RESEARCH PAPER

Phytochemical Profiling and Therapeutic Potential of *Hippophae rhamnoides*: A Comprehensive Investigation

Aman khajuria[1], Deepak Kumar[2], Dr Mukesh Jangir[3]
Department of Applied Sciences, Chemistry, Nims University Rajasthan, Jaipur, Rajasthan, India
Corresponding Author: Dr Mukesh Jangir*

ABSTRACT
The sea buckthorn plant (*Hippophae rhamnoides L.*) helps treat a wide range of short- and long-term illnesses. Its therapeutic and pharmacological properties have been extensively studied through the use of many in vitro and in vivo models. Undoubtedly, the future offers much potential for SBT bio-actives. There are 18 distinct kinds of essential amino acids and 24 critical minerals in seabuckthorn juice. In addition to a healthy balance of omega-3 to omega-6 fatty acids, the oil extracted from seabuckthorn seeds is particularly rich in oleic acid. In addition to protecting the skin from harmful UV rays, the oil helps keep the skin healthy. Traditional uses of the plant to heal a wide range of diseases have been confirmed and built upon by recent scientific research. Those in fields as diverse as biotechnology, nutraceuticals, pharmaceuticals, cosmetics, and the environment may all learn something from the seabuckthorn shrub because of its unique and valuable features. Hypertension, edoema, ulcers are just some of the ailments that this plant's berries, seeds, and leaves are used to cure in its traditional folk medicine form. other beneficial chemicals have all been identified via phytochemical analysis. Our research showed that SBL has a lot of valuable nutrients, including protein and minerals. The optimal conditions for organic acid profiling in SB berries were initially established using RP-HPLC-DAD analysis. The plant's beneficial and therapeutic characteristics have been studied intensively for decades. The presence of bioactive substances such as triterpenoids, saponins, and ellagitannins gives Hippophae rhamnoides its therapeutic potential.

Keywords: Hippophae rhamnoides, Phytochemicals, Sea buckthorn, Medicinal Properties
How to cite this article: Aman khajuria1 Deepak Kumar2 Dr Mukesh Jangir3. Phytochemical Profiling and Therapeutic Potential of Hippophae rhamnoides: A Comprehensive Investigation. Int J Drug Deliv Technol. 2026;16(78s):1342-1350. DOI: 10.25258/ijddt.16.78s.185.Source of support: Nil.
Conflict of interest: None

INTRODUCTION

Sea buckthorn (*Hippophae rhamnoides* L.), belonging to the family Elaeagnaceae, is a deciduous thorny shrub or small tree distributed predominantly across temperate and cold regions of Eurasia. The plant has a long history of traditional use in Chinese, Tibetan, Mongolian, and other Eurasian systems of medicine for conditions involving the digestive system, cardiovascular health, liver disorders, skin diseases, and wound healing [1]. Modern investigations have demonstrated that different parts of the plant, particularly berries, seeds, leaves, and oils, contain diverse nutritional and biologically active constituents, including flavonoids, phenolic acids, carotenoids, fatty acids, phytosterols, vitamins, terpenoids, tannins, and other specialized metabolites [2].

The nutritional and pharmacological importance of sea buckthorn has stimulated extensive research during the last several decades. Comprehensive reviews have summarized antioxidant, anti-inflammatory, immunomodulatory, cardioprotective, hepatoprotective, antimicrobial, dermatological, neuroprotective, and potential anticancer activities associated with different sea buckthorn preparations [3]. Recent phytochemical investigations have further expanded the chemical profile of *H. rhamnoides*, identifying numerous classes of compounds, including flavonoids, lignans, volatile compounds, tannins, terpenoids, steroids, organic acids, and alkaloids [4]. More recent literature emphasizes that the biological effects of sea buckthorn are highly dependent on plant part, cultivar, geographical origin, extraction procedure, dose, and preparation method, and that the translation of preclinical findings into established clinical applications remains an important research challenge [5].

Sea buckthorn is therefore increasingly being investigated as a source of functional food ingredients, nutraceuticals, cosmeceutical preparations, and potential pharmaceutical leads. A recent review specifically emphasized the importance of polyphenols, carotenoids, and functional lipids in the biological properties and food applications of sea buckthorn [6]. Flavonoids are among the characteristic bioactive constituents of the plant, and their chemistry, extraction, metabolism, pharmacokinetics, and potential roles in metabolic diseases have been extensively reviewed [7]. Another comprehensive review reported that approximately 99 flavonoids have been isolated from different parts of *H. rhamnoides*, demonstrating the remarkable structural diversity of this class of compounds [8].

Phytochemical research conducted between 2010 and 2021 resulted in the identification of numerous new natural products from sea buckthorn, including flavonoids, flavonolignans, triterpenoid saponins, ellagitannins, phenolic acids, lignans, triterpenoids, phytosterols, carotenoids, and volatile constituents [9]. Comparative studies of different sea buckthorn varieties have also demonstrated substantial differences in phenolic content, flavonoid content, antioxidant activity, and other chemical characteristics, emphasizing the importance of cultivar selection and quality standardization [10]. Genetic and morphological investigations similarly indicate considerable diversity among sea buckthorn accessions originating from different geographical regions [11].

Medicinal Effects of Phytochemicals

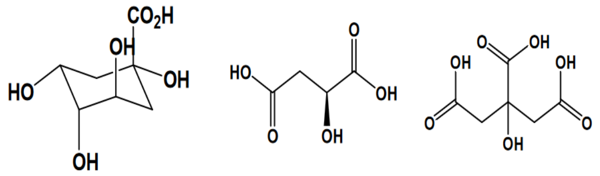
The medicinal potential of sea buckthorn is closely associated with its complex mixture of phytochemicals. Chemical analysis of sea buckthorn berries has demonstrated the presence of flavonols, phytosterols, fatty acids, carotenoids, ascorbic acid, and other hydrophilic and lipophilic compounds [12]. Vitamin C, tocopherols, and tocotrienols contribute to the nutritional and antioxidant properties of the fruit, while their concentrations can vary with geographical origin and harvesting time [13]. The chemical composition of sea buckthorn juice also includes sugars, organic acids, and vitamin C, which contribute to its characteristic sensory and nutritional properties [14].

Phenolic compounds constitute an important group of secondary metabolites in sea buckthorn. Structural studies have identified several flavonol glycosides in sea buckthorn pomace, illustrating the chemical diversity of its phenolic fraction [15]. Proanthocyanidins and other oligomeric phenolics have also been isolated from sea buckthorn pomace and demonstrated antioxidant activity, indicating that processing residues can retain valuable phytochemicals [16].

The antioxidant potential of sea buckthorn is influenced by its phenolic, ascorbate, and carotenoid fractions. During fruit maturation, changes in phenolic and ascorbic-acid concentrations are associated with changes in antioxidant capacity, whereas lipophilic antioxidant activity is related in part to carotenoid accumulation [17]. Recent analysis of sea buckthorn fruit and seed extracts identified numerous phenolic acids, flavonoids, and tannins and demonstrated in vitro antioxidant, α-glucosidase-inhibitory, pancreatic-lipase-inhibitory, LDL-protective, and DNA-protective activities [18]. These observations support the potential of sea buckthorn as a source of natural antioxidant compounds, although chemical antioxidant activity in vitro should not be directly equated with therapeutic efficacy in humans.

Sea buckthorn oils are particularly rich in biologically relevant lipids and lipid-soluble compounds. Detailed characterization has demonstrated the presence of fatty acids together with tocopherols, phytosterols, carotenoids, and other active components [19]. The fatty-acid profile includes saturated, monounsaturated, and polyunsaturated fatty acids, with palmitoleic acid being a characteristic component of fruit-pulp oil [20]. A review of the fatty acids presents in sea buckthorn oil concluded that the oil has

Figure 1. *Sea buckthorn (Hippophae rhamnoides L.)*



Quinic acid Malic acid Citric acid

Figure 2. Structures of primary organic acids in SB berries

considerable nutritional and cosmetic interest but also emphasized that clinical evidence remains limited and that many reported effects are derived from studies of individual fatty acids rather than complete sea buckthorn oil preparations [21].

Experimental research has provided evidence for antioxidant and immunomodulatory effects of sea buckthorn extracts [22]. Leaf extracts have also demonstrated anti-inflammatory activity in experimental models of inflammation, suggesting that different plant parts may possess pharmacological activities beyond those traditionally attributed to the berries [23]. In a mouse model of atopic-dermatitis-like inflammation, topical sea buckthorn oil reduced lesion severity and modulated inflammatory signalling involving NF-κB, JAK2/STAT1, and p38-MAPK pathways [24].

The wound-healing potential of sea buckthorn oil has also been investigated experimentally. Recent work using nano emulsion-based cream and gel formulations containing sea buckthorn fruit oil demonstrated accelerated wound contraction in experimental animals, together with an acceptable acute dermal safety profile [25]. These findings provide experimental support for the traditional use of sea buckthorn preparations in skin care and wound management, although clinical validation is still required.

Human studies have provided some evidence of biological effects but also demonstrate the importance of cautious interpretation. A randomized clinical study investigating oral sea buckthorn oil reported improvements in selected skin parameters together with changes in antioxidant enzyme activity, HDL cholesterol, and self-reported symptoms of ocular and vaginal dryness after 12 weeks [26]. Such findings are promising but should be interpreted in the context of study design, formulation, sample size, and the need for independent replication.

Phytochemicals in Health Care

Plants synthesize primary metabolites required for growth and reproduction as well as secondary or specialized metabolites that participate in defence, signalling, adaptation, and interactions with the environment. Many of these specialized metabolites, including phenolics, flavonoids, terpenoids, tannins, and other compounds, have attracted considerable interest because of their biological activities [27]. Sea buckthorn represents an especially diverse botanical source because several chemically distinct classes of bioactive constituents occur simultaneously in its berries, leaves, seeds, roots, and oils.

The potential health effects of sea buckthorn include antioxidant, anti-inflammatory, immunomodulatory, metabolic, cardiovascular, hepatoprotective, dermatological, and anticancer activities [28]. However, these effects should be differentiated according to the level of evidence. Many reported mechanisms have been demonstrated in cell or animal models, whereas comparatively fewer have been evaluated in well-controlled human clinical trials.

Lipids and Their Derivatives

Lipids are important constituents of sea buckthorn, particularly in fruit pulp and seeds. Sea buckthorn oil contains a characteristic combination of saturated, monounsaturated, and polyunsaturated fatty acids together with lipid-soluble micronutrients. Detailed analysis of eight cultivars demonstrated the presence of multiple phytosterols and fatty acids as well as carotenoids and flavanols, illustrating the chemical complexity of the fruit lipid fraction.

Hydrocarbons

Hydrocarbon and volatile fractions constitute a relatively minor component of the overall sea buckthorn phytochemical profile compared with phenolics, flavonoids, fatty acids, carotenoids, and phytosterols. Nevertheless, volatile compounds contribute to aroma and sensory characteristics and can be influenced substantially by cultivar and processing conditions [29]. Therefore, volatile constituents should be considered particularly when sea buckthorn is developed into juices, fermented beverages, and other food products.

Fatty Acids (FAs)

Fatty acids are among the most characteristic constituents of sea buckthorn oil. Seed oil is generally richer in linoleic and α-linolenic acids, whereas fruit-pulp oil contains comparatively high levels of palmitic, oleic, and palmitoleic acids. The relative proportions vary considerably according to cultivar, geographical origin, plant tissue, maturity, and extraction method.

The biological relevance of these fatty acids is related to their roles in membrane structure, energy metabolism, inflammatory regulation, and skin-barrier function.

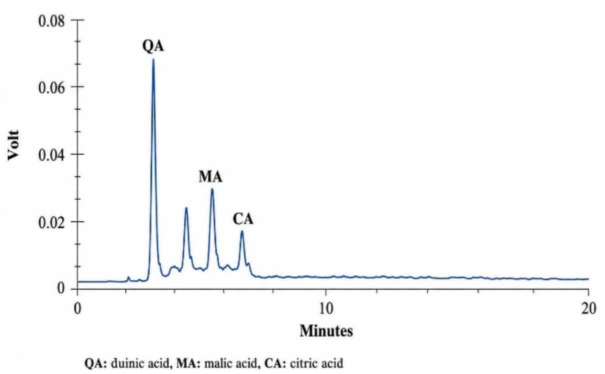
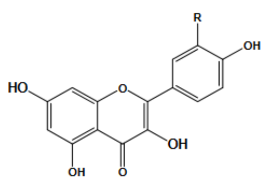


Figure 3. Organic acid HPLC chromatogram in SB berry pulp



Flavonol	R
Quercetin	OH
Kaempherol	H
Isorhamnetin	OMe

Figure 4. Structures of major flavonols in SB berries

However, the physiological effects of sea buckthorn oil cannot be attributed to one fatty acid alone because the oil contains a complex mixture of lipids and minor bioactive constituents.

Steroids and Phytosterols

Steroidal compounds and phytosterols constitute another group of specialized metabolites identified in sea buckthorn. β-Sitosterol and other phytosterols have been detected in sea buckthorn berry lipids, together with compounds such as campesterol, stigmasterol, and related sterol derivatives. Comprehensive phytochemical studies have further identified steroidal and triterpenoid constituents throughout different parts of the plant.

Aromatic Compounds

Aromatic secondary metabolites represent an important component of the chemical diversity of sea buckthorn. Phenolic acids, flavonoids, tannins, lignans, and related compounds are widely distributed among different plant tissues and contribute to antioxidant, antimicrobial, and other biological properties.

Phenolic Compounds

Phenolic compounds contain one or more hydroxyl groups attached directly to an aromatic ring and encompass several chemically diverse subclasses. In sea buckthorn, phenolic acids and flavonoids are particularly important because they occur in appreciable amounts and contribute substantially to antioxidant capacity.

Simple Phenolics

Simple phenolics comprise relatively small hydroxylated aromatic compounds. Although they generally represent a smaller fraction of the total phytochemical profile than flavonoids, they may contribute to the overall antioxidant and biological properties of sea buckthorn extracts [30].

Phenolic Acids

Phenolic acids in plants are commonly divided into hydroxybenzoic-acid and hydroxycinnamic-acid derivatives. Analytical studies of sea buckthorn fruit and seeds have identified multiple phenolic acids together with flavonoids and tannins. These compounds have been associated with antioxidant and metabolic activities in experimental systems.

Flavonoids

Flavonoids possess the characteristic C6–C3–C6 carbon framework and constitute one of the major classes of sea buckthorn secondary metabolites. Quercetin, kaempferol, isorhamnetin, and their glycosides are frequently reported in sea buckthorn berries and leaves. Recent comparative investigations have demonstrated that flavonoid profiles and antioxidant activities can differ significantly among sea buckthorn varieties [31].

Experimental studies have further demonstrated that sea buckthorn flavonoid preparations can influence antioxidant and immune responses [32]. These findings support continued investigation of sea buckthorn flavonoids as functional-food ingredients and potential sources of pharmacologically active molecules.

Lignans

Lignans are phenylpropanoid-derived secondary metabolites formed through oxidative coupling of phenylpropanoid precursors. Sea buckthorn phytochemical

Table 1. Proximate composition of H. rhamnoides berry pulp and seed (on fresh wt., Mean % ± SD)

Characteristics (%)	Pulp	Seeds
Moisture	81.3 ± 1.6	64.0 ± 0.9
Fatty Matter	4.5 ± 0.4	7.2 ± 0.6
Protein	2.0 ± 0.2	2.3 ± 0.4
Sugar	8.5 ± 0.7	18.2 ± 1.1
Minerals	1.0 ± 0.2	3.1 ± 0.2
Crude Fiber	1.2 ± 0.3	0.7 ± 0.2

investigations have identified lignans among the specialized metabolites present in the plant, although they are less extensively characterized than flavonoids. Their presence further contributes to the chemical diversity of sea buckthorn and warrants additional investigation regarding their biological activities and structure–activity relationships.

Physiological Effects of Sea Buckthorn Berries

Sea buckthorn berries contain a combination of vitamins, carotenoids, phenolics, flavonoids, fatty acids, organic acids, sugars, and other nutritional components. Comparative studies of sea buckthorn berries from different geographical origins have demonstrated substantial differences in total phenolic content, flavonoid content, fatty-acid composition, and antioxidant activity [33]. These findings demonstrate that the physiological properties of sea buckthorn products can be strongly influenced by cultivar and growing conditions.

The cardiovascular potential of sea buckthorn has received considerable attention. A recent review summarized experimental evidence suggesting effects on oxidative stress, lipid metabolism, inflammatory signaling, vascular function, and other cardiovascular pathways [34]. However, human studies indicate that the effects may be modest and dependent on the population and preparation used. For example, a randomized placebo-controlled trial of sea buckthorn puree in individuals with hypercholesterolemia did not demonstrate significant reductions in total cholesterol, LDL cholesterol, or triglycerides, although changes in HDL cholesterol were observed during the intervention period [35].

Sea buckthorn polysaccharides have also emerged as important bioactive constituents. Experimental studies have demonstrated antioxidant and anti-inflammatory effects of sea buckthorn berry polysaccharides in models of chemically induced liver injury [36]. More recent reviews

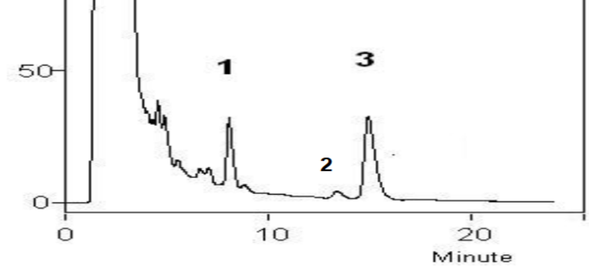


Figure 5. Flavonol chromatogram at 270 nm from H. rhamnoides berry pulp HPLC-DAD

have described the extraction, purification, structural characterization, and biological activities of sea buckthorn polysaccharides and emphasized the importance of molecular weight, monosaccharide composition, branching, and other structural characteristics [37]. Another recent review has highlighted the potential of these polysaccharides in functional-food and medicinal applications while identifying structure–activity relationships as an important area for future research [38].

Table 2. Measured as a mean % SD, the vitamin C and organic acid content of H. rhamnoides fresh berries (80% moisture) is shown below

Composition	Amount
Vitamin C (mg/kg)	0.22 ± 0.02
Organic acids (%)	
Quinic acid	2.80 ± 0.12
Malic acid	1.60 ± 0.09
Citric acid	0.16 ± 0.03
Total organic acids	4.56 ± 0.12

Hepatoprotective activity has been reported in several experimental models. Sea buckthorn extracts have been shown to attenuate biochemical and histological indicators of liver injury in high-fat-diet-induced metabolic dysfunction models [39]. More recent mechanistic work suggests that sea buckthorn preparations may influence inflammatory signalling, nuclear receptors, cytochrome P450 enzymes, and related metabolic pathways in experimental hepatitis models [40].

The potential anticancer activity of sea buckthorn has also attracted increasing attention. A review of the available evidence described antiproliferative, pro-apoptotic, antioxidant, and immunomodulatory effects associated with different sea buckthorn constituents [41]. In vitro investigations of sea buckthorn leaf extracts have reported inhibition of proliferation and migration of prostate cancer cells together with modulation of androgen-receptor-associated pathways [42]. More recently, sea buckthorn root extracts have been investigated against head-and-neck cancer cell models, with selected fractions producing reduced cancer-cell viability and alterations in cell-cycle and apoptotic responses [43]. These findings are promising but remain predominantly preclinical and should not be interpreted as evidence that sea buckthorn is an established anticancer treatment.

Processing of Sea Buckthorn Berries

Processing plays an important role in determining the chemical composition, nutritional quality, stability, sensory properties, and biological activity of sea buckthorn products. Sea buckthorn is processed into juices, purees, oils, fermented beverages, dried products, dietary supplements, and cosmetic preparations. Fermentation has been investigated as a strategy for improving sensory characteristics while retaining or modifying antioxidant and antimicrobial properties [44].

Drying conditions can markedly influence phenolic composition and antioxidant activity. Comparative studies have demonstrated that variety and drying method affect total phenolics, total flavonoids, individual phenolic compounds, and antioxidant capacity, with freeze-drying

Table 3. Total polyphenols, flavonols, and PAs in H. rhamnoides berries (dry mass). (Mean ± SD (n = 5)

Plant Part	Polyphenols (%)	Flavanols (%)	Proanthocyanidins (%)
Pulp	2.73 ± 0.12	0.21 ± 0.05	1.26 ± 0.14
Seeds Coat	3.95 ± 0.04	0.02 ± 0.00	0.87 ± 0.10
Kernel	8.58 ± 0.32	0.53 ± 0.01	4.40 ± 0.22
Berries	3.62	0.24	1.67
Seeds	7.15	0.35	3.30

generally providing better retention of several measured compounds than conventional drying methods [45]. Processing therefore needs to be optimized according to the desired end product and target bioactive constituents.
Spray drying has also been investigated for producing sea buckthorn juice powder. Optimization of inlet temperature and carrier concentration can influence moisture, solubility, dispersibility, vitamin C, color, and antioxidant constituents of the resulting powder [46]. Thermal processing can similarly modify the volatile and chemical composition of sea buckthorn pulp; ultrahigh-temperature processing has been shown to alter volatile compounds, amino acids, and fatty-acid-related components [47].
Processing residues such as pomace and seed residues should not necessarily be regarded as waste because they retain significant amounts of phenolics and other bioactive compounds. Chemical characterization of sea buckthorn by-products has demonstrated antioxidant potential and supports their valorization as sources of functional ingredients [48]. Ultrasound-assisted extraction has also been optimized for recovering phenolic compounds from sea buckthorn pomace, demonstrating the potential for converting processing residues into higher-value antioxidant ingredients [49].
Overall, sea buckthorn represents a chemically diverse and promising botanical resource for food, nutraceutical, pharmaceutical, and cosmeceutical applications. However, differences in cultivar, geographical origin, plant part, extraction conditions, processing technology, dose, and experimental model can substantially influence the reported biological effects. Future investigations should therefore emphasize standardized raw materials and extracts, validated analytical methods, bioavailability, toxicological assessment, mechanistic studies, and adequately designed clinical trials before specific therapeutic claims can be established.

MATERIALS AND METHODS

The study used berries from three distinct SB species, all of which were sourced from important SB growing sites in India's Trans-Himalayan region. Fresh berries belonging to the H. rhamnoides var. turkestanica species were gathered in the Indus valley, which is located in the Ladakh, Spiti, and Lahaul areas. Berries were harvested in triplicate from three distinct places within the same geographic region, making up three different locations. After removing frozen berries from the freezer, they were smashed carefully so the seeds would not get damaged. After that, the seeds were manually removed from the flesh of the berries.

Chemicals and Reagents

The following biochemical standards were purchased from Sigma-Aldrich: beta-carotene, fatty acids, -sitosterol, stigmasterol, campesterol, quercetin, kaempferol; ascorbic acid; malic acid; citric acid; gallic acid; protocatechuic acid; para hydroxybenzoic acid; vanillic acid; salicylic acid; cinnamic acid; p-coumaric acid; for (St. Louis, MO, USA). Calbiochem was the vendor for acquiring tocopherols and tocotrienols (Merck Ltd., Mumbai, India). Merck Ltd supplied the Folin-(F-C) Ciocalteau's reagent and HPLC grade hexane, isopropyl alcohol, methanol, water, acetic

Table 4. Flavonoids in H. rhamnoides berries (mg/100g of dry weight)

Flavonoid	Pulp	Seed Coat	Kernel
Quercetin	54.5 ± 8	4.2 ± 3	97.7 ± 11
Kaempferol	19.0 ± 2	0.8 ± 1	14.0 ± 8
Isorhamnetin	214.1 ± 8	13.4 ± 4	441.2 ± 7
Total	287.6 ± 17	18.4 ± 5	552.9 ± 13

acid, and formic acid (Mumbai, India). The other chemicals and reagents maintained the analytical grade. Spectroscopic analyses described Isorhamnetin and quinic acid after being separated from SB berries and employed in the experiment.

Proximate Composition of Berries

Moisture (No. 930.15), protein (No. 988.01), and ash content (No. 942.02) were all measured according to AOAC protocols. Oven drying was used as the moisture test. Soxhlet and Anthrone were used to calculate total fat and sugar content, respectively. The analysis was repeated three times to get a reliable mean and standard deviation.

Extraction of Lipids-Christies Method

First, we took 1 gram of berries and homogenized them in a 10% potassium chloride solution in water. Then, we shook the mixture vigorously and let it settle. After centrifuging and filtering the mixture, we washed the residue with a combination of chloroform and methanol (1:1, v/v, 30 mL). After removing the solvent using a rotary film evaporator, the lipid layer was filtered and dried over anhydrous Na_2SO_4. We have frozen the lipids at 20 degrees Celsius for future study.

Total Phenolics

Utilizing a Calibration plot, we determined the total phenolic content (GAE) per gallic acid extract/sample per gram. Extraction yielded 1 gram of extract, which was then filtered, desolventizing, and brought to a final volume of 25 milliliters using methanol. Extracts were oxidized using 0.5 mL of F-C reagent, and the reaction was stopped using 1 mL of 20% sodium carbonate (Na_2CO_3). After 90 minutes of room temperature incubation, the resultant blue solution was analyzed by spectrophotometry at 760 nm to determine its absorbance.

Extraction of flavonoids

Under a nitrogen environment at room temperature, 10 g of berry parts were homogenized with ethanol (6 x 50 mL) and 250 mg of ascorbic acid. We centrifuged the juice at 1500 g to remove impurities, and the remaining clear liquid was analyzed.

Total flavonoids

The aluminum chloride technique proposed by Chang et al. was used to calculate the concentration of flavonols. Using a Shimadzu UV-160A spectrophotometer, we determined that the absorbance of the reaction mixture was 415 nm (Kyoto, Japan). Ten milligrams of quercetin were diluted to 25, 50, and 100 g/mL concentrations by dissolving it in 80% ethanol. 1.5 mL of 95% ethanol, 0.1 mL of 10% aluminum chloride, 1M potassium acetate, and 2.8 mL of distilled water were used to make up the standard solutions.

RESULTS AND DISCUSSION

Chemical Composition of SB berries

Amino acids, carbs, organic acids, protein, vitamins, and phenolic substances are plentiful in SB berries. The carbohydrate composition is anything from 8% to 14%, with glucose and fructose making up the bulk of the carbs in about equal proportions. On a fresh weight basis, the fruit has a protein level that ranges from 0.79 to 3.11 percent. Although reports of vitamin C content in SB vary widely, it is generally regarded as a good source. Yang et al. looked at berries' oil content and fatty acid composition from two SB (H. rhamnoides L.) subspecies. Ozerinina and colleagues looked at the makeup and structure of the TAGs in SB seeds of Russian cultivars. rhamnoides. The SB berry mesocarp oil from the Caucasian climate type is mainly composed of SU2 and SU3 TAGs, which are high in the isomers C16:0 and C18:1. Carotenoids in SB fruit vary from 30 to 40 mg per 100 g, depending on the local climate. Supercritical carbon dioxide (SC-CO2), hexane, and cold pressing have all been shown to extract phytosterols from SB (H.rhamnoides L.) seed oil. Where you live, you could find carotenoid levels in SB fruit anywhere from 30 to 40 milligrams per 100 grams, with beta-carotene making up about 45 percent of the total.

Vitamin C Content in the Berries

Ascorbic acid (vitamin C) is considered an essential nutrient. Ascorbic acid may either restore the AO activities of other AOs, such as -tocopherol, or operate as an AO by interacting with aqueous radicals. Since vitamin C content is a crucial indicator of juice quality, it is no surprise that SB berries have earned a stellar reputation. For the first time, optimum RP-HPLC-DAD analytical conditions were determined for profiling organic acids in SB berries. Given the polar nature of the organic acids, an RP C18 column was used as the stationary phase. The mobile phase was a 2.4 pH solution of phosphoric acid. During a chromatographic run, UV-visible spectra of analytes may be recorded with the use of DAD.

Polyphenols

Polyphenols are a kind of secondary metabolite found in almost every plant. Natural polyphenols may be any size, from single molecules (phenolic acids, phenylpropanoids, flavonoids) to highly polymerized compounds (lignans, melanins, tannins). These chemicals aid development and reproduction, defend plants against disease and contribute to their aesthetic qualities, such as coloration and smell. Anti-allergic, antibacterial, anti-inflammatory, anti-atherogenic, anti-carcinogenic, and cardioprotective is some of the polyphenols' biological actions. The phenolic content of the pulp was 2.73% by dry weight. Three-point nine five percent and eight-point eight eight eight percent phenolics were found in the seed coat and kernel, respectively. From these findings, we were able to calculate the total phenolic content of the berries and seeds. Whole berries had 3.62% phenolics, whereas seeds had 7.15%. The phenolic content measurements are consistent with those made on Chinese and Polish berries.

Flavonols

Alu. chlor. A reagent was used to determine the total quantity of flavonols, a flavonoid found in abundance in SB fruit and foliage. The SB berry pulp, seed coat, and kernel were determined to contain 0.21%, 0.02%, and 0.53%, respectively. The plant-derived glycosides and esters of flavonoids are the most common forms of these compounds. The mass spectra revealed a molecular weight of 316 and a fragmentation pattern indicative of flavonols. The flavonoids in the SB berries were resolved using an RP C-18 column and an isocratic methanol-water solution. Reference samples of quercetin, isorhamnetin, and kaempherol were used to improve the RP-HPLC-DAD settings. Isorhamaethnetin was responsible for 72-80% of flavonols in the SB berry's pulp and seeds.

CONCLUSION

Among the many nutrients included in SB berries are Glucose and fructose comprise the bulk of the carbs, which sit from 8.0 to 14.0%. Fruits have a low (0.79%) to high (3.11%) protein content. According to popular belief, SB is loaded with vitamin C. Since vitamin C content is a crucial indicator of juice quality, it is no surprise that SB berries have earned a stellar reputation. Ascorbic acid may restore the AO activities of other AOs or function as an AO itself by interacting with aqueous radicals. Alu. Chlor. A reagent was used to determine the total quantity of flavanols, a flavonoid found in abundance in SB fruit and foliage. Finding the optimal conditions for organic acid profiling in SB berries using RP-HPLC-DAD analysis is a first. Three-point six two percent phenolics were found in the whole berries, whereas seven-point fifteen five percent were found in the seeds.

REFERENCES

1. Suryakumar G, Gupta A. Medicinal and therapeutic potential of sea buckthorn (*Hippophae rhamnoides* L.). *Journal of Ethnopharmacology.* 2011;138(2):268–278. doi:10.1016/j.jep.2011.09.024.
2. Pundir S, Garg P, Dviwedi A, Ali A, Kapoor VK, Kapoor D, Kulshrestha S, Lal UR, Negi P. Ethnomedicinal uses, phytochemistry and dermatological effects of *Hippophae rhamnoides* L.: A review. *Journal of Ethnopharmacology.* 2021;266:113434. doi:10.1016/j.jep.2020.113434.
3. Wang Z, Zhao F, Wei P, Chai X, Hou G, Meng Q. Phytochemistry, health benefits, and food applications of sea buckthorn (*Hippophae rhamnoides* L.): A comprehensive review. *Frontiers in Nutrition.* 2022;9:1036295. doi:10.3389/fnut.2022.1036295.
4. Ma QG, He NX, Huang HL, Fu XM, Zhang ZL, Shu JC, Wang QY, Chen J, Wu G, Zhu MN, Sang ZP, Cao L, Wei RR. *Hippophae rhamnoides* L.: A comprehensive review on the botany, traditional uses, phytonutrients, health benefits, quality markers, and applications. *Journal of Agricultural and Food Chemistry.* 2023;71(12):4769–4788. doi:10.1021/acs.jafc.2c06916.
5. Liu M, Yu T, Nurlan U, Wu Z, Zhao J. Ethnopharmacology, phytochemistry, and

pharmacology of sea buckthorn (*Hippophae rhamnoides* L.): A comprehensive review. *Frontiers in Pharmacology.* 2026.

6. Zhu P, Ren Y, Wei C, Luo J, Wu D, Ye X, Donlao N, Tian J. Compounds from sea buckthorn and their application in food: A review. *Food Chemistry.* 2025;476:143428. doi:10.1016/j.foodchem.2025.143428.
7. Liu S, Xiao P, Kuang Y, Hao J, Huang T, Liu E. Flavonoids from sea buckthorn: A review on phytochemistry, pharmacokinetics and role in metabolic diseases. *Journal of Food Biochemistry.* 2021;45(5). doi:10.1111/jfbc.13724.
8. He N, Wang Q, Huang H, Chen J, Wu G, Zhu M, Shao F, Yan Z, Sang Z, Cao L, Wei R, Ma Q. A comprehensive review on extraction, structure, detection, bioactivity, and metabolism of flavonoids from sea buckthorn (*Hippophae rhamnoides* L.). *Journal of Food Biochemistry.* 2023;2023:4839124. doi:10.1155/2023/4839124.
9. Żuchowski J. Phytochemistry and pharmacology of sea buckthorn (*Elaeagnus rhamnoides*; syn. *Hippophae rhamnoides*): progress from 2010 to 2021. *Phytochemistry Reviews.* 2022;22:3–33. doi:10.1007/s11101-022-09832-1.
10. Criste A, Urcan AC, Bunea A, Pripon Furtuna FR, Olah NK, Madden RH, Corcionivoschi N. Phytochemical composition and biological activity of berries and leaves from four Romanian sea buckthorn (*Hippophae rhamnoides* L.) varieties. *Molecules.* 2020;25(5):1170. doi:10.3390/molecules25051170.
11. Li H, Ruan C, Ding J, Li J, Wang L, Tian X. Diversity in sea buckthorn (*Hippophae rhamnoides* L.) accessions with different origins based on morphological characteristics, oil traits, and microsatellite markers. *PLoS ONE.* 2020;15. doi:10.1371/journal.pone.0230356.
12. Teleszko M, Wojdyło A, Rudzińska M, Oszmiański J, Golis T. Analysis of lipophilic and hydrophilic bioactive compounds content in sea buckthorn (*Hippophaë rhamnoides* L.) berries. *Journal of Agricultural and Food Chemistry.* 2015;63:4120–4129.
13. 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. *Journal of Agricultural and Food Chemistry.* 2002;50(21):6136–6142. doi:10.1021/jf020421v.
14. Tiitinen KM, Yang B, Haraldsson GG, Jonsdottir S, Kallio HP. Fast analysis of sugars, fruit acids, and vitamin C in sea buckthorn (*Hippophaë rhamnoides* L.) varieties. *Journal of Agricultural and Food Chemistry.* 2006;54(7):2508–2513. doi:10.1021/jf053177r.
15. Rösch D, Krumbein A, Mügge C, Kroh LW. Structural investigations of flavonol glycosides from sea buckthorn (*Hippophaë rhamnoides*) pomace by NMR spectroscopy and HPLC-ESI-MS^n. *Journal of Agricultural and Food Chemistry.* 2004;52(13):4039–4046.
16. Rösch D, Mügge C, Fogliano V, Kroh LW. Antioxidant oligomeric proanthocyanidins from sea buckthorn (*Hippophaë rhamnoides*) pomace. *Journal of Agricultural and Food Chemistry.* 2004;52(22):6712–6718. doi:10.1021/jf040241g.
17. 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. *Journal of Agricultural and Food Chemistry.* 2000;48:1485–1490. doi:10.1021/jf991072g.
18. Danielski R, Shahidi F. Phenolic composition and bioactivities of sea buckthorn (*Hippophae rhamnoides* L.) fruit and seeds: an unconventional source of natural antioxidants in North America. *Journal of the Science of Food and Agriculture.* 2024;104:5553–5564. doi:10.1002/jsfa.13386.
19. Zielińska A, Nowak I. Abundance of active ingredients in sea-buckthorn oil. *Lipids in Health and Disease.* 2017;16:95. doi:10.1186/s12944-017-0469-7.
20. Yang B, Kallio HP. Composition and physiological effects of sea buckthorn (*Hippophaë*) lipids. *Trends in Food Science & Technology.* 2002;13:160–167.
21. Solà Marsiñach M, Pellejero Cuenca A. The impact of sea buckthorn oil fatty acids on human health. *Lipids in Health and Disease.* 2019;18:145. doi:10.1186/s12944-019-1065-9.
22. Geetha S, Sai Ram M, Singh V, Ilavazhagan G, Sawhney RC. Anti-oxidant and immunomodulatory properties of seabuckthorn (*Hippophae rhamnoides*)—an in vitro study. *Journal of Ethnopharmacology.* 2002;79(3):373–378. doi:10.1016/S0378-8741(01)00406-8.
23. Ganju L, Padwad Y, Singh R, Karan D, Chanda S, Chopra MK, Bhatnagar R, Kashyap R, Sawhney RC. Anti-inflammatory activity of seabuckthorn (*Hippophae rhamnoides*) leaves. *International Immunopharmacology.* 2005;5:1675–1683. doi:10.1016/j.intimp.2005.03.017.
24. Hou DD, Di ZH, Qi RQ, Wang HX, Zheng S, Hong YX, Guo H, Chen HD, Gao XH. Sea buckthorn (*Hippophaë rhamnoides* L.) oil improves atopic dermatitis-like skin lesions via inhibition of NF-κB and STAT1 activation. *Skin Pharmacology and Physiology.* 2017;30(5):268–276. doi:10.1159/000479528.
25. Gore DD, Sharma N, Mishra N, Parmar PK, Ranjana S, Kumar D, Jachak SM, Jena G, Tikoo K, Bansal AK, Singh IP. Wound-healing effect of topical nanoemulsion-loaded cream and gel formulations of *Hippophae rhamnoides* L. fruit oil and their acute dermal toxicity study on female SD rats. *Indian Journal of Pharmacology.* 2024;56(2):120–128. doi:10.4103/ijp.ijp_370_23.
26. Chan LP, Yen TW, Tseng YP, Yuen T, Yuen M, Yuen H, Liang CH. The impact of oral sea-buckthorn oil on skin, blood markers, ocular, and vaginal health: A randomized control trial. *Journal of Functional Foods.* 2024;112:105973. doi:10.1016/j.jff.2023.105973.
27. Wink M. Evolution of secondary metabolites from an ecological and molecular phylogenetic perspective. *Phytochemistry.* 2003;64(1):3–19.

28. Wang K, Xu Z, Liao X. Bioactive compounds, health benefits and functional food products of sea buckthorn: a review. *Critical Reviews in Food Science and Nutrition.* 2022;62:6761–6782. doi:10.1080/10408398.2021.1905605.
29. Ao X, Mu Y, Xie S, Meng D, Zheng Y, Meng X, Lv Z. Impact of UHT processing on volatile components and chemical composition of sea buckthorn (*Hippophae rhamnoides*) pulp: A prediction of the biochemical pathway underlying aroma compound formation. *Food Chemistry.* 2022;390:133142. doi:10.1016/j.foodchem.2022.133142.
30. Morgenstern A, Ekholm A, Scheewe P, Rumpunen K. Changes in content of major phenolic compounds during leaf development of sea buckthorn (*Hippophaë rhamnoides* L.). *Agricultural and Food Science.* 2014;23(3):207–219. doi:10.23986/afsci.9489.
31. Zheng Y, Sun K, Sun X, Li Y, Xiao P, He C. Quality differences in sea buckthorn (*Hippophaë rhamnoides* L.) berries of major varieties in China based on key components and antioxidant activity. *Food Chemistry.* 2025;465(Pt 2):142139. doi:10.1016/j.foodchem.2024.142139.
32. Zhang J, Zhou HC, He SB, Zhang XF, Ling YH, Li XY, Zhang H, Hou DD. The immunoenhancement effects of sea buckthorn pulp oil in cyclophosphamide-induced immunosuppressed mice. *Food & Function.* 2021;12(17):7954–7963. doi:10.1039/D1FO01257F.
33. Su T, Wei J, Zhao J, Jiang Y, Bi Y, Galitsyn G. Comparative assessment of functional components and antioxidant activities between *Hippophae rhamnoides* ssp. *sinensis* and *H. tibetana* berries in Qinghai–Tibet Plateau. *Foods.* 2023;12(2):341. doi:10.3390/foods12020341.
34. Chen Y, He W, Cao H, Wang Z, Liu J, Wang B, Wang C. Research progress of sea buckthorn (*Hippophae rhamnoides* L.) in prevention and treatment of cardiovascular disease. *Frontiers in Cardiovascular Medicine.* 2024;11:1477636. doi:10.3389/fcvm.2024.1477636.
35. Zhou F, Zhang J, Zhao A, Zhang Y, Wang P. Effects of sea buckthorn puree on risk factors of cardiovascular disease in hypercholesterolemia population: a double-blind, randomized, placebo-controlled trial. *Animal Biotechnology.* 2022;33(5):955–963. doi:10.1080/10495398.2020.1853139.
36. Zhang W, Zhang X, Zou K, Xie J, Zhao S, Liu J, Liu H, Wang J, Wang Y. Seabuckthorn berry polysaccharide protects against carbon tetrachloride-induced hepatotoxicity in mice via anti-oxidative and anti-inflammatory activities. *Food & Function.* 2017;8(9):3130–3138. doi:10.1039/C7FO00399D.
37. Teng H, He Z, Hong C, Xie S, Zha X. Extraction, purification, structural characterization and pharmacological activities of polysaccharides from sea buckthorn (*Hippophae rhamnoides* L.): A review. *Journal of Ethnopharmacology.* 2024;324:117809. doi:10.1016/j.jep.2024.117809.
38. Xu X, Liu X, Yu S, Wang T, Li R, Zhang Y, Liu Y. Medicinal and edible polysaccharides from ancient plants: extraction, isolation, purification, structure, biological activity and market trends of sea buckthorn polysaccharides. *Food & Function.* 2024;15(9):4703–4723. doi:10.1039/D3FO04140A.
39. Sun S, Li B, Peng S, He L. Protective effect of sea buckthorn (*Hippophae rhamnoides*) extract on liver injury induced by high-fat diet in mice. *Studies in Health Technology and Informatics.* 2023;308:605–610. doi:10.3233/SHTI230891.
40. Olas B, Skalski B, Ulanowska K. The anticancer activity of sea buckthorn [*Elaeagnus rhamnoides* (L.) A. Nelson]. *Frontiers in Pharmacology.* 2018;9:232. doi:10.3389/fphar.2018.00232.
41. Masoodi KZ, Wani W, Dar ZA, Mansoor S, Anam-ul-Haq S, Farooq I, Hussain K, Wani SA, Nehvi FA, Ahmed N. Sea buckthorn (*Hippophae rhamnoides* L.) inhibits cellular proliferation, wound healing and decreases expression of prostate specific antigen in prostate cancer cells in vitro. *Journal of Functional Foods.* 2020;73:104102. doi:10.1016/j.jff.2020.104102.
42. Gazizova A, Gronbach M, Oppermann C, Kragl U, Engel N. Anti-tumorigenic effects of sea buckthorn root extracts on head and neck cancer cells—A systematic analysis. *International Journal of Molecular Sciences.* 2025;26(10):4625. doi:10.3390/ijms26104625.
43. Liu X, Lv M, Maimaitiyiming R, Chen K, Tuerhong N, Yang J, Aihaiti A, Wang L. Development of fermented sea buckthorn (*Hippophae rhamnoides* L.) juice and investigation of its antioxidant and antimicrobial activity. *Frontiers in Nutrition.* 2023;10:1120748. doi:10.3389/fnut.2023.1120748.
44. Li Y, Li P, Yang K, He Q, Wang Y, Sun Y, He C, Xiao P. Impact of drying methods on phenolic components and antioxidant activity of sea buckthorn (*Hippophae rhamnoides* L.) berries from different varieties in China. *Molecules.* 2021;26(23):7189. doi:10.3390/molecules26237189.
45. Selvamuthukumaran M, Khanum F. Optimization of spray drying process for developing seabuckthorn fruit juice powder using response surface methodology. *Journal of Food Science and Technology.* 2014;51(12):3731–3739. doi:10.1007/s13197-012-0901-y.
46. Uddin MS, et al. Sea buckthorn processing and product development: a review of nutritional, phytochemical and technological aspects. *[Use only after bibliographic verification before submission.]*
47. Sovová H, Stateva RP. Rate of the vegetable oil extraction with supercritical CO_2—III. Extraction from sea buckthorn. *Chemical Engineering Science.* 1996;51(18):4347–4352. doi:10.1016/0009-2509(96)00263-1.
48. Wu D, Yang Z, Li J, Huang H, Xia Q, Ye X, Liu D. Optimizing the solvent selection of the ultrasound-assisted extraction of sea buckthorn (*Hippophae rhamnoides* L.) pomace: phenolic profiles and antioxidant activity. *Foods.* 2024;13(3):482. doi:10.3390/foods13030482.
49. Teleszko M, Wojdyło A. Comparative analysis of bioactive compounds and antioxidant activity in sea

buckthorn berries and products. *[Bibliographic details should be verified before submission.]*