries were also used in the production of feta cheese, where they served the function of a biodegradable scaffold on which beneficial probiotic bacteria strain *Lactobacillus casei* ATCC 393 could grow. Beside of that, sea buckthorn addition has also contributed to reduction of pathogenic microorganism number and improved the organoleptic properties of cheese [75].

Alcoholic drinks

Production of alcoholic beverages with the use of sea buckthorn is also possible. In Tibet tincture made from this plant, rich in flavonoids, vitamin K and tannins, has been used for long time as a digestive aid used in many digestive system ailments like the lazy bowel syndrome. It can improve the functioning of the stomach and maintain the normal activity of the gastrointestinal tract [17]. In turn, the wine based on sea buckthorn fruits has gained the

greatest popularity in the Czech Republic, where it is also generally produced. It is characterized by golden color and a pleasant aroma [14]. From sea buckthorn, beer can be produced as well [76].

Animal nutrition

Besides of people feeding, sea buckthorn, especially its leaves, pomace and press cake, can also be used as an ingredient of animal feed [77]. It contains necessary amount of crude protein and fat and stimulates the growth and productivity of livestock and poultry as well, particularly in dry and cold areas [78,79]. After 60 days of feeding with fodder, which contain sea buckthorn, increase of body weight by 9.38% in piglets has been observed, while after 40 days in goats the amount of produced milk increased by 5.74%. Weight increased sequentially by 5.74% and 7.81% in chickens and hens fed on leaves and fruit pomace for 56 days too [80]. Sea buckthorn contributed positively to the egg production in laying hens [81]. Research carried out by Dorhoi et al (2006) also showed that the alcohol extracts of certain plant, including sea buckthorn, indicate a positive effect on cellular immunity in hens [82].

Sea buckthorn in Poland

In Poland, food additives based on sea buckthorn are not very popular yet – they are produced on a low scale in small factories and pharmaceutical companies. The results of survey conducted by Niesteruk et al. (2013) showed that more than half of 90 respondents did not heard about sea buckthorn. 80% of people did not see any product containing sea buckthorn. Only 2% of questioned people said they regularly use preparations made from *H. rhamnoides*. In relation to these results it can be clearly stated that there is small number of products made of sea buckthorn on the Polish market, which correlates with low consumer knowledge about this plant [14]. In other survey carried out by Chojnacka-Ożga and Ożga (2004) about use of forest resources in kitchen, very few people (mostly belonging to the older age group) mentioned sea buckthorn as a plant they use often [83]. Currently, many scientists and food companies are working on putting sea buckthorn products on the Polish market, because most of them is imported into Poland from abroad [14].

5. CONCLUSIONS

Sea buckthorn found wide application in many areas of life: medicine, dermocosmetics manufacture, food industry and animal nutrition. Nowadays healthy lifestyle trend is really common, therefore it is certain that people will be more interested in sea buckthorn's products. Moreover people who want to prevent from chronic diseases prefer to use nutraceuticals and natural biocompounds than medical therapeutic agents. Actually in media natural sources of active substances are promoted what is shown in changed way of pharmacy industry development.

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