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Review

Sea Buckthorn Oil—A Valuable Source for Cosmeceuticals

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Abstract: Sea buckthorn (*Hippophae rhamnoides* L., *Elaeagnaceae*.) is a thorny shrub that has small, yellow to dark orange, soft, juicy berries. Due to hydrophilic and lipophilic ingredients, berries have been used as food and medicine. Sea buckthorn (SB) oil derived from berries is a source of valuable ingredients for cosmeceuticals. The unique combination of SB oil ingredients, in qualitative and quantitative aspects, provides multiple benefits of SB oil for internal and external use. Externally, SB oil can be applied in both healthy and damaged skin (burns or skin damage of different etiology), as it has good wound healing properties. Due to the well-balanced content of fatty acids, carotenoids, and vitamins, SB oil may be incorporated in cosmeceuticals for dry, flaky, burned, irritated, or rapidly ageing skin. There have been more than 100 ingredients identified in SB oil, some of which are rare in the plant kingdom (e.g., the ratio of palmitoleic to γ-linolenic acid). This review discusses facts related to the origin and properties of SB oil that make it suitable for cosmeceutical formulation.

Keywords: *Hippophae rhamnoides* sea buckthorn oil; fatty acids; cosmetics; human health; wound healing; anti-aging properties

1. Introduction

Sea buckthorn (SB) (*Hippophae rhamnoides* L.) is a thorny, soil-adhering, deciduous shrub or small tree [1,2]. It is naturally found in Northern and Central Europe, Caucasus, and Asia (Siberia, China, and Tibet). Since it has been recognized as a highly valuable plant, SB has been cultivated in different parts of the world, including many countries in Europe, Canada, Russia, and China. [1,3,4]. It is an anti-erosive plant that enhances the soil content since its roots have nitrogen-fixing properties [1–3]. In natural habitats, it may reach up to 4 m in height [3].

The aim of this review is to discuss the use of sea buckthorn oil, pricipally for cosmetological purposes, in the light of its rich chemical composition. SB oil can be obtained from two parts of the plant-seed or pericarp. Triglycerides, the main constituents of SB oil, due to their fatty acid content (Table 1), are responsible for maintaining the hydration of epidermis by creating an occlusive film on the skin [5,6].

Table 1. Composition of fatty acids in sea buckthorn (SB) oil.

Common Name	Systematic Name	Content in wt %	General Formula	Numerical Symbol	Omega Family
		saturated fatty acids			
palmitic acid	hexadecanoic acid	30–33	$CH_3(CH_2)_{14}COOH$	C16:0	-
stearic acid	octadecanoic acid	<1	$CH_3(CH_2)_{16}COOH$	C18:0	-
		unsaturated fatty acids			
palmitoleic acid	(Z)-9-hexadecenoic acid	30–35	$C_{16}H_{30}O_2$	C16:1	7
oleic acid	(Z)-9-octadecenoic acid	14–18	$C_{18}H_{34}O_2$	C18:1	9
linoleic acid (LA)	(Z,Z)-9,12-octadecadienoic acid	5–7	$C_{18}H_{32}O_2$	C18:2	6
α-linolenic acid (ALA)	(Z,Z,Z)-9,12,15- octadecatrienoic acid	30	$C_{18}H_{30}O_2$	C18:3	3
γ-linolenic acid (GLA)	(Z,Z,Z)-6,9,12- octadecatrienoic acid	35	$C_{18}H_{30}O_2$	C18:3	6
gondoic acid	(Z)-11-eicosenoic acid	2	$C_{20}H_{38}O_2$	C20:1	9

1.1. Botanical Features

The name of genus *Hippophae* comes from two Greek words—"*hippo*", which means horse, and "*phaos*", which means to shine; the leaves of this plant were used in ancient times as horse fodder, which gave the horses a shiny coat [3,7]. It belongs to the Elaeagnaceae family and should not be mistaken with the buckthorns of the Rhamnaceae family—*rhamnus* (lat.) means thorny. Sea buckthorn is also known as Siberian pineapple, sandthorn, sallowthorn, and seaberry. [7].

The bark is smooth and sometimes cracked, is either brown or black, and has silvery lines [7,8]. The leaves are narrow and lanceolate with silvery-green upper faces covered by hairs underneath. The fruit is a round berry, varying in color from pale yellow or orange to red. The berries ripen in September but may stay on the branches the whole winter. The seed is brown, shiny, and has a smooth surface [3,8,9]. The fruit tastes very sour, with a slight bitterness, and has a faint odor [3].

The specificity of this shrub is that it may withstand extremes in temperature, from −43 to +40 °C. It is considered an air-pollution-, drought- and frost-tolerant plant [3,8]. Fruit is widely exploited due to its hydrophilic and lipophilic ingredients that are beneficial for human health, but harvesting sea buckthorn fruit is difficult because of the dense thorn arrangement among the berries. The only way to obtain the fruit is often to remove the entire branch of the shrub. This is the reason why berries can be harvested only once every two years [1–3].

1.2. Methods for Obtaining the SB Oil

SB oil may be extracted in the process of the mechanical cold pressing of seeds, which contain up to 12.5 wt % of oil. The oil is obtained by extraction or in the cold pressing of fruit pulp, which contains 8–12 wt % of oil. The obtained fractions are filtered. The whole process is shown in Figure 1 [10].

The two types of oils differ significantly in terms of appearance and properties. The oil obtained from juicy berries is a thick, dark orange or red-orange liquid with a characteristic smell and a sour taste if it is pressed from the fruit. Both oils contain a wide range of essential unsaturated fatty acids (UFAs), in particular palmitoleic acid (C16:1), which is highly valued in cosmetology. Of all vegetable oils, SB fruit oil has the highest concentration of palmitoleic acid (ω-7) at 30–35 wt %, which is not as high as that of SB seed oil [8]. Both oils abound in tocopherols, tocotrienols, and plant sterols. Unlike seed oil, pulp oil has a high concentration of carotenoids [11].

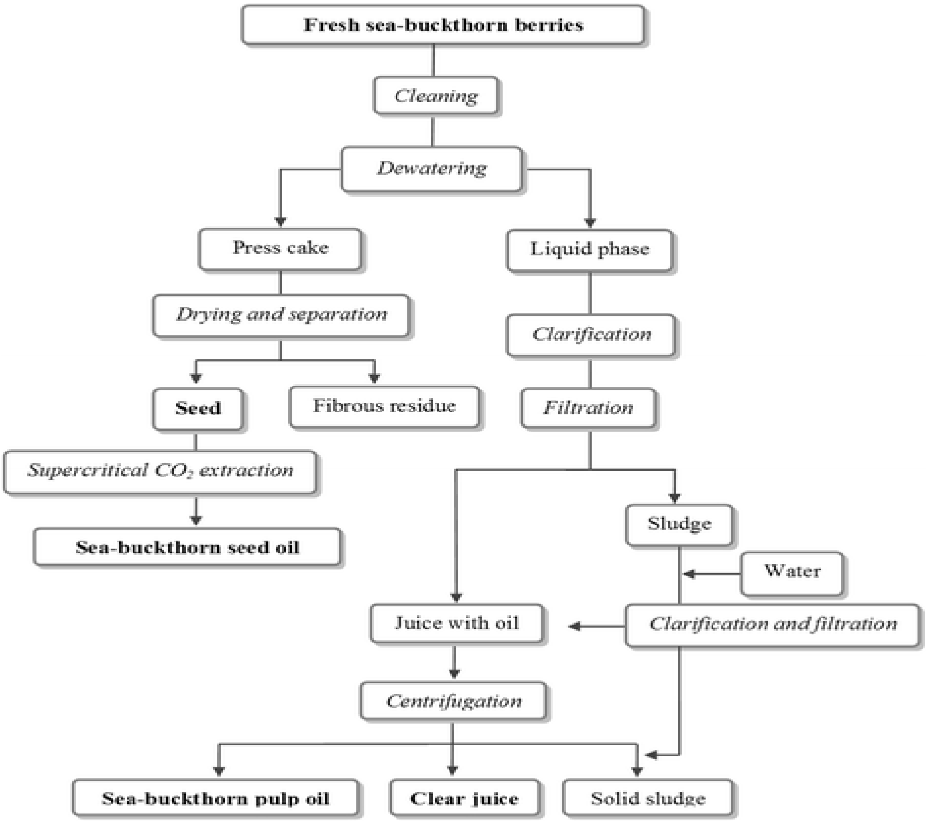

Figure 1. Method for processing SB berries.

Cenkowski et al. (2006) compared different extraction methods in terms of how they affect the quality of SB oil by measuring the amount of fatty acids, tocopherols, carotenoids, and sterols. Petroleum-ether extraction consistently recovered oils with higher amounts of all analyzed nutritional components [12]. Yang and Kallio (2002) suggested that solvent extraction is not suitable for SB oil extraction because harmful solvent residues can be left behind in the extracted oil, which contributes to environmental pollution [13]. Aqueous extraction and screw pressing methods are limited by the type of material (seeds vs. pulp) that can be processed, as shown in Table 2 [14]. The supercritical CO_2 method was flexible in extracting both seed and pulp oils, with relatively high concentrations of all identified nutritional compounds. The addition of co-solvents with CO_2 may enhance selectivity for extracting additional nutritional components [12].

Table 2. The effect of screw press and aqueous extraction methods on changes of nutritional components in oils (the order of increasing concentration: low < high < highest).

Oil Components		**Extraction Method**	
		Screw Press	**Aqueous**
Seed oil	fatty acids	similar concentrations for most fatty acids	
	tocopherols	low	n/a *
	carotenoids	low	n/a
	sterols	high	n/a
Pulp oil	fatty acids	similar concentrations for most fatty acids	
	tocopherols	n/a	high
	carotenoids	n/a	high
	sterols	n/a	low

* n/a = not applicable, no oil extracted.

2. Sea Buckthorn Berries-Chemical Composition

Reports estimate between 100 and 200 ingredients present in the whole plant. Thus, *Hippophae rhamnoides* has a long history of application as food and medicine [3].

There have been around 14 vitamins identified in sea buckthorn berries, including vitamin A, C, D, E, F, K, P, and B complex vitamins (B_1, B_2, B_6) [15,16]. Vitamin C is present in very high amounts (up to 900 mg%). In comparison with citric fruits, sea buckthorn berries have about a 14-fold higher amount of vitamin C than oranges [17–19]. The amount of vitamin C is conditioned by the variety of the plant and its geographical location. Sea buckthorn growing in the coastal parts of Europe may contain 120–315 mg% of vitamin C in fresh fruit, while that growing in the Alps may contain up to 405–1100 mg% [19–22].

The berries contain vitamin E (110–160 mg%), vitamin A (up to 60 mg%), and B vitamins ($B_1{}^{-}$ up to 0.035 mg%, $B_2{}^{-}$ up to 0.056 mg%, and $B_6{}^{-}$ up to 0.079 mg%) [17–21,23]. The amount of carotenoids is high. The amount of beta-carotene may be 40–100 mg%, while other carotenoids (lycopene, cryptoxanthin, physalien, and zeaxanthin) may reach 180–250 mg% [24–26]. The fruits contain phenolic (salicylic, p-coumaric, m-coumaric, p-hydroxyphenyl lactic acid, and gallic acid) and amino acids, sugars, numerous minerals (Table 3), and flavonoids (flavan-3-ols, catechin, epicatechin, gallocatechin, epigallocatechin, kaempferol, quercetin, isorhamnetin, myricetin, rutin, and proanthocyanidins) [17–19,21–23]. Zadernowki et al. (2005) determined the composition of phenolic acids in several varieties of sea buckthorn berries. Salicylic acid was the principal phenolic acid, accounting for 55–74.3% of the total phenolic acids present. The phenolic acids liberated from esters and glycosidic bonds constituted the majority of the phenolic acids in the berries, whereas the free phenolic acids constituted only up to 2.3% of the total phenolic acids present [27].

Berries are the richest source of lipids. They are located in fruit (the pericarp) or in seed. Both types of fatty oil isolated either from fruits or seeds are rich in liposoluble vitamins and plant sterols [28]. Depending on the plant origin, the harvesting time, and the method of oil isolation, the composition of fatty oil from fruits may vary [29,30]. Both qualitative and quantitative content of fatty acids (FAs) may differ in SB oil depending if the oil is from fruits or from seeds, being up to 8 wt % from the fruits and up to 12.5 wt % from the seeds [16,17]. The concentration of C16 FAs is higher in the pericarp fruit oil, while concentration of C18 FAs is higher in the seed oil [29,30]. There have been 8 FAs reported in the pericarp oil: myristic, palmitic, palmitoleic, stearic, oleic, linoleic, arachidic, and α-linolenic acids. Seed oil has two additional acids—lauric and pentadecanoic. Both oils are rich in UFAs, but pericarp oil is richer in monounsaturated fatty acids (MUFAs), while the seed oil is richer in polyunsaturated fatty acids (PUFAs). The quantitative concentrations of palmitic, palmitoleic, and oleic acids in pericarp oil are as follows: 35.2%, 28,5%, and 29.9%, respectively; in the seed oil, quantitative concentrations of oleic, linoleic, and α-linolenic acids are as follows: 23.7%, 37.6%, and 20.5%, respectively [28].

Table 3. Composition and significance of micronutrients and macronutrients in fruits (wt %).

Micronutrients			Macronutrients				
potassium	magnesium	calcium	iron	zinc	manganese	copper	nickel
168–219	8.3–9.5	5–7.2	1.24	0.25	0.25	0.006	0.015
affects muscle spasms	with calcium is responsible for the proper functioning of the nervous system	for the proper functioning of the muscular system	component of hemoglobin, myoglobin and coenzymes many enzymes involved, among others, in the formation of ATP	participates in various stages of protein biosynthesis, ingredient of insulin (also plays an important role in the storage of the pancreas), regulates the concentration of vitamin A is used in the formation of bone, stimulates growth and tissue repair (wound healing)	necessary for proper development of tissue (especially bone) and for the functioning of the central nervous system	cofactor of many enzymes	component of urease - an enzyme decomposing urea into ammonia and carbon dioxide

3. Lipophilic Profile of SB Oil

PUFAs present in SB oil are as follows: ά-linolenic acid (ω-3) C18:3 (30 wt %), γ-linolenic acid (ω-6) C18:3 (35.5 wt %), linoleic acid (ω-6) C18:2 (5–7 wt %); while the MUFAs present are as follows: oleic acid (ω-9) C18:1 (14–18 wt %) and eicosanoic acid (ω-9) C20:1 (2 wt %) [8,29,31].

3.1. Unsaturated Fatty Acids

UFAs, as colorless liquids with double bonds, are mostly in a *cis* configuration [8]. It was observed that UFAs improve skin structure, appearance and tone by multiple synergistic effects, such as plasma circulation enhancement of necessary nourishment and oxygen to skin, and removal of toxin excess. UFAs exert their effects after reaching deeper skin layers and are converted to prostaglandins [32].

The presence of γ-linolenic acid (GLA) assures the proper transport of nutrients and it is a building material of intracellular cement and skin cell membranes phospholipids [8,29]. The lack or insufficiency of GLA may cause skin dryness, rigidity, and susceptibility to lesions. It was observed that skin allergies, inflammations, infections, and the ageing process may be attenuated by the skin penetration of GLA from SB oil [30,32]. SB oil has been used as a source of GLA, even in the oral treatment of atopic dermatitis [33].

Linoleic acid (LA), as an ω-6 acid and a constituent of intracellular cement, has been shown to play a role in cellular regeneration and regulation of the skin sebaceous glands function. Supplementation with LA is used in oily and problematic skin care since it unblocks pores and lowers the number of blackheads. A decrease in LA level was observed in patients with acne prone skin [8]. The significance of LA and ά-linolenic acid present in SB oil is that these acids cannot be produced by the human body, while other UFAs found in SB oil (GLA, oleic acid, and palmitoleic acid) may in fact be produced by the body under certain conditions [12,31].

3.2. Saturated Fatty Acids

Most saturated fatty acids (SFAs) possess straight hydrocarbon chains with an even number of carbon atoms (usually 12–22 carbon atoms) [34]. The main function of SFAs in skin metabolism is to provide adequate turgor, firmness, smoothness, and softness of the skin. They enhance a protective barrier role of the skin by an occlusion effect and consequently block transepidermal water loss [5,35].

SFAs present in SB oil are basically nourishing ingredients but may also serve for the stabilization of SB oil, as they prolong its resistance to oxidation [12].

The following SFAs were identified in SB oil: lauric acid (C12:0), myristic acid (C14:0), pentadecanoic acid (C15:0), palmitic acid (C16:0), stearic acid (C18:0), and arachidic acid (C20:0). The concentration of palmitic and stearic acid was determined as 30–33 wt % and <1 wt %, respectively [16,17].

3.3. Complex Lipids

Complex lipids found in SB oil are phospholipids, glycolipids, and sterols [8].

3.3.1. Phospholipids and Glycolipids

Phospholipids, as fatty acid esters of glycerol or sphingosine as a base, have one or more fatty acids attached together with a phosphate group and an alcohol linked to it. The fatty acid part of the molecule is hydrophobic, while the rest is hydrophilic [36]. These lipids, with a moisturizing and softening skin effect, are known to improve elasticity of the skin, reduce inflammation, and promote skin regeneration and cell renewal [37]. Lecithin or phosphatidylcholine is characterized by moisturizing and cell renewal properties, delays the aging process, and may help removing excessive sebum from the hair. According to the literature data, there is a range from 0.2–0.5 to 1 wt % of phospholipids in the SB oil from fruit pericarp (of which about 5.8 wt % is lecithin) [8].

3.3.2. Sterols

Sterols are solid alcohols of the steroid group [16]. They strengthen the lipid barrier of the skin, protect the skin from external noxious substances, and decrease the water loss, improving skin elasticity and firmness. The sterols in SB oil may originate from the seed (0.1–0.2%) or from the pericarp (0.02–0.04%) [29]. Beta-sitosterol as a main sterol compound makes up 57–83 wt % of total sterols and 576.9 mg/100 g of oil [38]. There has been 60–70% of sitosterol in SB oil from the seeds and 80% of sitosterol in SB oil from the fruit pericarp. Isofructosterol is present in concentrations of 10–20% in SB seed oil and of 2–5% in the SB fruit pericarp oil. Campesterol, stigmasterol, citrostadienol, avenasterol, cycloartenol, and obtusifoliol have also been identified in the seed oil [29,39].

This complex lipid composition makes SB oil suitable for cosmetics and cosmeceuticals [37].

4. Internal Application of Sea Buckthorn Benefits for Human Health

Sea buckthorn fruits have been used in ancient Indian, Chinese, and Tibetan medicine for dysfunctions of alimentary, respiratory, and circulatory system. SB oil used internally has positive effects on the digestive system lowering inflammation. Oral application is adjuvant in the treatment of gastric, duodenal, and intestinal ulcer [8,40]. It has been shown to reduce inflammation processes in the vagina and cervix [41]. A high amount of vitamin C makes it suitable for immune deficiencies; due to its antioxidant activity, it removes free radicals and strengthens the immune system [32,42]. SB oil lowers blood cholesterol, which helps to prevent atherosclerosis [43,44]. At a university in Finland, sea buckthorn was tested and shown to significantly increase the level of beneficial high-density lipoprotein (HDL) cholesterol fraction [17]. It reduces the risk of thrombophlebitis and is enrolled in the control of bleeding [45]. Febrile states respond positively to SB oil [46], as well as symptoms of rheumatoid disease [6]. Some of the lipophilic components ($\acute{\alpha}$- and γ-linolenic acids) of SB oil positively influence brain functions and the central nervous system by an antidepressant effect [47]. Its advantage as an adjuvant in cancer therapy is that fastens regeneration after use of chemotherapy. The favoring feature of SB oil is that it is considered safe, with no potential harmful effects. It can be consumed by pregnant and breastfeeding women [8].

The suggested pharmaceutical form that would be ideal for the application of SB oil are capsules, because of the problem with rancidity (presence of unsaturated fatty acids) [5]. Different fractions of SB fruits were investigated for antioxidant activity and its relationship to different phytonutrients. The capacity of the crude extracts, such as the phenolic and ascorbate extracts, to scavenge radicals decreased significantly with increased maturation. The antioxidant capacity of the lipophilic extract increased significantly and corresponded to the increase in total carotenoids [48].

5. External Application of Sea Buckthorn Benefits for Human Health

In comparison to other vegetable oils, SB oil is considered to have a unique composition of carotenoids, fatty acids, and complex lipids [23,31].

SB oil contains a rare palmitoleic acid (ω-7 acid), a component of skin lipids, that stimulates regenerative processes in the epidermis and promotes wound healing. In other words, the oil has the ability to activate physiological skin functions for minimizing scars and skin regeneration. The proposed mechanisms of action of SB oil are the stimulation of epidermis regeneration and collagen synthesis, so SB oil was found to stimulate wound healing, even healing of necrotic tissue [5,49]. These mechanisms have been connected to the content of unsaturated ω-3 and ω-6 fatty acids, carotenoids, and tocopherols, which stimulate fibroblast proliferation, collagen biosynthesis, and expression of specific matrix metalloproteinases that induce tissue reparation and angiogenesis [50]. Preparations containing SB oil have been found to promote wound healing. In the presence of liquid crystals, SB oil may exhibit wound healing even in a lower concentration [51].

SB oil has been used in the treatment of different skin diseases (e.g., eczema, dermatoses, ulceration, psoriasis, and atopic dermatitis). Externally applied SB oil may also reduce bedsores, spots, acne, scars, discoloration, and allergic and inflammatory lesions of the skin [33,52].

SB Oil in Cosmetics

SB oil used in cosmetics has been obtained by different processes and is intended for the treatment of mature skin [5,12]. One of the ways to obtain lipids for cosmetics is to squeeze berries in order to obtain the juice that separates into three layers. The upper layer is a thick orange cream, the middle is a mixture of UFAs and SFAs, and the lower layer is watery juice. The two upper layers have been processed and used for making skin care products [26,29].

Both SFAs and UFAs in SB oil improve the level of skin hydration. Ω fatty acids-oleic acid as ω-9, linoleic acid as ω-6, and ά-linolenic acid as ω-3 acid reduce transdermal water loss [53,54]. UFAs are part of the receptors that stimulate the production of skin barrier lipids and proteins—precursors of the natural hydrating factor [33]. Research has shown that the one-time application of creams consisting of natural emollients (such as SB oil or olive oil, both in concentrations of 40%) lead to a statistically significant increase in skin hydration, compared to creams with the same quantity of synthetic emollient (such as isopropyl myristate). None of the formulations change pH values of the skin [50,55].

Components of SB oil reach different layers of epidermis, due to the presence of fatty acids with various properties that enhance dermal transportation [32]. SB oil, as a powerful antioxidant, may delay the aging process by removing free radicals. Most commonly, it is added to anti-aging and anti-wrinkle cosmetics due to its firming and tonifying properties for aging skin [5]. Hwang et al. (2012) suggested a sea buckthorn fruit blend against skin aging, because it functions by regulating moisture content, matrix metalloproteinase expression levels, and superoxide dismutase (SOD) activity [56]. SB oil alleviates dry, irritated, rough, flaking, and itchy skin [57]. Skin damage caused by exposure to UV radiation or X-rays is successfully treated with SB oil due to its high concentration of carotenoids and tocopherols [58]. It can also be used as an adjuvant therapy for skin alterations caused by chemical compounds [5].

SB oil is often used in different cosmetic procedures (peelings, baths, masks, hair removal, etc.) due to its smoothing effect on the skin [8]. It strengthens hair, so it has been used in shampoos, conditioners, and other hair products, targeting the recovery of the damaged hair, elasticity restoration, and the prevention of hair loss. Intensive color of the oil is due to its carotenoid concentration, which makes skin more elastic after cutaneous applications [8,59].

6. Conclusions

Hippophae rhamnoides is a plant that has been researched in different fields—biotechnology, nutraceutical, pharmaceutical, cosmetic, and environmental sciences. Berries of sea buckthorn contain fatty oil. A complex but well-balanced composition of lipids and other ingredients of SB oil makes it suitable for cosmetics and especially for cosmeceuticals.

As the mechanisms of action by which the external application of SB oil achieves medical benefits have been increasingly specified, this natural substance has become more valuable in cosmeceuticals. Use of SB oil may lead to an increased number of possible formulations, which may in turn lead to improved auxiliary treatments of different skin diseases.

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References

1. Wang, R.; Zong, S.X.; Yu, L.F.; Lu, P.F.; Luo, Y.Q. Rhythms of volatile release from female and male sea buckthorn plants and electrophysiological response of sea buckthorn carpenter moths. *J. Plant Interact.* **2014**, *9*, 763–774. [CrossRef]
2. Fu, L.; Su, H.; Li, R.; Cui, Y. Harvesting technologies for sea buckthorn fruit. *Eng. Agric. Environ. Food* **2014**, *7*, 64–69. [CrossRef]
3. Li, T.S.C. Product development of sea buckthorn. In *Trends in New Crops and New Uses*; Janick, J., Whipkey, A., Eds.; ASHS Press: Alexandria, VA, USA, 2002; pp. 393–398.
4. Bartish, I.V.; Jeppsson, N.; Nybom, H.; Swenson, U. Phylogeny of hippophae (elaeagnaceae) inferred from parsimony analysis of chloroplast DNA and morphology. *Syst. Bot.* **2002**, *27*, 41–54.
5. Zielińska, A.; Nowak, I. Fatty acids in vegetable oils and their importance in cosmetic industry. *Chem. Aust.* **2014**, *68*, 103–110.
6. Isayev, J.I.; Karimov, Y.B.; Kazimov, H.A. New technology of sea-buckthorn oil extraction. *Azerbaijan Med. J.* **2005**, *2*, 7–9.
7. United States Department of Agriculture. *PLANTS Profile for Hippophae rhamnoides L. (seaberry)*; United States Department of Agriculture: Washington, DC, USA, 2007.
8. Zielińska, A.; Nowak, I. Abundance of active ingredients in sea-buckthorn oil. *Lipids Health Dis.* **2017**, *16*, 95. [CrossRef] [PubMed]
9. Korekar, G.; Dolkar, P.; Singh, H.; Srivastava, R.B.; Stobdan, T. Genotypic and morphometric effect on fruit oil content in seventeen natural population of Seabuckthorn (*Hippophae rhamnoides* L.) from trans-Himalaya. *Natl. Acad. Sci. Lett.* **2013**, *36*, 603–607. [CrossRef]
10. Arumughan, C.; Venugopalan, V.V.; Ranjith, A.; Sarinkumar, K.; Mangalagowri, P.; Sawhney, R.C.; Attrey, D.P.; Banerjee, P.K.; Chaurasia, O.P. A novel Green Approach to the Integrated Processing of Sea Buckthorn Berries for Therapeutic and Nutraceutical Values. Indian Patent 648/DEL, 2 June 2006.
11. Arif, S.; Ahmed, S.D.; Shah, A.H.; Hassan, L.; Awan, S.I.; Hamid, A.; Batool, F.L. Determination of optimum harvesting time for Vitamin C, oil and mineral elements in berries sea buckthorn (*Hippophae rhamnoides*). *Pak. J. Bot.* **2010**, *42*, 3561–3568.
12. Cenkowski, S.; Yakimishen, R.; Przybylski, R.; Muir, W.E. Quality of extracted sea buckthorn seed and pulp oil. *Can. Biosyst. Eng.* **2006**, *48*, 309–316.
13. Kallio, H.; Yang, B.; Peippo, P.; Tahvonen, R.; Pan, R. Triacylglycerols, glycerophospholipids, tocopherols, tocotrienols in berries and seeds of two sspecies (ssp.sinensis and mongolica) of sea buckthorn (Hippophaë rhamnoides). *J. Agric. Food Chem.* **2002**, *50*, 3004–3009. [CrossRef] [PubMed]
14. Yakimishen, R.; Cenkowski, S.; Muir, W.E. Oil recoveries from sea buckthorn seeds and pulp. *Appl. Eng. Agric.* **2005**, *21*, 1047–1055. [CrossRef]
15. Chen, L.; Xin, X.; Yuan, Q.; Su, D.; Liu, W. Phytochemical properties and antioxidant capacities of various colored berries. *J. Agric. Food Chem.* **2014**, *94*, 180–188. [CrossRef] [PubMed]
16. Yang, B.; Karlsson, R.M.; Oksman, P.H.; Kallio, H.P. Phytosterols in sea buckthorn (Hippophaë rhamnoides L.) berries: Identification and effects of different origins and harvesting times. *J. Agric. Food Chem.* **2001**, *49*, 5620–5629. [CrossRef] [PubMed]
17. Kallio, H.P.; Yang, B. Health effects of sea buckthorn berries; research and strategies at the university of Turku, Finland. *Acta Hortic.* **2014**, *1017*, 343–349. [CrossRef]
18. Górnaś, P.; Šne, E.; Siger, A.; Segliņa, D. Sea buckthorn (*Hippophae rhamnoides* L.) leaves as valuable source of lipophilic antioxidants: The effect of harvest time, sex, drying and extraction methods. *Ind. Crops Prod.* **2014**, *60*, 1–7. [CrossRef]
19. Kallio, H.; Yang, B.; Peippo, P. Effects of different origins and harvesting time on vitamin C, tocopherols, and tocotrienols in sea buckthorn (Hippophaë rhamnoides) berries. *J. Agric. Food Chem.* **2002**, *50*, 6136–6142. [CrossRef] [PubMed]
20. Yang, B.; Kallio, H. Effects of harvesting time on triacylglycerols and glycerophospholipids of sea buckthorn (Hippophaë rhamnoides L.) berries of different origins. *J. Food. Compos. Anal.* **2002**, *15*, 143–157. [CrossRef]
21. Seglina, D.; Karklina, D.; Ruisa, S.; Krasnova, I. The effect of processing on the composition of sea buckthorn juice. *J. Fruit. Ornam. Plant Res.* **2006**, *14*, 257–263.

22. Rösch, D.; Bergmann, M.; Knorr, D.; Kroh, L.W. Structure−antioxidant efficiency relationships of phenolic compounds and their contribution to the antioxidant activity of sea buckthorn juice. *J. Agric. Food Chem.* **2003**, *51*, 4233–4239. [CrossRef] [PubMed]
23. Zeb, A. Chemical and nutritional constituents of sea buckthorn juice. *Pak. J. Nutr.* **2004**, *3*, 99–106.
24. Selvamuthukumaran, M.; Khanum, F. Development of spiced seabuckthorn [Elaeagnus rhamnoides (L.) a. Nelson syn. *Hippophae rhamnoides* L.] mixed fruit squash. *Indian J. Tradit. Knowl.* **2014**, *13*, 132–141.
25. Pop, R.M.; Weesepoel, Y.; Socaciu, C.; Vincken, J.P.; Gruppen, H.; et al. Carotenoid composition of berries and leaves from six Romanian sea buckthorn (*Hippophae rhamnoides* L.) varieties. *Food Chem.* **2014**, *147*, 1–9. [CrossRef] [PubMed]
26. Stobdan, T.; Korekar, G.; Srivastava, R.B. Nutritional attributes and health application of seabuckthorn (*Hippophae rhamnoides* L.)—A review. *Curr. Nutr. Food Sci.* **2013**, *9*, 151–165. [CrossRef]
27. Zadernowski, R.; Naczk, M.; Czaplicki, S.; Rubinskiene, M.; Szałkiewicz, M. Composition of phenolic acids in sea buckthorn (*Hippophae rhamnoides* L.) berries. *J. Am. Oil Chem. Soc.* **2005**, *82*, 175–179. [CrossRef]
28. Cupara, S.M.; Sobajic, S.S.; Tadic, V.M.; Arsic, I.A.; Djordjevic, S.M.; Runjajic-Antic, D.; et al. Dry sea buckthorn berries (Hippophae rhamnoides L.)-fatty acid and carotene content in pericarp and seed oil. *HealthMed* **2010**, *4*, 789–793.
29. Yang, B.; Kallio, H. Composition and physiological effects of sea buckthorn lipids. *Trends Food Sci. Technol.* **2002**, *13*, 160–167. [CrossRef]
30. Yang, B.; Kallio, H.P. Fatty acid composition of lipids in sea buckthorn (Hippophaë rhamnoides L.) berries of different origins. *J. Agric. Food Chem.* **2011**, *49*, 1939–1947. [CrossRef]
31. Kim, K.B.; Nam, Y.A.; Kim, H.S.; Hayes, A.W.; Lee, B.M. α-Linolenic acid: Nutraceutical, pharmacological and toxicological evaluation. *Food Chem. Toxicol.* **2014**, *70*, 163–178. [CrossRef] [PubMed]
32. Geetha, R.M.; Sai, V.; Singh, G.; Ilavazhagan, M.; Sawhney, R.C. Anti-oxidant and immunomodulatory properties of seabuckthorn (*Hippophae rhamnoides*)—An in vitro study. *J. Ethnopharmacol.* **2002**, *79*, 373–378. [CrossRef]
33. Yang, B.; Kalimo, K.; Mattila, L.; Kallio, S.; Katajisto, J.; Peltola, O.J.; Kallio, H.P. Effects of dietary supplementation with sea buckthorn seed and pulp oils on atopic dermatitis. *J. Nutr. Biochem.* **1999**, *10*, 622–630. [CrossRef]
34. Rustan, A.; Drevon, C. Fatty acids: Structures and properties. *Encycl. Life Sci.* **2005**. [CrossRef]
35. Proksch, E.; Brandner, J.M.; Jensen, J.M. The skin: An indispensable barrier. *Exp. Dermatol.* **2008**, *17*, 1063–1072. [CrossRef] [PubMed]
36. Krejcarová, J.; Straková, E.; Suchý, P.; Herzig, I.; Karásková, K. Sea buckthorn (Hippophae rhamnoides L.) as a potential source of nutraceutics and its therapeutic possibilities—A review. *Acta Vet. Brno* **2015**, *84*, 257–268. [CrossRef]
37. Edraki, M.; Akbarzadeh, A.; Hosseinzadeh, M.; Salehi, A.; Koohi-Hosseinabadi, O. Healing effect of sea buckthorn, olive oil, and their mixture on full-thickness burn wounds. *Adv. Skin Wound Care* **2014**, *27*, 317–323. [CrossRef] [PubMed]
38. Yang, B.; Kallio, H.; Koponen, J.; Tahvonen, R. Free and esterified sterols in seed oil and pulp/peel oil of sea buckthorn (Hippophae rhamnoides L.). In *Biologicaly-Active Phytochemicals*; Pfannhauser, W., Fenwick, R., Khokhar, S., Eds.; The Royal Chemistry Society: Cambridge, UK, 2001; pp. 24–27.
39. Li, T.S.; Beveridge, T.; Drover, J. Phytosterol content of sea buckthorn (Hippophae rhamnoides L.) seed oil: Extraction and identification. *Food Chem.* **2007**, *101*, 1633–1639. [CrossRef]
40. Zhou, Y.; Jiang, J.; Song, Y.; Sun, S. Research on the anti-gastric ulcer effect of sea buckthorn seed oil. *Hippophae* **1994**, *7*, 33–36.
41. Wu, A.R.; Su, Y.C.; Li, J.F.; Liu, Q.L.; Lu, J.X.; Che, X.P.; Qian, C.M. Observation on the clinical effect of sea buckthorn oil suppository on chronic cervicitis. *Hippophae* **1992**, *5*, 22–25.
42. Wang, X.Q.; Hu, Q.H.; Liu, Y.Z.; Zhao, C.; Wu, R.F.; Cui, X.H.; Liu, J.M.; Feng, X.J. Studies on effects of sea buckthorn on humoral immune function of experimental animals. *Ningxia Med. J.* **1989**, *11*, 281–282.
43. Larmo, P.S.; Yang, B.; Hurme, S.A.; Alin, J.A.; Kallio, H.P.; Salminen, E.K.; Tahvonen, R.L. Effect of a low dose of sea buckthorn berries on circulating concentrations of cholesterol, triacylglycerols, and flavonols in healthy adults. *Eur. J. Nutr.* **2009**, *48*, 277–282. [CrossRef] [PubMed]
44. Basu, M.; Prasad, R.; Jayamurthy, P.; Pal, K.; Arumughan, C.; Sawhney, R.C. Anti-atherogenic effects of seabuckthorn (Hippophaea rhamnoides) seed oil. *Phytomedicine* **2007**, *14*, 770–777. [CrossRef] [PubMed]

45. Kumar, R.; Kumar, G.P.; Chaurasia, O.P.; Singh, S.B. Phytochemical and pharmacological profile of seabuckthorn oil: A review. *Res. J. Med. Pl.* **2011**, *5*, 491–499. [CrossRef]
46. Shikov, A.; Pozharitskaya, O.; Makarov, V.; Wagner, H.; Verpoorte, R.; Heinrich, M. Medicinal plants of the Russian pharmacopoeia; their history and applications. *J. Ethnopharmacol.* **2014**, *154*, 481–536. [CrossRef] [PubMed]
47. Uauy, R.; Dangour, A.D. Nutrition in brain development and aging: Role of essential fatty acids. *Nutr. Rev.* **2006**, *64*, 24–33. [CrossRef]
48. Gao, X.; Ohlander, M.; Jeppsson, N.; Björk, L.; Trajkovski, V. Changes in antioxidant effects and their relationship to phytonutrients in fruits of sea buckthorn (Hippophae rhamnoides L.) during maturation. *J. Agric. Food Chem.* **2000**, *48*, 1485–1490. [CrossRef] [PubMed]
49. Ito, H.; Asmussen, S.; Traber, D.L.; Cox, R.A.; Hawkins, H.K.; Connelly, R.; Traberal, L.D.; Walker, T.W.; Malgerud, E.; Sakurai, H.; et al. Healing efficacy of sea buckthorn (Hippophae rhamnoides L.) seed oil in an ovine burn wound model. *Burns* **2014**, *40*, 511–519. [CrossRef] [PubMed]
50. Cupara, S.; Arsic, I.; Homsek, I.; Tadic, V.; Jankovic, S.; Djordjevic, S. Moisturizing effect of o/w oleosom structure creams containing seabuckthorn fatty oil and olive oil. In Proceedings of the 6th World Meeting on Pharmaceutics, Biopharmaceutics and Phramaceutical Technology, Barcelona, Spain, 7–10 April 2008; p. 35.
51. Cupara, S.M.; Ninkovic, M.B.; Knezevic, M.G.; Vuckovic, I.M.; Jankovic, S.M. Wound healing potential of liquid crystal structure emulsion with sea buckthorn oil. *HealthMed* **2011**, *5*, 1218–1223.
52. Yang, B.; Kalimo, K.; Tahvonen, R.; Mattila, L.; Katajisto, J.; Kallio, H. Effects of dietary supplementation with sea buckthorn (*Hippophaë rhamnoides*) seed and pulp oils on the fatty acid composition of skin glycerophospholipids of patients with atopic dermatitis. *J. Nutr. Biochem.* **2000**, *11*, 338–340. [CrossRef]
53. Lee, S.; Gura, K.M.; Kim, S.; Arsenault, D.A.; Bistrian, B.R.; Puder, M. Current clinical applications of Ω-6 and Ω-3 fatty acids. *Nutr. Clin. Pract.* **2006**, *21*, 323–341. [CrossRef] [PubMed]
54. Yen, C.H.; Dai, Y.S.; Yang, Y.H.; Lee, J.H.; Chiang, B.L. Linoleic acid metabolite levels and transepidermal water loss in children with atopic dermatitis. *Ann. Allergy Asthma Immunol.* **2008**, *100*, 66–73. [CrossRef]
55. Cupara, S.; Arsic, I.; Homsek, I.; Tadic, V.; Jevtovic, I.; Petrovic, M. In vivo case study: Investigation of o/w cream containing sea buckthorn oil on skin moisture. In Proceedings of the 7th central European Symposium on Pharmaceutical Technology and Biotechnology, Ljubljana, Slovenia, 18–20 September 2008.
56. Hwang, I.S.; Kim, J.E.; Choi, S.I.; Lee, H.R.; Lee, Y.J.; Jang, M.J. UV radiation-induced skin aging in hairless mice is effectively prevented by oral intake of sea buckthorn (Hippophae rhamnoides L.) fruit blend for 6 weeks through MMP suppression and increase of SOD activity. *Int. J. Mol. Med.* **2012**, *30*, 392–400. [CrossRef] [PubMed]
57. Bath-Hextall, F.J.; Jenkinson, C.; Humphreys, R.; Williams, H.C. Dietary supplements for established atopic eczema. *Cochrane Database Syst. Rev.* **2012**, *2*, CD005205.
58. Korać, R.R.; Khambholja, K.M. Potential of herbs in skin protection from ultraviolet radiation. *Pharmacogn. Rev.* **2011**, *5*, 164–173. [CrossRef] [PubMed]
59. Beveridge, T.; Li, T.S.; Oomah, B.D.; Smith, A. Sea buckthorn products: Manufacture and composition. *J. Agric. Food Chem.* **1999**, *47*, 3480–3488. [CrossRef] [PubMed]