Journal of Ethnopharmacology 213 (2018) 183–190

Contents lists available at ScienceDirect

Journal of Ethnopharmacology

journal homepage: www.elsevier.com/locate/jethpharm

Review

The beneficial health aspects of sea buckthorn (*Elaeagnus rhamnoides* (L.) A.Nelson) oil

Beata Olas*

Department of General Biochemistry, Faculty of Biology and Environmental Protection, University of Lodz, Pomorska 141/3, 90-236 Lodz, Poland

ARTICLE INFO

Keywords:
Elaeagnus rhamnoides (L.) A.Nelson
Oil
Fatty acids
Health

ABSTRACT

Ethnopharmacological context: Plant oils are known to have biological activity. This review paper summarizes the current knowledge of the composition of sea buckthorn (*Elaeagnus rhamnoides* (L.) A.Nelson) seed and pulp oil and its beneficial health aspects.
Materials and methods: In vitro and in vivo studies on humans and animals have found sea buckthorn oil to have a variety of beneficial properties to human health, and indicate that it may be a valuable component of human and animal nutrition. Various bioactive substances are present in all parts of sea buckthorn, and these are used traditionally as raw material for health foods and as nutritional supplements. The oil, berries, leaves and bark have medicinal properties, and the fruits have a unique taste; these parts can be processed to make oil, juice, jam, jellies and candies, as well as alcoholic and non-alcoholic beverages.
Results: Sea buckthorn oil may be extracted from the seed or the pulp. The mature seeds contain 8–20% oil and the dried fruit pulp about 20–25%, while the fruit residue contains about 15–20% oil after juice extraction. These oils have high concentrations of lipophilic constituents, most commonly unsaturated fatty acids (UFAs), phytosterols and vitamins A and E. These components have a multifunctional effect on human health, with the fatty acids playing an important function in modifying cerebrovascular and cardiovascular disorders. The oil also has anti-oxidant, anti-inflammatory and anti-depressive properties.
Conclusion: Sea buckthorn is a unique plant. Its beneficial properties against cardiovascular disorders have been attributed to its high UFA content and range of phytosterols, especially beta-sitosterol. However, its different action on the human organism remain unclear, and further well-controlled, high-quality experiments with human subjects are required to determine the prophylactic and therapeutic doses of sea buckthorn oil for use in clinical studies. Additional studies are also needed to understand the action by which the oil exerts its beneficial properties, i.e. its cardioprotective and anti-cancer activity.

1. Introduction

Sea buckthorn (*Elaeagnus rhamnoides* (L.) A.Nelson) is a bush or small tree. It belongs to the *Elaeagnaceae* family, which is naturally distributed throughout Eurasia from the Baltic Sea and North Sea in the west to Central Asia in the east (Xing et al., 2002). Although a unique mixture of bioactive compounds is found throughout the plant, this is especially the case for the fruits, which are known as seaberry or Siberian pineapple (Teleszko et al., 2015). In vitro studies, and in vivo human and animal models, have found the juices, jams and oil derived from the fruits to have a range of beneficial anti-inflammatory, anticancer, antioxidant and anti-atherosclerotic effects; these have been attributed to the presence of phenolics, vitamins, minerals, amino acids, fatty acids and phytosterols (Zeb, 2006; Basu et al., 2007; Kumar et al., 2011; Suryakumar and Gupta, 2011; Xu et al., 2011; Christaki, 2012; Teleszko et al., 2015; Wang et al., 2016).

Plant oils are usually lipophilic or hydrophobic materials which can be extracted with nonpolar solvents such as hexane. The presence of highly nutritional and medicinal components in the oil from sea buckthorn fruits has prompted a growth of interest in its potential as a functional food product (Ding et al., 2016). Oil can be extracted from the seeds and the pulp (Zeb, 2006; Christaki, 2012): the mature seeds contain 8–20% oil, the dried fruit pulp (flesh and peel) about 20–25%, and the fruit residue contains about 15–20% oil after juice extraction (Kumar et al., 2011; Christaki, 2012). These oils have high concentrations of lipophilic constituents, predominantly unsaturated fatty acids

Abbreviations: HDL, high density lipoprotein; LDL, low density lipoprotein; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; UFAs, unsaturated fatty acids

* Correspondence address: Faculty of Biology and Environmental Protection, University of Lodz, Pomorska 141/3, 90-236 Lodz, Poland.
E-mail address: beata.olas@biol.uni.lodz.pl.

https://doi.org/10.1016/j.jep.2017.11.022
Received 30 August 2017; Received in revised form 17 November 2017; Accepted 17 November 2017
Available online 21 November 2017
0378-8741/

(UFAs) in triglyceride form, phytosterols and vitamins A and E; these have a positive influence on human health, especially on the cardiovascular system (Kumar et al., 2011; Olas, 2016a, 2016b). However, it is important to emphasize that the precise cardioprotective influence of the oil on the human organism remains unclear, and although some papers offer a glimpse into its effects (e.g. Johansson et al., 2000; Lehtonen et al., 2011), further animal studies are needed to better appreciate the true value of sea buckthorn as a source of medical and nutritional compounds. For example, Basu et al. (2007) found sea buckthorn seed oil to have anti-atherogenetic properties.

The yield and composition of the oil depend on extraction technique, solvent type and environmental factors. Kumar et al. (2011) list four extraction techniques that may be employed for the isolation of pulp and seed oil: petroleum-ether solvent extraction, screw pressing, aqueous extraction and supercritical fluid extraction with the use of carbon dioxide. In contrast, it is not possible to obtain oil from the seeds by aqueous extraction, or from the pulp-flakes by screw pressing, and the two methods of extraction produce oils with the lowest amounts of nutritionally-important components. Supercritical fluid extraction is an advanced method for seed oil extraction which results in greater concentrations of total carotenoids and individual tocopherols from the pulp-flakes and seed oil, and of phytosterols (β-sitosterol and campesterol) from the seed oil; however, this technique has no effect on the concentrations of phytosterols extracted from pulp-flake oil (Kumar et al., 2011). In addition, oil content, and hence the antioxidant activity of the product, will also be affected by the morphology of the fruit, such as its colour and size, as well as the choice of harvesting time (Yang and Kallio, 2002; Christaki, 2012) and the choice of production process (Kasparavicience et al., 2004).

For diet supplementation, dry fruit and leaf extracts are typically administered at a dose of 500–2000 mg daily, while the oil is administered at doses of 2000 – 5000 mg (Sea Buckthorn, available online, accessed on 11 October 2017). The oils are typically incorporated in vegetable-based capsules, gelatin and liquids for oral administration (Yang and Kallio, 2002) and in commercially-available cosmetics, such as cream and shampoo (Bal et al., 2011). Fortunately, toxicity studies indicate no adverse effects in subjects administered with sea buckthorn seed oil (Upadhyay et al., 2009). The aim of this paper is to briefly review the composition and nutritional aspects of sea buckthorn seed and pulp oil, and their beneficial effects on human health.

2. History and traditional uses of sea buckthorn

Sea buckthorn has been used for many years in traditional medicine (Suryakumar and Gupta, 2011) in both Asia and Europe. Its health benefits have been detailed in various sources including the Siu Yidian and the Jing Zhu Ben Cao, dating back to the Tang (618–907 CE) and Qing Dynasties, respectively. Sea buckthorn was being used as a medicinal remedy in Tibet in 900 CE and "the RGyud Bzi" (The Four Books of Pharmacopoeia) of the Tang Dynasty describes the medicinal use of sea buckthorn, as do other ancient Tibetan medicinal texts. Sea buckthorn has been used in traditional Mongolian medicine since the 13th Century, when the RGyud Bzi was disseminated throughout Mongolia. Sea buckthorn berries have been used as a source of herbal medicines and as a health food in Central Asia and Europe (Suryakumar and Gupta, 2011; Li and Hu, 2015). Local people also used the berries for treatment of skin diseases, hypertension and problems with the digestive system in Central Asia, and for the treatment of skin diseases, gastrointestinal diseases, asthma and rheumatism in the Indian Himalayas and Russia (Suryakumar and Gupta, 2011; Malinowska and Olas, 2016; Olas, 2016b).

The first clinical studies on their medicinal use were initiated in Russia during the 1950s (Gurevich, 1956). However, China was the first country to recognize sea buckthorn as a drug, being formally included in the Chinese pharmacopoeia in 1977 (The State of Pharmacopoeia Commission of P.R. China, 1977). In addition, various drugs have been developed from sea buckthorn in these countries and have been incorporated in various formulations such as powders, liquids, pastes and even aerosols (Li and Schroeder, 1996). Chinese medicinal literature has described the use of the fruits for treating a range of conditions including circulatory diseases, hepatic disorders, fever, cold, toxicity, inflammation, metabolic disorders, cough and gynecological diseases (Ballabh and Chausais, 2007; Kumar et al., 2011). The flowers are also used as a skin softener in Tajikistan (Kumar et al., 2011).

Sea buckthorn oil is approved for clinical use in hospitals in Russia and in China. ClinicalTrials.gov (2017) describes sea buckthorn oils as dietary supplements which play an important role in modulating various conditions, including skin aging, dry eye syndromes, mucous membrane disorders, and the risk factors for age-related macular degeneration. More details about its history and traditional use are given by Suryakumar and Gupta (2011) and Olas (2016b); however, the plant has also been recorded as a source of firewood and decorative elements (Suryakumar and Gupta, 2011; Malinowska and Olas, 2016; Olas, 2016b), and has been used to rehabilitate degraded ecological regions in Germany (Xing et al., 2002; Olas, 2016b).

3. Botanical characteristics of sea buckthorn

The plant names have been checked and updated with The Plant List version 1.1 (www.theplantlist.org) (2017) of the Royal Botanic Gardens, Kew and the Missouri Botanical Garden (accessed November 2017). *Elaeagnus rhamnoides* (L.) A.Nelson is an accepted name in the genus *Elaeagnus* (family *Elaeagnaceae*). Other plants (*Hippophae salicifolia* D.Don, *Hippophae goniocarpa* Y.S. Lian & et al. ex Swenson & Bartish, *Hippophae gyantsensis* (Rousi) Y.S. Lian, *Hippophae litangensis* Y.S. Lian & X.L. Chen ex Swenson & Bartish, *Hippophae neurocarpa* S.W. Liu & T.N. He and *Hippophae tibetana* Schltdl) are in the genus *Hippophae* (family *Elaeagnaceae*).

The natural distribution of sea buckthorn ranges Great Britain and France in the west to Mongolia in the east, including parts of Europe, Scandinavia and central Asia. It typically grows as a shrub, but sometimes also as a small tree growing to 5–8 m tall; however, specimens as tall as 10 m have been found (Niesteruk et al., 2013). The leaves are hydrolapathum-shaped, the top is grey-green, smooth and shiny, while the bottom is hirsute, reflective white or with a light brown shade. The young shoots have silver hairs. The buds on the shoots are golden-copper in colour, and are larger and more numerous in male than female individuals (Hu, 2005; Banas, 2013).

Sea buckthorn is a diclinous plant. It has both male and female reproductive organs. The female flowers are yellow, while the male flowers have a greenish colour and are collected in spherical inflorescences. Pollen is spread by the wind. Blooming occurs at the end of April and is observed before the leaves develop (Niesteruk et al., 2013). The fruits are orange berries measuring 6–9 mm in diameter, and are soft, juicy and rich in oils (Suryakumar and Gupta, 2011). The plant has the ability to symbiose with *Actinomycetes frankia*, which has allowed the plant to grow on poor and sandy soils (Banas, 2013; Niesteruk et al., 2013).

4. Hydrophilic compounds in sea buckthorn fruits (berries)

Sea buckthorn berries are characterized by high concentrations of phenolics, especially flavonols. Teleszko et al. (2015) identified a total of 11 flavonols in the fruits of eight chosen cultivars of *Hippophae mongolica* (Rousi) Tzvelev: six compounds derived from isorhamnetin, four from quercetin and one from kaempferol. The examined cultivars were 'Aromatnaja', 'Avgustinka', 'Botaniczeskaja', 'Botaniczeskaja Ljubitelskaja', 'Moskwiczanka', 'Luczistaja', 'Podarok Sadu' and 'Porożrachnaja'.

In vitro and in vivo studies indicate that the phenolic compounds demonstrate various biological activities and antioxidant properties (Chauhan et al., 2007; Michel et al., 2012; Olas et al., 2016). However, some papers report that phenolic compounds may sometimes behave like prooxidants, and sometimes possess both antioxidant and prooxidant properties (Hagerman et al., 1998; Fukumoto and Mazza, 2000; Veskouis et al., 2012; Cotoras et al., 2014). In addition, phenolic compounds have different biological properties when studied in vivo and in vitro, and these are dependent on a range of factors, including the class of phenolic compound, their concentration and method of consumption. Michel et al. (2012) found that of the various organs of sea buckthorn, the ethanolic extracts of the seed and root demonstrated the greatest antioxidant properties; however, the phenolic compounds themselves were not specified. In addition, a methanolic extract of sea buckthorn seeds was found to demonstrate antioxidant properties in an in vitro model based on 1,1-diphenyl-2-picrylhydrazine and a liposome model system (Negi et al., 2005).

In contrast, Gao et al. (2000) report changes strongly correlated with total phenolic and ascorbic acid content, and hence antioxidant activity, occurring as the berries mature. Korekar et al. (2011) also observed a significant correlation between phenolic content and the antioxidant capacity of extracts from various parts of sea buckthorn, with the strongest antioxidant properties demonstrated by the bark, followed by the seeds, leaves and pulp.

Recently, various papers have indicated that pan assay-inhibiting compounds (PAINS compounds), such as phenolic compounds, inhibit all assays by interacting with proteins; they also demonstrate poor bioavailability and fast metabolism (Baell and Walters, 2014; Bisson et al., 2016). Therefore, the results of experiments with phenolic compounds or extracts regarding their biological properties, including their antioxidant activity, should be interpreted with caution.

Sea buckthorn fruits are also rich sources of vitamin C (L-ascorbic acid), which has beneficial properties for health, including antioxidant properties. The mean concentration of vitamin C in raw material is about 80 mg/100 g, (Teleszko et al., 2015) which is higher than other popular fruits (Lee and Kader, 2000; Teleszko et al., 2015). In addition, the content of vitamin C depends on the variety of the plant and its geographical location: 120–315 mg/100 vitamin in fresh fruits for sea buckthorn growing in Europe; 405–110 mg/100 g for the species growing in the Alps; about 2500 mg/100 g for Chinese sea buckthorn (Lee and Kader, 2000; Kallio et al., 2002; Yang and Kallio, 2002; Zeb, 2011; Korekar et al., 2013; Fu et al., 2014; Teleszko et al., 2015; Zielinska and Nowak, 2017). The vitamin C concentration of sea buckthorn berries is compared with that of other popular fruits in Table 1.

5. Lipophilic compounds in sea buckthorn oil

The berries and their products, especially the oil, contain an interesting composition of lipophilic compounds. The oil from the seed and fruit pulp is a source of healthy unsaturated fatty acids which have a multifunctional influence on human health (Zeb, 2011; Gupta and Upadhyay, 2011). These acids play an important function in modifying cerebrovascular and cardiovascular disorders, and have been found to stimulate the immune system, and promote cognitive function and bone health. Increasing their level in the human diet has been shown to have a positive effect on such neurological disorders as depression, schizophrenia and Alzheimer's in subjects of all ages (EFSA, 2009).

Table 1
Comparison of vitamin C concentration in sea buckthorn fruits and other popular fruits (Lee and Kader, 2000; Kallio et al., 2002; Yang and Kallio, 2002; Zeb, 2011; Korekar et al., 2013; Fu et al., 2014; Teleszko et al., 2015; Zielinska and Nowak, 2017; compilation of date).

Fruits	Concentration of vitamin C (mg/100 g f.w.)
Lemons	About 74
Mandarins	About 38
Sea buckthorn	120–315 (for plant growing in Europe)
	405–1100 (for plant growing in Alps)
	About 2500 (for plant growing in Chine)
Strawberries	About 65

The fatty acid content of whole fruit oil ranges from 31% to 33% (28–37% palmitoleic acid, 12–18% linoleic acid, 3–8% alpha-linoleic acid and < 2% stearic acid) (Przybylowicz, 2011; Fatima et al., 2012; Olas, 2016b). In addition, the oil from the pulp is a rich source of linoleic acid, palmitoleic acid, palmitic acid and oleic acid (Przybylowicz, 2011; Fatima et al., 2012; Olas, 2016b). In a study of sea buckthorn pulp oil from eight chosen cultivated varieties of *Hippophae mongolica* (Rousi) Tzvelev (Russian sea buckthorn cultivars) grown in Poland (‘Aromatnaja’, ‘Avgustinka’, ‘Botaniczeskaja’, ‘Botaniczeskaja Ljubitelskaja’, ‘Moskwiczanka’, ‘Luczistaja’, ‘Podarok Sadu’ and ‘Porożrachnaja’), Teleszko et al. (2015) identified 11 fatty acids. Table 2 presents the polyunsaturated (PUFA), monounsaturated (MUFA) and saturated fatty acid (SFA) composition of the pulp oils (Teleszko et al., 2015). However, in these experiments, whole fruits with seeds and skin were examined.

Dulf (2012) describes the fatty acid composition of the oils and the major lipid fractions of pulp/peel, seed and whole fruit oils of six chosen varieties of *Hippophae carpatica* (Rousi) Landolt cultivated in Romania (‘Auras’, ‘Serpenta’, ‘Tiberiu’, ‘Victoria’, ‘Ovidiu’, ‘Silvia’), based on gas chromatography-mass spectrometry. The predominant fatty acids in the pulp and peel, and in the whole fruit (the total lipids) were found to be palmitic (23–40%), oleic (20–53%) and palmitoleic (11–27%); however, higher levels of polyunsaturated fatty acids were observed in oil from the pulp and seeds (65–72%). The predominant fatty acids in the major lipid fraction of the fruit pulp and peel oils were oleic (20–40%), followed by palmitic (17–27%), palmitoleic (10–20%) and linoleic (10–20%) acids, while those in the major lipid fraction of seed oil were polyunsaturated fatty acids.

Cakir (2004) identified 39 constituents in the oil of sea buckthorn fruits grown in Turkey, representing 94.6% of the total content. These included ethyl dodecenoate (39.4%), ethyl octanoate (9.9%), decanol (5.6%), ethyl decanoate (5.5%) and ethyl dodecanoate (3.7%), among others. In addition, 15 different fatty acids were identified: palmitoleic acid (47.8%) and palmitic acid (29.3%) predominated in the seed mesocarp, while in the seeds, oleic acid (32.8%) predominated, followed by palmitic acid (26.3%) and linoleic acid (21.7%). Bekker and Glushenkowa (2001) found the major fatty acids in the mesocarp of seeds from plants grown in Uzbekistan to be palmitoleic acid and palmitic acid. Moreover, Ranjith et al. (2006) found palmitoleic acid to be the dominant fatty acid in various species grown in India (32–53%).

Various authors (Bekker and Glushenkowa, 2001; Cakir, 2004; Ranjith et al., 2006; George and Cenkowski, 2007; Przybylowicz, 2011; Dulf, 2012; Teleszko et al., 2015; Zielinska and Nowak, 2017) have demonstrated that palmitoleic, palmitic and oleic acids predominate in sea buckthorn fruit: a significant finding considering that few fruits, other than macadamia nuts, have high concentrations of palmitoleic acid. As palmitoleic acid is a major component of skin fat, sea buckthorn oil can be used for the production of cosmetics, or as a cosmetic itself: one example being the Polish cosmetic “*Make your own natural cosmetic cream*” (Bialek et al., 2016). The oil has been characterized with a peroxidability index of 8.9.

Sea buckthorn oil contains a range of other bioactive compounds (Fig. 1): many of these are lipophilic, such as vitamins A and E, which act as antioxidants. In addition, the oil from the seeds and pulp contain large amounts of beta-sitosterol, as well as other phytosterols. This group includes both unsaturated and saturated sterols, known as stanols, with an alkane bond at the C_1 position on the B ring (Alasalvar and Bolling, 2015). Phytosterols have prophylactic properties against hypercholesterolemia-induced cardiovascular disorders and can act as part of a treatment regimen by lowering serum cholesterol concentrations. In addition, they also have anti-cancer, anti-bacterial and anti-inflammatory properties (Beveridge et al., 2002; Sajfratova et al., 2010). The total phytosterol content isolated from sea buckthorn from

Table 2
Fatty acid profile of oil from different parts of sea buckthorn (Dulf, 2012; Teleszko et al., 2015; modified).

Pulp oil (fraction from whole fruits (with seeds and skin))	Whole fruit oil	Pulp/peel oil	Seed oil
Eight chosen cultivated varieties of *Hippophae mongolica* (Rousi) Tzvelev (Russian sea buckthorn cultivars): 'Aromatnaja', 'Avgustinka', 'Botaniczeskaja', 'Botaniczeskaja Ljubitelskaja', 'Luczistaja', 'Moskwiczanka', 'Podarok Sadu', 'Porożrachnaja', grown in Poland	Six chosen varieties of *Hippophae carpatica* (Rousi) Landolt cultivated in Romania ('Auras', 'Serpenta', 'Tiberiu', 'Victoria', 'Ovidiu', 'Silvia')	Six chosen varieties of *Hippophae carpatica* (Rousi) Landolt cultivated in Romania ('Auras', 'Serpenta', 'Tiberiu', 'Victoria', 'Ovidiu', 'Silvia')	Six chosen varieties of *Hippophae carpatica* (Rousi) Landolt cultivated in Romania ('Auras', 'Serpenta', 'Tiberiu', 'Victoria', 'Ovidiu', 'Silvia')
Saturated fatty acids (SFAs)	**Saturated fatty acids (SFAs)**	**Saturated fatty acids (SFAs)**	**Saturated fatty acids (SFAs)**
C14:0 (myristic acid)	C14:0 (myristic acid)	C14:0 (myristic acid)	C14:0 (myristic acid)
C16:0 (palmitic acid)	C15:0 (pentadecanic acid)	C15:0	C15:0
C18:0 (stearic acid)	C16:0 (palmitic acid)	C16:0 (palmitic acid)	C16:0 (palmitic acid)
C20:0 (arachidic acid)	C17:0 (margaric acid)	C17:0 (margaric acid)	C17:0 (margaric acid)
Monounsaturated fatty acids (MUFAs)	C18:0 (stearic acid)	C18:0 (stearic acid)	C18:0 (stearic acid)
C16:1 omega 7 (palmitoleic acid)	C20:0 (arachidic acid)	C20:0 (arachidic acid)	C20:0 (arachidic acid)
C18:1 omega 9 (oleic acid)	**Monounsaturated fatty acids (MUFAs)**	**Monounsaturated fatty acids (MUFAs)**	**Monounsaturated fatty acids (MUFAs)**
C18:1 omega 7 (cis-vaccenic acid)	C16:1 omega 7 (palmitoleic acid)	C16:1 omega 7 (palmitoleic acid)	C16:1 omega 7 (palmitoleic acid)
C20:1 omega 9 (eicosenoic acid)	C16:1 omega 9	C16:1 omega 9	C18:1 omega 9 (oleic acid)
	C18:1 omega 9 (oleic acid)	C18:1 omega 9 (oleic acid)	C18:1 omega 7 (cis-vaccenic acid)
Polyunsaturated fatty acids (PUFAs)	C18:1 omega 7 (cis-vaccenic acid)	C18:1 omega 7 (cis-vaccenic acid)	C20:1 omega 9 (eicosenoic acid)
	C20:1 omega 9 (eicosenoic acid)		
C16:2 omega 7 (hexadecadienoic acid)	**Polyunsaturated fatty acids (PUFAs)**	C20:1 omega 9 (eicosenoic acid)	**Polyunsaturated fatty acids (PUFAs)**
C18:2 omega 6 (linoleic acid)	C18:2 omega 6 (linoleic acid)	**Polyunsaturated fatty acids (PUFAs)**	C18:2 omega 6 (linoleic acid)
C18-3 omega 3 (linolenic acid)	C18-3 omega 3 (linolenic acid)	C18:2 omega 6 (linoleic acid)	C18-3 omega 3 (linolenic acid)
		C18-3 omega 3 (linolenic acid)	

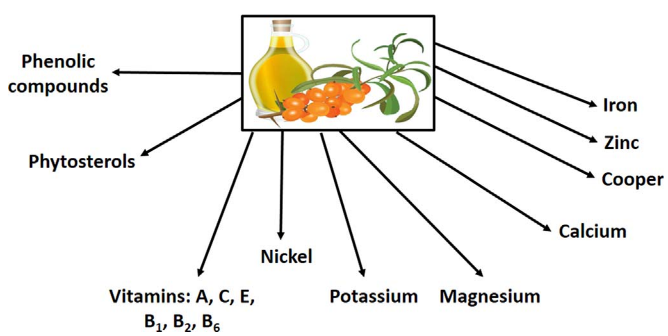


Fig. 1. Other bioactive compounds contained in sea buckthorn oil (Zielinska and Nowak, 2017; modified).

China and Finland ranges from 120 to 180 mg/100 g in the seeds, and from 1200 to 2300 mg/100 g in the oil (Sajfratova et al., 2010). Beta-sitosterol is the major sterol found in the seeds, constituting 57–76% of seed phytosterols (Yang et al., 2011; Li et al., 2007; Sajfratova et al., 2010). However, the concentration of phytosterol depends on the method of extraction: supercritical fluid extraction gives higher phytosterol concentrations in seed oil than cold pressing or extraction with hexane (Li et al., 2007). Sajfratova et al. (2010) report the average yield of beta-sitosterol to be 31 mg/100 g of sea buckthorn seeds using supercritical carbon dioxide extraction. In addition, the oil is not only a good source of beta-sitosterol, but also Δ^5-avensterol (Bal et al., 2011).

In the study of eight *Hippophae mongolica* (Rousi) Tzvelev cultivars, Teleszko et al. (2015) found the total concentration of sterols in the lipid fraction from the pulp to range from 6168 μg/100 ml (for 'Moskwiczanka') to 13,378 μg/100 ml (for 'Aromatnaja'). In addition, 14 phytosterols were identified, i.e. beta-sitosterol, stigmasterol, campesterol, Δ^5 –avenastenol, Δ^7 –avenastenol, citrostadienol and 24-methylenecycloartanol. The chemical structures of selected phytosterols are presented in Fig. 2. In addition, sea buckthorn was found to be a valuable source of squalene, and the predominant phytosterol was also β-sitosterol. High carotenoid concentrations were also noted in the berries, particularly the soft parts, with a mean value of 11 mg/100 g f.w.. However, these concentrations vary with cultivar, with 'Moskwiczanka' demonstrating the greatest concentration (about 24 mg/100 g f.w.) of the eight examined cultivars (Teleszko et al., 2015).

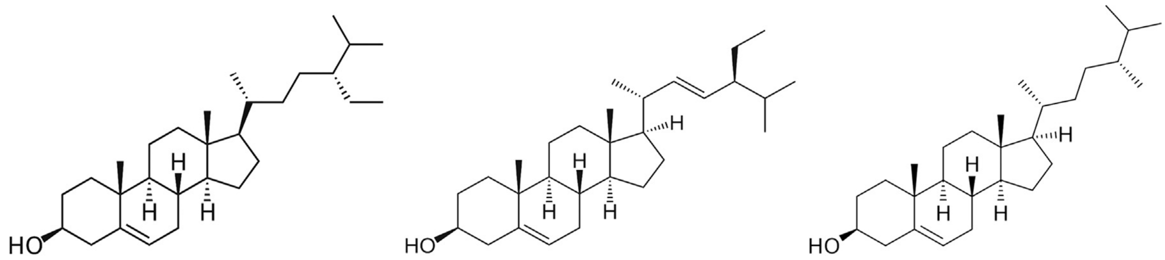
Sea buckthorn oil is also a more plentiful source of β–sitosterol than extra virgin olive oil (Olas, 2016a, 2016b); this is an important point because phytosterols, particularly β–sitosterol, play an important function in the prophylaxis and treatment of cardiovascular disorders stimulated by hypercholesterolemia. They are also a source of stanols such as sitostanol (Li et al., 2007; Teleszko et al., 2015); the concentration of beta-sitosterol in sea buckthorn oil and other popular plant oils is described in Table 3.

The carotenoid concentration in sea buckthorn berries is similar to that found in other popular vegetables: tomatoes are known to have about 13 mg/100 g f.w., and carrots about 9 mg/100 g f.w.. Beta-carotene predominates in sea buckthorn fruit (15–55% of all compounds), with other carotenoids including zeaxanthin and lycopene also present, but in lower concentrations (Yang and Kallio, 2001, 2002; Teleszko et al., 2015). Przybylowicz (2011) also notes the presence of carotenoids in the seed oil and pulp oil: 10–50 mg/100 g for seed oil and 350–520 mg/100 g for pulp oil. These carotenoids may enhance the immune system, as well as acting as free-radical scavengers (Kumar et al., 2011). Beta-carotene has been reported that in most Eastern European countries beta-carotene concentration acts as a quality indicator in sea buckthorn oil (Suryakumar and Gupta, 2011). Other vitamins, including tocotrienols and tocopherols are also found in sea buckthorn oils (Przybyłowicz, 2011). More details about chemical and physical properties of sea buckthorn oil are described by Zielinska and Nowak (2017).

6. The beneficial function of sea buckthorn oil on health

6.1. Cardioprotective properties and modulation of hypoxia

The various medicinal properties of sea buckthorn oils against cardiovascular diseases have been attributed to its high UFA content (Shi et al., 1994; Hsu et al., 2009; Malinowska and Olas, 2016; Olas, 2016a, 2016b). Basu et al. (2007) found sea buckthorn seed oil to have significant anti-atherogenic properties when administered to normal albino rabbits and hypercholesterolemic ones fed on a high cholesterol diet for two months; this was based on a comparison of blood triglyceride, total cholesterol, low density lipoprotein (LDL) cholesterol and



Beta-sitosterol **Stigmasterol** **Campesterol**

Fig. 2. Chemical structure of selected phytosterols of oil from sea buckthorn fruits.

Table 3
The concentration of beta-sitosterol in sea buckthorn oil and other popular plant oils [Olas (2016a, 2016b); modified].

Oil	Concentration of β-sitosterol [mg/100 g]
Sea buckthorn seed oil	599–748
Sea buckthorn pulp oil	522–577
Canola oil	378
Extra virgin olive oil	117
Kernel oil	134
Sesame oil	367
Soybean oil	221
Sunflower oil	238

high density lipoprotein (HDL) cholesterol concentrations before and after administering 1 ml seed oil. They suggest that the cardioprotective effects of the oil may be due to the presence of UFAs, phytosterols and vitamins A and E; these may have synergistic actions on cardiovascular health when given in combination.

Supplementation with the oil from the berries also normalizes plasma lipid concentrations in hyperlipidemic subjects (Jiang et al., 1993). Johannson et al. (2000) found the pulp and seed oil to have anti-aggregation activities in normolipidemic subjects following oral administration of ten 500 mg capsules per day for four weeks, suggesting that the oils may play a beneficial role as anti-platelet (anti-aggregation) factors in the cardiovascular system (Johansson et al., 2000). Guo et al. (2017) report that the administration of sea buckthorn berry extracts significantly reduced total cholesterol and LDL-cholesterol, and significantly elevated HDL-cholesterol level in subjects with cardiovascular risk, but no such effect was observed in healthy subjects. The authors attribute these cardio-protective effects to the chemical content of sea buckthorn, especially β-sitosterol and flavonoids.

Suchal et al. (2016) report that administration of pulp oil serves a protective function against myocardial ischemia-reperfusion injury in rats through the activation of the protein kinase B (Akt) – endothelial nitric oxide synthase (eNOS) signaling pathway. Wistar rats were orally administered 5, 10 and 20 ml/kg/day doses of sea buckthorn pulp oil for 30 days. Ischemia was induced on day 31. Pretreatment with 20 mg/kg pulp oil stabilized cardiac function and myocardial antioxidant level (i.e. glutathione), and inhibited lipid peroxidation to a greater degree than the ischemia-reperfusion (control) group. In addition, the pulp oil improved hemodynamic and contractive function, decreased tumor necrosis factor level and inhibited the activities of enzymes acting as myocyte injury markers, i.e. lactate dehydrogenase (Suchal et al., 2016).

Cardiovascular diseases are often correlated with obesity, which may be influenced by the consumption of fruits and vegetables, and their products: i.e. teas, oils, syrups and extracts (Hasani-Ranjbar et al., 2013). Lehtonen et al. (2011) suggest that supplementation with sea buckthorn oil for 33–35 days may have a positive influence on the occurrence of metabolic diseases in overweight and obese women.

Sea buckthorn seed oil was also found to serve a protective function against ischemic cerebral infraction and hypoxia-induced transvascular fluid leakage in rats (Cheng et al., 2003; Purushothaman et al., 2008).

6.2. Hepatoprotective properties

Hsu et al. (2009) examined the protective effects of sea buckthorn seed oil on hepatic damage in mice induced by carbon tetrachloride (CCl_4). It was found that oral supplementation of seed oil from sea buckthorn at doses of 0.26, 1.3 and 2.6 mg/kg for eight weeks reduced the degree of lipid peroxidation in the liver, and reduced previously elevated levels of cholesterol, triglyceride, alkaline phosphatase, alanine aminotransferase and aspartate aminotransferase in serum. The activities of various antioxidant enzymes, i.e. catalase, superoxide dismutase, glutathione reductase and glutathione peroxidase, were also found to increase. In addition, the seed oil was found to have comparable activity to silymarin (200 mg/kg), a standard drug used in the prevention and treatment of liver diseases, when applied at all tested doses.

6.3. Anticarcinogenetic potential

The anticarcinogenetic potential of lipids obtained from sea buckthorn plants has been described in a review by Zeb (2006). However, their medicinal and prophylactic doses remain unknown, and no clinical experiments have yet been performed. Nevertheless, Kumar et al. (2011) describe that oil from sea buckthorn plays an important role in cancer therapy, especially treatments based on chemotherapy and radiotherapy regimes. They describe that taking sea buckthorn seed oil is associated with increased appetite, restoration of kidney and liver functions, and maintaining the patients in good health. Sea buckthorn seed oil contains a wealth of vitamins, particularly A and E and beta-carotene, and it may well offer protective effects against cervical cancer (Beveridge, 2007).

6.4. Antioxidant and other biological properties

Sea buckthorn seed oil has strong antioxidant properties, protecting against the oxidative stress associated with lipids that have undergone thermal oxidation. In addition, it reduces hepatotoxic effects and liver degeneration in rabbits (Zeb and Ullah, 2015). The oil may also bestow a protective antioxidant effect on injuries induced by sulfur dioxide inhalation in mice (Ruan et al., 2003), and may ameliorate oxidative damage, i.e. lipid peroxidation and protein carbonylation, to the colon in rats (Li et al., 2014).

A recent study by Diandong et al. (2016) found that oil extracted from sea buckthorn fruit flesh, seeds and peel protects against chronic stress-induced inhibition of natural killer cells in rats when applied at a dose of 10 ml/kg for 21 days. Sea buckthorn oil is known to have anti-inflammatory properties (Istrati et al., 2016), and improve the immune response of broilers and promote tissue regeneration (Lavinia et al., 2009).

Table 4
The beneficial health aspects of sea buckthorn oil (in vivo experiments).

Oil	Dose	Days/weeks/ months	Subjects	Effects	References
Animal studies					
Seed oil	1 ml daily	2 months	20 male white albino rabbits (normal and hypercholesterolemic animals)	Anti-atherogenic property	Basu et al. (2007)
Seed oil	0.26; 1.3 and 2.6 mg/kg daily	8 weeks	72 male ICR mice	Hepatoprotective effect and antioxidant property; inhibiting lipid peroxidation and increasing activity of antioxidant enzymes in the liver (CCl_4 – the inducer of oxidative stress)	Hsu et al. (2009)
Seed oil	1–3 g/kg	14 days	Rabbits	Antioxidant property; protecting against the oxidative produced by thermally oxidized lipids	Zeb and Ullah (2015)
Seed oil	5 ml/animal, twice a day	4–25 days	20 dogs	Relieving dexamethasone – induced gastric ulceration and erosion	Dogra et al. (2013)
Seed oil	0.35, 0.7 and 1.4 g/kg body weight	4 weeks	60 male S.D. rats	Anti-depression properties	Tian et al. (2015)
Pulp oil	5, 10 and 20 ml/kg/day	30 days	72 adult male albino Wistar rats (aged 6–8 weeks)	Cardioprotective effect; protecting against myocardial ischemia-reperfusion injury	Suchal et al. (2016)
Pulp oil	Diet containing sea buckthorn pulp oil	28 days	24 Wistar rats	Affecting adipose tissue and liver by diet	Czaplicki et al. (2017)
Pulp and seed oil	10 mg/g/day	7 days	C57/B6 mice	Protecting against radiation-induced acute intestinal injury	Shi et al. (2017)
Pulp and seed oil	3.5 and 7 ml/kg/day	7 days	Sprague-Dawley rats	In the treatment of gastric ulcer disease	Xing et al. (2002)
Berry oil	100, 200 and 300 mg/kg/day	4 weeks	Rats	Alleviating insulin resistance	Gao et al. (2017)
Oil extracted from fruit flesh, seeds and peel	10 ml/kg daily	21 days	40 Wistar rats	Protecting against chronic stress – induced inhibition of natural killer cells	Diandong et al. (2016)
Human studies					
Seed oil	10 oil capsules per day	4 months	78 patients; they had a history of atopic dermatosis from childhood with persistent symptoms during the last 6 months	Beneficial effect on atopic dermatosis	Yang et al., (1999, 2000)
Pulp and seed oil	Ten 500 mg capsules per day	4 weeks	12 healthy normolipidemic men (aged 20–59 years)	Anti-platelet property (anti-aggregatory property)	Johansson et al. (2000)
Pulp and seed oil	2 g of oil daily (in the form of 2 capsules twice day with a meal)	3 months	20- to 75-y – old women and men	Reducing the increase of the osmotic concentration in tear film during the cold season and positively affects dry eye symptoms	Larmo et al. (2010)
Berry and seed oil	The amount of fractions in the berry diets was equivalent to an average daily dose of 100 g fresh berries	33–35 days	110 female volunteers	Anti-obesity properties	Lehtonen et al. (2011)

Sea buckthorn seed oil is known to relieve dexamethasone-induced gastric ulceration and erosion in dogs when administered at 5 ml/animal, twice daily (Dogra et al., 2013). Some evidence also suggests that the oil may also have anti-depression properties (Tian et al., 2015).

Yang et al. (1999, 2000) report that while the seed oil has a beneficial effect on atopic dermatosis, the pulp oil has no effect. The authors attribute this difference in activity to differences in their fatty acid composition. However, both oils absorb ultraviolet light and promote healthy skin: sea buckthorn oil was used in a skin cream by Russian cosmonauts as protection against solar radiation (Christaki, 2012). The oils are also used as raw material for the cosmetic industries (Suryakumar and Gupta, 2011). Table 4 presents the beneficial aspects of sea buckthorn oil in in vivo experiments. Although many observations are based on animal studies, there have also been trials in humans (Table 4).

7. Medicines and health products from sea buckthorn

Various forms of medicines and health products based on sea buckthorn are available in China: (I) raw plant materials, such as clear juice, unstrained juice, concentrated juice, fruit oil, seed oil, fruit residual oil, raw powder and pigment; (2) beverages including soft drinks (syrup), nutrient solution and alcoholic drinks, e.g. wine and, beer; (3) cosmetics such as skin care cream, hair shampoo, body lotion and beauty cream; (4) medicines, e.g. (acetylsalicylic) Flavonoid Tablets used to treat ischemic cardiopathy and oil-embolus extractum, as well as capsules for treating ulcer and inflammation (Mingyu et al., 1991).

The fruits are also consumed in other countries as various products such as juices, jams and wines (Beveridge et al., 1999). The fruit of sea buckthorn can be also used to make pies and liquors (Li and Hu, 2015). The ripe fruits can be used to make refreshing drinks, the leaves to make tea, and the seeds to make oil (Hu, 2005). In addition, sea buckthorn yellow is a food colorant listed under the China national food additive hygiene standard GB 2760-2011 (Li and Hu, 2015).

8. Conclusion

Sea buckthorn is a unique plant with great medical value. Various parts, especially the fruit, are sources of many bioactive compounds with antioxidant, anti-platelet, anti-cancer, anti-bacterial and antiviral activities (Christaki, 2012). Its nutritional and medicinal potential make it a functional food. In addition, sea buckthorn oil contains a unique range of compounds (Suryakumar and Gupta, 2011; Xu et al., 2011; Malinowska and Olas, 2016; Olas, 2016a, 2016b; Zielinska and Nowak, 2017).

In vivo and in vitro studies have found the bioactive elements present in sea buckthorn oils to have cardioprotective properties and to protect against cardiovascular diseases via a range of mechanisms, such as reducing plasma LDL concentration, inhibiting platelet activation and ameliorating oxidative stress. In addition, its preventive properties against cardiovascular disorders have been attributed to its high unsaturated fatty acid content and range of constituent phytosterols, especially beta-sitosterol.

Although the cardioprotective action of the oil on humans is not well known, these properties could be clarified by animal studies and in vitro trials. Therefore, further well-controlled and high-quality studies based on human subjects are required to determine the prophylactic and therapeutic doses of sea buckthorn oil for use in later clinical studies. Further studies are also needed to understand the various beneficial properties of the oil, such as those regarding cancer and cardiac disease, from the mechanistic point of view.

The oil also has high concentrations of palmitoleic acid, which is a major component of skin fat, and contains a number of other lipophilic and hydrophilic compounds, whose other properties and clinical potential remain the subject of further experiments. Future research may open the way to more effective use of sea buckthorn oil as a cosmetic, i.e. in treatment of dermatosis or other skin diseases, or as a nutraceutical in the general promotion of health.

References

Alasalvar, C., Bolling, B.W., 2015. Review of nut phytochemicals, fat-soluble bioactives, antioxidant components and health effects. Br. J. Nutr. 113, S68–S78.
Baell, J.B., Walters, M.A., 2014. Chemical con artists foil drug discovery. Nature 518, 481–483.
Bal, L.M., Meda, V., Naik, S.N., Satya, S., 2011. Sea buckthorn berries: a potential source of valuable nutrients for nutraceuticals and cosmeceuticals. Food Res. Int. 44 (1781-1727).
Ballabh, B., Chausais, O.P., 2007. Traditional medicinal plants of cold desert Ladakh-used in treatment of cold, cough and fever. J. Ethnopharmacol. 112, 34–349.
Banas, J., 2013. Zwyczajny- niezwyczajny. Niezwykła Piekarska Przyroda i formy jej ochrony. Eko-Dodatek 1–2.
Basu, M., Prasad, R., Jayamurthy, P., Pal, K., Arumughan, C., Sawhney, R.C., 2007. Anti-atherogenic effects of seabuckthorn (*Hippophaea rhamnoides*) seed oil. Phytomedicine 14, 770–777.
Bekker, N.P., Glushenkowa, A.I., 2001. Components of certain species of Elaeagnaceae family. Chem. Nat. Compd. 37, 97–116.
Beveridge, T.H.J., 2007. Chemical components contribute to the therapeutic claims. In: Li, T.S.C., Beveridge, T.H.J. (Eds.), Sea Buckthorn: A New Medicinal and Nutritional Botanical 6. Agriculture and Agri-Food Canada, pp. 50–53.
Beveridge, T.H.J., Li, T.S.C., Dave Oomah, B., Smith, A., 1999. Sea buckthorn products: manufacture and composition. J. Agric. Food Chem. 47, 3480–3488.
Beveridge, T.H.J., Li, T.S.C., Drover, J.C.G., 2002. Phytosterol content in American ginseng seed oil. J. Agric. Food Chem. 50, 744–750.
Bialek, A., Bialek, M., Jelinska, M., Tokarz, A., 2016. Fatty acid profile of new promising unconventional plant oils for cosmetic use. Int. J. Cosmet. Sci. 38, 382–388.
Bisson, J., McAlpine, J.B., Frisen, J.B., Chen, S.N., Graham, J., Pauli, G.F., 2016. Can invalid bioactives undermine natural product-based drug discover? J. Med. Chem. 59, 1671–1690.
Cakir, A., 2004. Essential oil and fatty acid composition of the fruits of Hippophae rhamnoides L. (Sea buckthorn) and Myrytus communis L. from Tyrkey. Biochem. Syst. Ecol. 32, 809–816.
Chauhan, A.S., Negi, P.S., Ramteke, R.S., 2007. Antioxidant and antibacterial activities of aqueous extract of seabuckthorn (*Hippophae rhamnoides*) seeds. Fitoterapia 78, 590–592.
Cheng, J., Kondo, K., Suzuki, Y., Ikeda, Y., Meng, X., Umemura, K., 2003. Inhibitory effects of total flavones of *Hippophae rhamnoides* L. on thrombosis in mouse femoral artery and in vitro platelet aggregation. Life Sci. 72, 2263–2271.
Christaki, E., 2012. Hippophae rhamnoides L (Sea buckthorn): a potential source of nutraceuticals. Food Pub. Health 2, 69–72.
ClinicalTrials.gov, 2017. A Service of the U.S. National Institutes of Health. 〈http://clinicaltrials.gov〉.
Cotoras, M., Vinaco, H., Melo, R., Aguirre, M., Silva, E., Mendoza, L., 2014. In vitro and in vivo evaluation of the antioxidant and prooxidant activity of phenolic compounds obtained from grape (*Vitis vinifera*) pomace. Molecules 19, 21154–21167.
Czaplicki, S., Ogrodowska, D., Zadernowski, R., Konopka, I., 2017. Effect of se buckthorn (Hippophae rhamnoides L.) pulp oil consumption on fatty acids and vitamin A and E accumulation in adipose tissue and liver of rats. Plant Foods Hum. Nutr. 72, 198–204.
Diandong, H., Feng, G., Zaifu, L., Helland, T., Wixin, F., Liping, C., 2016. Sea buckthorn (Hippophae rhamnoides L.) oil protects against chronic stress-induced inhibitory function of natural killer cells in rats. Int. J. Immunopathol. Pharmacol. 29, 76–83.
Ding, J., Ruan, C.J., Guan, Y., Sham, J.Y., Li, H., Bao, Y.H., 2016. Characterization and identification of ISSR markers associated with oil content in sea buckthorn berries. Genet. Mol. Res. 15.
Dogra, R., Tyagi, S.P., Kumar, A., 2013. Efficacy of sea buckthorn (Hippophae rhamnoides) oil vis-a-vis other standard drugs for management of gastric ulceration and erosions in dogs. J. Vet. Inter. Med. 1–11.
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, 1–12.
EFSA, 2009. Opinion of the scientific panel on dietetic products, nutrition and allergies on a request from the commission related to labelling reference intake values for n-3 and n-6 polyunsaturated fatty acids. EFSA J. 1176, 1–11.
Fatima, T., Snyder, C.L., Schroeder, W., Cram, D., Datla, R., Wishart, D., Weselake, R.J., Krishma, P., 2012. Fatty acid composition of developing sea buckthorn (Hippophae rhamnoides L.) berry and the transcriptome of the mature seed. PLoS One 7, 1–18.
Fu, L., Su, H., Li, R., Cui, Y., 2014. Harvesting technologies for sea buckthorn fruit. Eng. Agric. Environ. Food 7, 64–69.
Fukumoto, L.R., Mazza, G., 2000. Assessing antioxidant and prooxidant activities of phenoic compounds. J. Agric. Food Chem. 48, 3597–3604.
Gao, S., Guo, Q., Qin, C., Shang, R., Zhankg, Z., 2017. Sea buckthorn fruit oil extract alleviates insulin resistance through the PI3K/Akt signaling pathway in type 2 diabetes mellitus cells and rats. J. Agric. Food Chem. 65, 1328–1336.
Gao, X., Ohlander, M., Jeppsson, N., Bjork, L., Trajkovski, V., 2000. Changes in antioxidant effects and their relationship to phytonutrients in fruits of sea buckthorn (*Hippophae rhamnoides* L.) during maturation. J. Agric. Food Chem. 48, 1485–1490.
George, S.D., Cenkowski, S., 2007. Influence of harvest time on the quality of oil-based compounds in sea buckthorn (Hippophae rhamnoides L. ssp. sinensis) seed and fruit. J. Agric. Food Chem. 55, 8054–8061.
Guo, X., Yang, B., Cai, W., Du, L., 2017. Effect of sea buckthorn (Hippophae rhamnoides L.) on blood lipid profiles; a systematic review and meta-analysis from 11

independent randomized controlled trials. Trends Food Sci. Technol. 61, 1–10.
Gupta, A., Upadhyay, N.K., 2011. Sea buckthorn (Hippophe rhamnoides L.) seed oil: usage in bums, uclers, and mucosal injuries. In: Preedy, V.R., Watson, R.R., Patel, V.B. (Eds.), Nut and Seeds in Healthy and Disease Prevention 120. Elsevier, pp. 1011–1018.
Gurevich, S.K., 1956. The application of sea buckthorn oil on ophthalmology. Vesttn. Ottomologu 2, 30–33.
Hagerman, A.E., Riedl, K.M., Jones, G.A., Sovik, K.N., Ritchared, N.T., Hartzfeld, P.W., Riechel, T.L., 1998. High molecular weight plant polyphenolics (tannins) as biological antioxidants. J. Agric. Food Chem. 46, 1887–1892.
Hasani-Ranjbar, S., Jouyandeh, Z., Abdollahi, M., 2013. A systemic review of anti-obesity medicinal plants – an update. J. Diabetes Metab. Disord. 12, 1–10.
Hsu, Y.W., Tsai, C.F., Chen, W.K., Lu, F.J., 2009. Protective effects of seabuckthorn (Hippophae rhamnoides L.) seed oil against carbon tertrachloride-induced hepatotoxicity in mice. Food Chem. Toxicol. 47, 2281–2288.
Hu, S., 2005. *Hippophae rhamnoides* L. – Sea buckthorn, shaji. In: Food Plants of China, The Chinese University Press, p. 572.
Istrati, D., Lacatusu, I., Bordei, N., Badea, G., Oprea, O., Stefan, L.M., Stan, R., Badea, N., Meghea, A., 2016. Phyto-mediated nanostructured carriers based on dual vegetable actives involved in the prevention of cellular damage. Mater. Sci. Eng. C 64, 249–259.
Jiang, Y., Zhou, Y., Bi, C., Li, J., Yang, J., Yu, Z., Hu, Z., Zhao, S., 1993. Research on the clinical effects of sea buckthorn oil on hyperlipaemia. Hippophae 6, 23–24.
Johansson, A.K., Korte, H., Yang, B., Stanley, J.C., Kallio, H.P., 2000. Sea buckthorn berry oil inhibits platelet aggregation. J. Nutr. Biochem. 11, 491–495.
Kallio, H., Yang, B., Peippo, P., 2002. Effects of different origins and harvesting time on vitamin C, tocopherols, and tocotrienols in sea buckthorn (Hippophae rhamnoides) berries. J. Agric. Food Chem. 50, 6136–6142.
Kasparavicience, G., Briedis, V., Ivanauskas, L., 2004. Influence of sea buckthorn oil production technology on its antioxidant activity. Medicina 40, 753–757.
Korekar, G., Stobdan, T., Singh, H., Chaurasia, O., Singh, S., 2011. Phenolic content and antioxidant capacity of various solvent extracts from seabuckthorn (*Hippophae rhamnoides* L.) fruit pulp, seeds, leaves and stem bark. Acta Aliment. 40, 449–458.
Korekar, G., Dolkar, P., Singh, H., Srivastava, R.B., Stobdan, T., 2013. Genotypic and morphometric effect on fruit oil content in seventeen natural population of seabuckthorn (Hippophae rhamnoides L.) from trans-Himalaya. Natl. Acad. Sci. Lett. 36, 603–607.
Kumar, R., Kumar, G.P., Chaurasia, O.P., Singh, S., 2011. Phytochemical and pharmacological profile of seabuckthorn oil: a review. Res. J. Med. Plant 5, 491–499.
Larmo, P.S., Jarvien, R.L., Setala, N.L., Yang, B., Viitanen, M.H., Engblom, J.R., Tahvonen, R.L., Kallio, H.P., 2010. Oral sea buckthorn oil attenuates tear film osmoloarity and symptoms in individuals with dry eye. J. Nutr. 140, 1462–1468.
Lavinia, S., Gabi, D., Drinceanu, D., Daniela, D., Stef, D., Daniela, M., Julean, C., Romana, T., Corionovoschi, N., 2009. The effect of medicinal plants and plant extracted oils on broiler duodenum morphology and immunological profile. Rom. Biotechnol. Lett. 14, 4606–4614.
Lee, S.K., Kader, A.A., 2000. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biol. Technol. 20, 207–220.
Lehtonen, H.M., Suomela, J.S., Tahvonen, R., Yang, B., Venojarvi, M., Kallion, H., 2011. Different berries and berry fractions have various but slightly positive effects on the associated variables of metabolic diseases on overweight and obese women. Eur. J. Clin. Nutr. 65, 394–401.
Li, R.J., Tian, J.J., Li, W.Q., Cheng, F.Q., Gao, G.S., 2014. Effect of 2-amino-1-methyl-6-phenylimidazo [4, 5-b] pyridine on oxidative stress and gene expression of c-fos, c-jun, p16 and Rb in rat colons and protective role of seabuckthorn seed oil. J. Environ. Sci. Health Part B 49, 279–289.
Li, T.S.C., Schroeder, W.R., 1996. Sea buckthorn (*Hippophae rhamnoides* L.): a multipurpose plant. Hort Technology 6, 370–380.
Li, T.S.C., Beveridge, T.H.Y., Drover, J.C.G., 2007. Phytosterol content of sea buckthorn (Hippophae rhamnoides L.) seed oil: extraction and identification. Food Chem. 101, 1633–1639.
Li, Y., Hu, C., 2015. Hippophae rhamnoides L. (Shaji, Common Sea-buckthorn). In: Liu, Y., Wang, Z., Zhang, J. (Eds.), Dietary Chinese Herbs: Chemistry, Pharmacology and Clinical Evidence 46. Springer Science and Business Media, pp. 411.
Malinowska, P., Olas, B., 2016. Sea buckthorn – valuable plant for health. Kosmos 2, 285–292.
Michel, T., Destandan, E., Le Floch, G., Lucchesi, M.E., Elfakir, C., 2012. Antimicrobial, antioxidant and phytochemical investigations of sea buckthorn (*Hippophae rhamnoides* L.) leaf, stem, root and seed. Food Chem. 131, 754–760.
Mingyu, X., Xiaoxuman, S., Jinhua, C., 1991. The medicinal research and development of seabuckthorn. J. Water Soil Conserv. China 1–11.
Negi, P.S., Chauhan, A.S., Sadia, G.A., Rohinishree, Y.S., Ramteke, R.S., 2005. Antioxidant and antibacterial activities of various seabuckthorn (*Hippophae rhamnoides* L.) seed extracts. Food Chem. 92, 119–124.
Niesteruk, A., Lewandowska, H., Golub, Z., Swislocka, R., Lewandowski, W., 2013. Zainteresujmy się rokitnikiem. Preparaty z rokitnika zwyczajnego (Hippophae rhamnoides L.) jako dodatki do żywności oraz ocena ich rynku w Polsce. Kosmos 4, 571–581.
Olas, B., 2016b. The multifunctionality of berries toward blood platelets and the role of berry phenolics in cardiovascular disorders. Platelets 1–10.
Olas, B., 2016a. Sea buckthorn as a source of important bioactive compounds in cardiovascular diseases. Food Chem. Toxicol. 97, 199–204.
Olas, B., Kontek, B., Malinowska, P., Żuchowski, J., Stochmal, A., 2016. Hippophae rhamnoides L. fruits reduce the oxidative stress in human blood platelets and plasma. Oxid. Med. Cell. Longev. 1–8.
Przybyłowicz, M., 2011. Zastosowanie oleju rokitnikowego w kosmetologii. Biotechnologia.pl.
Purushothaman, J., Suryakumar, G., Shukla, D., Malhotra, A.S., Kasiganesan, H., Kumar, R., Sawhney, R.C., Chami, A., 2008. Modulatory effects of sea buckthorn (Hippophae rhamnoides L.) in hypobaric hypoxia induced cerebral vascular injury. Brain Res. Bull. 77, 246–252.
Ranjith, A., Kumar, K.S., Venugopalan, V.V., Arumughan, C., Sawhney, R.C., Singh, V., 2006. Fatty acids, tocols, and carotenoids in pulp oil of three sea buckthorn species. (*H. rhamnoides, H. salicifolia, and H. tibetana*) grown in the India Himalayas. JAOCS 88, 359–364.
Ruan, A., Min, H., Meng, Z., Lu, Z., 2003. Protective effects of seabuckthron seed oil on mouse injury induced by sulfur dioxide inhalation. Inhal. Toxicol. 15, 1053–1058.
Sajfratova, M., Lickova, I., Wimmerova, M., Sovova, H., Wimmer, Z., 2010. B-Sitosterol: supercritical carbon dioxide extraction from sea buckthorn (Hippophae rhamnoides L.) seeds. Int. J. Mol. Sci. 11, 1842–1850.
Sea Buckthorn, 2017. Available online: 〈https://examine.com/supplements/sea-buckthorn/〉 (Accesses on 11 October 2017).
Shi, H.L., Cai, H.J., Chen, X.Y., Yang, C.M., 1994. Studies on the antioxidative effects of Hippophae rhamnoides L. seed oil. Acta Nutr. Sin. 3, 292–295.
Shi, J., Wang, L., Lu, Y., Ji, Y., Dong, K., Kong, X., Sun, W., 2017. Protective effects of seabuckthorn pulp and seed oils against radiation-induced acute intestinal injury. J. Radiat. Res. 58, 24–32.
Suchal, K., Bhatia, J., Malik, S., Malhotra, R.K., Gamad, N., Goyal, S., Nag, T., Arya, D.S., Ojha, S., 2016. Seabuckthorn pulp oil protects against myocardial ischemia-reperfusion injury in rats through activation of Akt/eNOS. Front. Pharmacol. 7, 1–12.
Suryakumar, G., Gupta, A., 2011. Medicinal and therapeutic potential of Sea buckthorn (*Hippophae rhamnoides* L.). J. Ethnopharmacol. 138, 268–278.
Teleszko, M., Wojdylo, A., Rudzinska, M., Oszmiański, J., Golis, T., 2015. Analysis of lipophilic and hydrophilic bioactive compounds content in sea buckthorn (*Hippophae rhamnoids L.*) berries. J. Agric. Food Chem. 63, 4120–4129.
The Plant List version 1.1 〈www.theplantlist.org〉 (Accessed November 2017).
The State of Pharmacopoeia Commission of P.R. China, 1977. Pharmacopeia of the People's Republic of China 1997, Beijing.
Tian, J.S., Liu, C.C., Xiang, H., Zheng, X.F., Peng, G.J., Zhang, X., Du, G.H., Qin, X.M., 2015. Investigation of the antidepressant effect of sea buckthorn seed oil through the GC-MS-based metabolomics approach coupled with multivariate analysis. Food Funct. 6, 3585–3592.
Upadhyay, N.K., Kumar, R., Mandotra, S.K., Meena, R.M., Siddiqui, M.S., Sawhney, R.C., Gupta, A., 2009. Safety and wound healing efficacy of sea buckthorn (Hippophae rhamnoides L.) seed oil in experimental rats. Food Chem. Toxicol. 47, 1146–1153.
Veskouis, A.S., Kyparos, A., Nikolaidis, M.G., Stagos, D., Aligiannis, N., Halabalaki, M., Chronis, K., Goutzourelas, N., Skaltsounis, L., Kouretas, D., 2012. The antioxidant effects of a polyphenol-rich grape pomace extract in vitro do not correspond in vivo using exercise as an oxidant stimulus. Oxid. Med. Cell. Longev. 185867.
Wang, Y., Zhao, L., Huo, Y., Zhou, F., Wu, W., Lu, F., Yang, X., Guo, X., Chen, P., Deng, Q., Ji, B., 2016. Protective effect of proanthocyanidins from sea buckthorn (Hippophae rhamnoides L.) seed against visible light-induced retinal degeneration in vivo. Nutrients 8, 1–13.
Xing, J., Yang, B., Dong, Y., Wang, B., Wang, J., Kallio, H.P., 2002. Effects of sea buckthorn (*Hippophaë rhamnoides L.*) seed and pulp oils on experimental models of gastric ulcer in rats. Fitoterapia 73, 644–650.
Xu, Y.J., Kaur, M., Dhillon, R.S., Tappia, P.S., Dhalla, N.S., 2011. Health benefits of sea buckthorn for the prevention of cardiovascular diseases. J. Funct. Foods 3, 2–12.
Yang, B., Kallio, H., 2002. Composition and physiological effects of sea buckthorn (Hippophae) lipids. Trends Food Sci. Technol. 13, 160–167.
Yang, B., Kallio, H.P., 2001. Fatty acid composition of lipids in sea buckthorn (Hippophae rhamnoides L.) berries of different origins. J. Agric. Food Chem. 1939–1947.
Yang, B., Kalimo, K.O., Mattila, L.M., Kallio, S.E., Katajisto, J.K., Kallio, H.P., 1999. Effects of dietary supplementation with sea buckthorn (Hippophae rhamnoides) seed and pulp oils on atopic dermatitis. J. Nutr. Biochem. 10, 622–630.
Yang, B., Kalimo, K.O., Tahvonen, R.L., Mattila, L.M., Katajisto, J.K., Kallio, H.P., 2000. Effect of dietary supplementation with sea buckthorn (Hippophae rhmanoides) seed and pulp oils on the fatty acid composition of skin glyceophospholipids of patients with atopic dermatitis. J. Nutr. Biochem. 11, 338–340.
Yang, B., Karlsson, R.M., Oksman, P.H., Kallio, H.P., 2011. Phytosterols in sea buckthorn (Hippophae rhamnoides L.) berries: identifications and effects of different origins and harvesting times. J. Agric. Food Chem. 49, 5620–5629.
Zeb, A., 2006. Anticarcinogenic potential of lipids from hippophae – evidence from the recent literature. Asian Pac. J. Cancer Prev. 7, 32–34.
Zeb, A., 2011. Sea buckthorn (Hippophae rhamnoides L. sp. Turkestanica) seeds: chemical and physiochemical properties. In: Preedy, V.R., Watson, R.R., Patel, V.B. (Eds.), Nut and Seeds in Healthy and Disease Prevention 120. Elsevier, pp. 1011–1018.
Zeb, A., Ullah, S., 2015. Sea buckthorn seed oil protects against the oxidative stress produced by thermally oxidized lipids. Food Chem. 186, 6–12.
Zielinska, A., Nowak, I., 2017. Abundance of active ingredients in sea-buckthorn oil. Lipids Health Dis. 16, 1–11.