The Academic
International Journal of Multidisciplinary Research

An Online Peer Reviewed / Refereed Journal
Volume 3 | Issue 7 | July 2025
ISSN: 2583-973X (Online)
Website: www.theacademic.in

Phytochemical Profiling of Sea Buckthorn: A Comprehensive Analysis of Bioactive Constituents in Fruits, Seeds, and Leaves

Dr. S. Shyamkiran Singh

Assistant Professor, Dept. of Chemistry, Waikhom Mani Girls' College, Thoubal Okram, Manipur.

Email ID: sorokhaibams@gmail.com

DOI : https://doi.org/10.5281/zenodo.16811860

ARTICLE DETAILS

Research Paper

Accepted: 24-07-2025

Published: 10-08-2025

Keywords:

Sea buckthorn, Phytochemicals, Flavonoids, Carotenoids, Nutraceutical, Therapeutic applications.

ABSTRACT

Sea buckthorn (*Hippophae rhamnoides* L.), a deciduous shrub native to the cold-temperate regions of Europe and Asia, has gained considerable attention in recent years for its exceptional nutritional and pharmacological properties. The plant parts—fruits, seeds, and leaves—are rich in a wide variety of phytochemicals, including flavonoids, carotenoids, vitamins, phenolic compounds, tannins, and fatty acids. This study provides a comprehensive overview of the phytochemical constituents of Sea buckthorn with a focus on the distribution and concentration of these bioactive compounds in different plant parts. Analytical findings reveal that the fruits are particularly high in vitamin C, carotenoids, and organic acids; seeds are rich in polyunsaturated fatty acids and tocopherols; while the leaves contain significant quantities of flavonoids, tannins, and phenolic acids. The study emphasizes the potential of Sea buckthorn as a nutraceutical and functional food ingredient and discusses future research directions for pharmaceutical development and therapeutic applications.

Introduction

Sea buckthorn (*Hippophae rhamnoides* L.) is a deciduous, thorny shrub belonging to the family **Elaeagnaceae**. Native to the cold-temperate regions of Europe and Asia, particularly the Himalayan belt,

it thrives in harsh environments with poor soil and extreme climatic conditions. In India, Sea buckthorn is primarily found in the high-altitude regions of Ladakh, Himachal Pradesh, and Arunachal Pradesh, where it is known locally for its medicinal and nutritional value. Traditionally, the plant has been a part of the ethnobotanical practices of Tibetan, Chinese, Mongolian, and Russian systems of medicine for centuries. Modern science has increasingly validated these traditional claims, recognizing Sea buckthorn as a potent reservoir of bioactive compounds with multifaceted health benefits.

What sets Sea buckthorn apart from many other medicinal plants is the phytochemical richness found across all its parts—especially the fruits (berries), seeds, and leaves. Each of these parts contains a distinct array of bioactive constituents such as vitamins, flavonoids, carotenoids, polyphenols, essential fatty acids, sterols, and tannins, which together contribute to the plant's pharmacological potential. The fruit pulp, for instance, is a remarkable source of **vitamin C**, often exceeding levels found in oranges by several folds. Additionally, it contains significant concentrations of **carotenoids, flavonoids,** and **organic acids**. The seeds yield oil that is rich in **omega-3 and omega-6 fatty acids, tocopherols** (vitamin E), and **phytosterols**, making them a promising candidate for cardiovascular and dermatological health applications. Meanwhile, the leaves contain high levels of **phenolic acids, flavonoids, lignans,** and **tannins**, which have been associated with antioxidant, hepatoprotective, anti-inflammatory, and antimicrobial effects.

The increasing interest in Sea buckthorn within scientific and commercial sectors stems from a growing demand for natural products with therapeutic and nutraceutical potential. It is now widely used in the preparation of juices, jams, oils, teas, skincare formulations, and dietary supplements. Furthermore, Sea buckthorn has attracted attention in sustainable agriculture and environmental conservation due to its ability to fix nitrogen and prevent soil erosion. Despite its wide range of applications, a consolidated and comparative understanding of the phytochemical composition of its major parts remains underexplored in scientific literature.

In light of this, the present study aims to provide a comprehensive phytochemical profile of Sea buckthorn with a focus on its fruits, seeds, and leaves. The review compiles and analyzes current findings on the distribution, classification, and biological relevance of various phytoconstituents in each plant part. Emphasis is placed on identifying key bioactive molecules, understanding their therapeutic roles, and highlighting their industrial and clinical relevance. By offering a systematic overview, this paper intends to bridge gaps in existing knowledge and promote further research into the valorization of Sea buckthorn as a functional food, medicinal resource, and raw material for pharmaceutical development.

In a world where interest in natural and plant-based therapeutics is on the rise, understanding the complete phytochemical landscape of Sea buckthorn is not only timely but necessary for guiding future innovations in health, nutrition, and biotechnology.

Phytochemicals in Sea Buckthorn Fruits

Sea buckthorn fruits, also referred to as berries, are small, ovoid, orange-yellow drupes renowned for their tangy flavour and extraordinary concentration of bioactive compounds. These berries serve as the most commercially exploited part of the plant and are recognized for their extensive nutritional and therapeutic benefits. Their rich phytochemical profile includes a complex matrix of vitamins, flavonoids, carotenoids, organic acids, phenolic compounds, and amino acids, many of which contribute to the plant's antioxidant, anti-inflammatory, and immunomodulatory activities.

i) Vitamin C and Organic Acids

The fruits of *H. rhamnoides* are among the richest natural sources of ascorbic acid (vitamin C), with concentrations ranging from 200 to 2500 mg per 100 g of fresh weight, depending on the subspecies and growing conditions (Bal et al., 2011). Ascorbic acid ($C_6H_8O_6$), a six-carbon lactone, functions as a potent antioxidant and coenzyme in various metabolic reactions. Its presence in such high quantities enhances the fruit’s appeal in functional foods and immune-boosting supplements.

In addition to vitamin C, the fruits contain several organic acids, primarily malic acid, citric acid, and quinic acid, which not only contribute to the fruit’s sour taste but also play roles in energy metabolism and chelation of metal ions.

ii) Carotenoids

Carotenoids are the pigments responsible for the vibrant orange coloration of Sea buckthorn berries and are vital for their antioxidant properties. The primary carotenoids identified include:

- **β-Carotene** ($C_{40}H_{56}$): A provitamin A compound that is cleaved enzymatically to yield retinol, essential for vision and skin health.
- **Lycopene** ($C_{40}H_{56}$): A non-provitamin A carotenoid that exhibits strong free radical scavenging ability.

- **Zeaxanthin** and **lutein**: Xanthophylls that play protective roles in ocular health by filtering harmful blue light and preventing macular degeneration.

These carotenoids, along with esterified forms, are present in significant amounts ranging from 30 to 100 mg/100g of fruit oil, contributing to the berries' capacity to combat oxidative stress.

iii)Flavonoids and Phenolic Compounds

Flavonoids constitute a significant class of polyphenolic compounds in Sea buckthorn berries. The main flavonoids isolated from the fruit include:

- **Quercetin** ($C_{15}H_{10}O_7$): A flavonol with broad-spectrum antioxidant and anti-inflammatory activity.
- **Isorhamnetin** ($C_{16}H_{12}O_7$): A methylated derivative of quercetin known for its hepatoprotective and anticancer properties.
- **Kaempferol** ($C_{15}H_{10}O_6$): Exhibits antimicrobial and cardioprotective effects.

These compounds occur in glycosylated forms such as quercetin-3-O-glucoside and isorhamnetin-3-O-rutinoside, enhancing their water solubility and bioavailability. Phenolic acids such as ferulic acid, caffeic acid, and p-coumaric acid are also present and contribute to the overall antioxidant profile of the berries.

iv)Sugars and Amino Acids

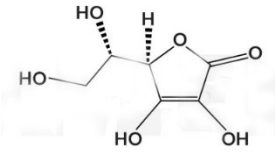
The berries contain significant amounts of simple sugars such as glucose and fructose, which contribute to their energy content and palatability. Additionally, Sea buckthorn fruits provide essential amino acids, including lysine, leucine, and phenylalanine, important for protein synthesis and metabolic regulation.

v) Fatty Acids in Fruit Pulp Oil

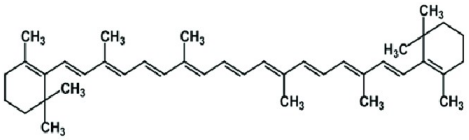
Unlike most fruits, Sea buckthorn pulp contains oil-rich cells with high concentrations of palmitoleic acid (omega-7), oleic acid (omega-9), linoleic acid (omega-6), and palmitic acid. Palmitoleic acid ($C_{16}H_{30}O_2$) is especially noteworthy for its skin-regenerating properties and is rarely found in plant-based oils.

Illustrative Chemical Structures

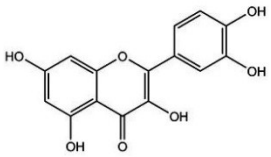
- **Ascorbic acid (Vitamin C):** A five-membered lactone ring with two hydroxyl groups and a side-chain bearing another hydroxyl; water-soluble.



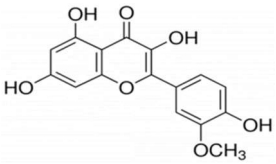
- **β-Carotene:** A long conjugated polyene chain with two terminal β-ionone rings; fat-soluble and orange in colour.



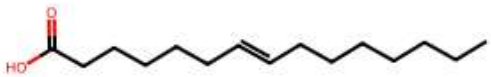
- **Quercetin:** A polyphenolic structure with two aromatic rings connected by a three-carbon bridge forming a heterocyclic pyrone ring.



- **Isorhamnetin:** Similar to quercetin but with a methyl group attached at the 3'-hydroxyl on the B-ring.



- **Palmitoleic acid:** A monounsaturated fatty acid with a double bond at the Δ9 position; chain of 16 carbon atoms.



Sea buckthorn fruits represent a unique natural matrix where water-soluble vitamins coexist with lipid-soluble carotenoids and polyphenols, offering a multi-pronged mechanism of action against oxidative stress, inflammation, and chronic diseases. Their complex yet balanced phytochemical profile makes them a prime candidate for application in dietary supplements, functional beverages, dermatological formulations, and even pharmaceutical excipients. The diversity of compounds also suggests potential synergistic interactions that warrant further investigation through bioavailability studies and clinical trials.

Phytochemicals in Sea Buckthorn Seeds

Sea buckthorn seeds, often discarded during juice and pulp extraction, are in fact a highly valuable source of numerous phytochemicals with nutritional and therapeutic significance. They are typically small, brown, and hard-textured, embedded within the fleshy mesocarp of the berry. Upon extraction, the seeds yield a golden-yellow oil, which is chemically distinct from the oil derived from the pulp. Unlike the fruit oil, which contains significant levels of carotenoids and palmitoleic acid, seed oil is notably rich in essential fatty acids, tocopherols, phytosterols, and phenolic compounds, contributing to a range of bioactivities including antioxidant, anti-inflammatory, cardioprotective, and skin-regenerative effects.

i) Fatty Acids

The most prominent phytochemicals in Sea buckthorn seed oil are polyunsaturated fatty acids (PUFAs), particularly linoleic acid (omega-6) and α-linolenic acid (omega-3). These are essential fatty acids, meaning they must be obtained through diet.

- **Linoleic acid ($C_{18}H_{32}O_2$):** An omega-6 fatty acid with two double bonds (Δ9, Δ12). It plays a key role in maintaining cell membrane integrity, regulating skin barrier function, and modulating inflammation.

- **α-Linolenic acid (ALA, $C_{18}H_{30}O_2$):** An omega-3 fatty acid with three double bonds (Δ9, Δ12, Δ15), essential for cardiovascular, cognitive, and inflammatory health.

The seed oil contains approximately 34–40% linoleic acid and 25–30% α-linolenic acid, resulting in an ideal omega-6:omega-3 ratio close to 1:1, which is considered highly beneficial for reducing chronic inflammation and oxidative stress (Yang et al., 2001). This composition differentiates Sea buckthorn seed oil from most other plant oils, which often exhibit a much higher omega-6:omega-3 imbalance.

ii) **Tocopherols and Tocotrienols (Vitamin E)**

Sea buckthorn seeds are a rich source of vitamin E, particularly tocopherols and tocotrienols, which are fat-soluble antioxidants. These compounds protect cell membranes from lipid peroxidation and enhance immune function.

- **α-Tocopherol ($C_{29}H_{50}O_2$):** The most biologically active form of vitamin E, comprising a chromanol ring and a saturated phytyl side chain. Sea buckthorn seed oil contains between 100–160 mg/100g of α-tocopherol.

- **γ-Tocopherol and δ-Tocopherol:** Also present in minor quantities, they exhibit potent peroxyl radical-scavenging activity and modulate inflammatory responses.

Tocopherols not only stabilize the oil against oxidation but also contribute to its wound-healing and anti-aging properties when applied topically or consumed as a dietary supplement.

iii)Phytosterols

Sea buckthorn seed oil contains significant amounts of phytosterols, predominantly β-sitosterol, along with campesterol and stigmasterol. Phytosterols are structurally similar to cholesterol and compete with it for absorption in the intestines, thereby reducing serum cholesterol levels.

- **β-Sitosterol ($C_{29}H_{50}O$):** Known for its cholesterol-lowering, anti-inflammatory, and immune-enhancing effects.

- **Campesterol ($C_{28}H_{48}O$)** and **stigmasterol ($C_{29}H_{48}O$):** Offer additional anti-inflammatory and anticancer benefits.

These sterols, in combination with PUFAs and tocopherols, support cardiovascular health, hormone balance, and metabolic regulation.

iv)**Phenolic Compounds**

Although phenolics are less abundant in the seed than in the fruit or leaf, recent studies have identified the presence of simple phenols, tannins, and lignans in seed extracts. Compounds such as ferulic acid, vanillic acid, and gallic acid have been reported, contributing to the seed's mild antioxidant and antimicrobial properties. Additionally, proanthocyanidins, a class of condensed tannins, have been detected and are believed to synergize with fatty acids to enhance skin health and barrier function.

v) Proteins and Amino Acids

Defatted Sea buckthorn seed flour contains a notable amount of plant proteins (~20–25%), and essential amino acids such as arginine, lysine, isoleucine, and valine, which are necessary for tissue repair, enzyme

synthesis, and immune modulation. These components may add further value in the development of plant-based protein supplements and fortified food products.

Sea buckthorn seeds, once considered a byproduct of fruit processing, are now recognized as a treasure trove of bioactive lipids, antioxidants, and sterols. Their unique fatty acid composition, highlighted by a balanced omega-6 to omega-3 ratio, combined with significant levels of vitamin E and β-sitosterol, positions them as a valuable ingredient in functional foods, dietary supplements, and cosmeceuticals. The oil extracted from seeds is particularly suited for cardiovascular, dermatological, and anti-aging applications. Future research should focus on advanced extraction technologies (such as supercritical CO_2 extraction), standardization of oil quality, and clinical validation of its health claims to facilitate its broader use in pharmaceutical and nutraceutical industries.

Phytochemicals in Sea Buckthorn Leaves

While Sea buckthorn fruits and seeds have received considerable scientific and commercial attention, the leaves of *Hippophae rhamnoides* represent an underutilized but chemically rich component of the plant. Traditionally used in herbal teas and ethnomedicinal decoctions, the leaves contain a wide spectrum of polyphenols, flavonoids, phenolic acids, tannins, and lignans, making them a promising source of natural antioxidants, antimicrobial agents, and anti-inflammatory compounds. Recent phytochemical investigations reveal that the bioactive profile of Sea buckthorn leaves is not only diverse but also significantly potent in terms of pharmacological activities.

i) Flavonoids

Flavonoids are among the most abundant and bioactive constituents of Sea buckthorn leaves. These polyphenolic compounds are known for their potent antioxidant properties, which help neutralize reactive oxygen species and reduce oxidative damage in tissues.

- **Quercetin ($C_{15}H_{10}O_7$):** A well-known flavonol with strong anti-inflammatory, vasodilatory, and anti-cancer properties. Quercetin acts as a free radical scavenger and modulates enzymes involved in oxidative stress.
- **Kaempferol ($C_{15}H_{10}O_6$):** This flavonol shows antimicrobial, cardioprotective, and neuroprotective activities by influencing cell signaling pathways and gene expression.

- **Isorhamnetin ($C_{16}H_{12}O_7$):** A methylated derivative of quercetin, particularly abundant in the leaves, known for its hepatoprotective and cytoprotective effects.

These flavonoids are often present as glycosides—compounds like quercetin-3-O-glucoside or isorhamnetin-3-O-rutinoside—which enhance their water solubility and bioavailability. The high flavonoid content contributes to the leaves' strong antioxidant activity, with total flavonoid concentrations ranging from 10–15% of dry leaf weight, depending on the region and growth stage.

ii) Phenolic Acids

Sea buckthorn leaves are also rich in hydroxybenzoic and hydroxycinnamic acids, which provide antioxidant and antimicrobial effects and modulate inflammatory pathways. Key phenolic acids identified include:

- **Gallic acid ($C_7H_6O_5$):** A trihydroxybenzoic acid known for its strong antioxidant activity and potential in cancer prevention.
- **Chlorogenic acid ($C_{16}H_{18}O_9$):** A major antioxidant in the leaves that helps regulate glucose metabolism and may exhibit anti-obesity effects.
- **Caffeic acid ($C_9H_8O_4$)** and **p-coumaric acid ($C_9H_8O_3$):** Hydroxycinnamic acids with potent radical-scavenging properties, also involved in UV protection and anti-inflammatory mechanisms.

These phenolic acids act synergistically with flavonoids to boost the overall antioxidant capacity of the leaves.

iii) Tannins

Sea buckthorn leaves are rich in hydrolyzable and condensed tannins, accounting for up to 5–8% of the dry weight. These polyphenolic compounds bind proteins and metal ions, contributing to astringent, antimicrobial, and detoxifying properties.

- **Ellagitannins and gallotannins:** Hydrolyzable tannins that break down into ellagic and gallic acid upon hydrolysis.
- **Proanthocyanidins (condensed tannins):** Polymers of flavan-3-ols such as catechin and epicatechin. They inhibit lipid peroxidation and suppress inflammation and allergic responses.

Tannins are also known to protect against microbial infections and digestive disturbances, supporting the traditional use of leaf decoctions in gastrointestinal disorders.

iv) Lignans and Saponins

In addition to polyphenols, Sea buckthorn leaves also contain bioactive lignans and saponins:

- **Lignans**, such as **secoisolariciresinol**, are phenylpropanoid dimers with antioxidant, estrogenic, and hepatoprotective effects.
- **Saponins** are glycosylated triterpenoids or steroids that exhibit antimicrobial, expectorant, and immune-boosting properties. They form foam in aqueous solutions and may aid in nutrient absorption and cholesterol metabolism.

These compounds, although present in lower concentrations than flavonoids or phenolic acids, contribute significantly to the therapeutic profile of the leaves.

Table 1: Comparative Summary of Major Phytochemicals in Sea Buckthorn Fruits, Seeds, and Leaves

Plant Part	Major Phytochemicals	Chemical Class	Biological/Pharmacological Significance
Fruits	Vitamin C (Ascorbic acid)	Water-soluble vitamin	Antioxidant, immune support, collagen synthesis
	β-Carotene, Lycopene, Zeaxanthin, Lutein	Carotenoids	Antioxidant, vision protection, skin health
	Quercetin, Isorhamnetin, Kaempferol	Flavonoids	Anti-inflammatory, anticancer, vascular protection
	Malic acid, Citric acid	Organic acids	Digestive support, pH buffering
	Palmitoleic, Oleic acids	Monounsaturated fatty acids	Skin regeneration, wound healing
Seeds	α-Linolenic acid (ALA), Linoleic acid	Omega-3 and Omega-6 PUFAs	Cardioprotective, anti-inflammatory, brain health
	α-, γ-, δ-Tocopherols	Vitamin E (Tocopherols)	Antioxidant, cell membrane stability

Plant Part	Major Phytochemicals	Chemical Class	Biological/Pharmacological Significance
	β-Sitosterol, Campesterol	Phytosterols	Hypocholesterolemic, immune-modulating
	Proanthocyanidins, Phenolic acids	Polyphenols	Antioxidant, antimicrobial
Leaves	Quercetin, Kaempferol, Isorhamnetin	Flavonoids	Antioxidant, hepatoprotective, anti-inflammatory
	Gallic acid, Chlorogenic acid, Caffeic acid	Phenolic acids	Antimicrobial, UV-protective, anti-diabetic
	Ellagitannins, Proanthocyanidins	Tannins	Antidiarrheal, antioxidant, antimicrobial
	Saponins, Lignans	Glycosides and Polyphenols	Immunostimulant, cholesterol-lowering, liver tonic

Nutritional and Therapeutic Applications

The chemical richness of Sea buckthorn leaves supports their use in multiple therapeutic and functional domains:

- **Antioxidant and Anti-inflammatory Effects:** High polyphenolic content enhances cellular defense mechanisms against oxidative stress and chronic inflammation.
- **Hepatoprotective Activity:** Flavonoids and lignans contribute to liver detoxification and regeneration.
- **Antimicrobial and Antiviral Effects:** Tannins and saponins exhibit strong inhibitory activity against bacteria, fungi, and certain viruses.
- **Metabolic Regulation:** Phenolic acids and flavonoids support blood glucose regulation and lipid metabolism, offering potential in managing diabetes and obesity.

Leaf extracts are currently being explored for inclusion in **herbal teas, nutraceutical tablets, animal feed additives**, and **natural preservatives**, with emerging evidence supporting their potential in chronic disease prevention and wellness management.

Sea buckthorn leaves, although less commercially exploited compared to fruits and seeds, are an exceptionally rich source of flavonoids, phenolic acids, tannins, and minor phytoconstituents like lignans and saponins. These compounds not only contribute to the plant's defence mechanisms but also offer a range of health-promoting effects in humans. Given their antioxidant, hepatoprotective, and anti-inflammatory activities, the leaves present a sustainable and economical source of high-value phytochemicals. Future research should focus on green extraction technologies, optimization of bioavailability, and validation of clinical efficacy to fully utilize this underexplored botanical resource.

Comparative Summary of Bioactives in Plant Parts

Compound Class	Fruits	Seeds	Leaves
Vitamin C	High	Absent	Moderate
Carotenoids	Very high	Low	Low
Flavonoids	Moderate	Low	High
Phenolic Acids	Moderate	Moderate	High
Fatty Acids	Moderate (pulp oil)	Very high	Low
Tocopherols (Vit. E)	Moderate	High	Low
Amino Acids & Proteins	Present	Present	Present

Therapeutic and Pharmacological Applications of Sea buckthorn Phytochemicals

The therapeutic relevance of *Hippophae rhamnoides* (Sea Buckthorn) lies in the combined and synergistic action of its rich phytochemical components—vitamins, flavonoids, phenolic acids, carotenoids, essential fatty acids, phytosterols, and tannins—distributed across various plant parts. These bioactive molecules have been extensively studied for their antioxidant, anti-inflammatory, hepatoprotective, cardioprotective, antimicrobial, immunomodulatory, and wound-healing properties. This section synthesizes the existing scientific evidence regarding the pharmacological benefits of Sea Buckthorn's major phytoconstituents, offering insights into their mechanisms of action and clinical relevance.

i) Antioxidant and Free Radical Scavenging Activity

Oxidative stress—caused by an imbalance between reactive oxygen species (ROS) and antioxidant defenses—is implicated in numerous chronic diseases including cancer, cardiovascular disorders, diabetes, and neurodegeneration. Sea buckthorn fruits, seeds, and leaves are all potent sources of antioxidants that neutralize ROS and protect cellular components from damage.

- **Vitamin C** (ascorbic acid) in fruits acts as a powerful water-soluble antioxidant that regenerates other antioxidants like vitamin E and inhibits lipid peroxidation.
- **Carotenoids** (β-carotene, lycopene, lutein) quench singlet oxygen and protect against photodamage and oxidative aging.
- **Flavonoids and phenolic acids** (quercetin, isorhamnetin, gallic acid) scavenge superoxide and hydroxyl radicals, chelate pro-oxidant metal ions, and modulate antioxidant enzyme systems (SOD, catalase, glutathione peroxidase).

Studies have shown that aqueous and ethanolic extracts of Sea buckthorn leaves and fruits significantly reduce oxidative markers in vitro and in vivo, suggesting their potential in oxidative stress-related disorders.

ii) Anti-inflammatory and Immunomodulatory Effects

Chronic inflammation underlies many non-communicable diseases including arthritis, cardiovascular disease, and cancer. Sea buckthorn phytochemicals modulate inflammatory pathways and immune cell functions:

- **Quercetin** and **Kaempferol** inhibit the activation of nuclear factor kappa B (NF-κB), a key transcription factor in the inflammatory cascade.
- **Tocopherols** and **polyunsaturated fatty acids (PUFAs)** from seed oil reduce the synthesis of pro-inflammatory cytokines (e.g., IL-6, TNF-α).
- **Saponins and tannins** from leaves exhibit anti-inflammatory effects by inhibiting cyclooxygenase and lipoxygenase enzymes, which are involved in prostaglandin biosynthesis.

These properties support the use of Sea buckthorn in the management of inflammatory conditions, such as rheumatoid arthritis, asthma, and dermatitis.

iii) Cardioprotective and Lipid-Lowering Activities

The balanced omega-6 to omega-3 fatty acid ratio in seed oil, along with phytosterols like β-sitosterol, contributes to cholesterol-lowering and vascular protective effects:

- **PUFAs** help reduce triglycerides, lower LDL cholesterol, and improve endothelial function.
- **Phytosterols** compete with dietary cholesterol for intestinal absorption, reducing serum cholesterol levels by 10–15%.
- **Flavonoids** and **tocopherols** exhibit vasodilatory and anti-platelet aggregation effects, improving blood circulation and reducing cardiovascular risk.

Animal studies and small clinical trials have demonstrated reductions in total cholesterol, improved HDL levels, and lowered blood pressure upon supplementation with Sea Buckthorn oil.

iv) Hepatoprotective and Gastrointestinal Benefits

Sea Buckthorn leaves and fruits possess hepatoprotective potential, largely attributed to flavonoids, lignans, and tannins:

- These compounds enhance detoxifying enzyme systems in the liver, such as glutathione-S-transferase and catalase.
- **Isorhamnetin** and **Chlorogenic acid** reduce liver enzyme levels (ALT, AST) in chemically induced liver injury models, indicating reduced hepatocellular damage.
- Leaves are traditionally used in decoctions to treat gastrointestinal ailments such as diarrhoea, ulcers, and indigestion, likely due to astringent tannins and antimicrobial phenolics.

v) Dermatological and Wound Healing Properties

One of the most commercially validated uses of Sea buckthorn is in skin health and dermatology. Both pulp and seed oils are used in ointments, creams, and serums for treating burns, eczema, acne, and sun damage.

- **Palmitoleic acid (omega-7)** from fruit pulp oil supports skin regeneration and repair of epithelial tissues.
- **Tocopherols and carotenoids** protect skin cells from UV radiation, oxidative stress, and premature aging.
- **Flavonoids and phytosterols** enhance collagen synthesis and reduce inflammatory cytokines, accelerating wound healing.

Several studies confirm improved re-epithelialization and reduced scarring in burn and wound models treated with Sea Buckthorn oil-based formulations.

vi) Antimicrobial and Antiviral Activities

The phenolic compounds, tannins, and flavonoids present in Sea Buckthorn leaves and fruits have demonstrated broad-spectrum antimicrobial activity:

- **Flavonoids and phenolic acids** disrupt microbial cell walls, inhibit enzyme activity, and interfere with DNA synthesis in bacteria and fungi.
- **Tannins** exhibit protein-precipitating and enzyme-inhibitory effects, making them effective against gastrointestinal pathogens.
- Preliminary research also suggests antiviral potential against enveloped viruses, though further investigation is needed.

This supports the traditional use of leaf infusions for treating infections and the modern use of fruit and leaf extracts in natural preservatives and oral hygiene products.

Sea buckthorn's pharmacological potential is rooted in its diverse array of bioactive constituents that act on multiple physiological targets. From antioxidant and anti-inflammatory effects to cardiovascular protection, hepatoprotection, dermatological healing, and antimicrobial defense, the plant offers a holistic therapeutic profile. These benefits, supported by both traditional wisdom and modern pharmacological studies, make *Hippophae rhamnoides* a valuable resource for the development of natural health products. As research continues, focus should be placed on clinical trials, formulation science, and bioavailability studies to fully harness its medicinal promise.

Traditional Uses of Sea Buckthorn

Sea Buckthorn (*Hippophae rhamnoides* L.) has a long and diverse history of use in traditional medicine systems across Eurasia, particularly in Tibetan, Chinese, Mongolian, Russian, and Indian traditions. Its diverse pharmacological benefits were understood and utilized centuries before modern science began exploring its phytochemical composition. The plant was traditionally employed for treating ailments of the skin, liver, heart, digestive system, and immune system, and was revered for its rejuvenating and healing properties.

i) Traditional Use in Himalayan and Indian Ethnomedicine

In India, Sea Buckthorn grows naturally in cold-arid regions of Ladakh, Himachal Pradesh, Uttarakhand, and parts of Arunachal Pradesh. Known locally by names such as *Chharma* (in Ladakhi) and *Dhar-Bu*, the plant is central to traditional healthcare among local ethnic communities such as the Ladakhis, Brokpas, and Monpas.

- **Fruits and juices** are traditionally consumed to increase vitality, stamina, and immunity, particularly to withstand high-altitude conditions.
- **Decoctions of leaves and bark** are used to treat coughs, respiratory infections, diarrhoea, and gastrointestinal ulcers.
- **Fruit pulp oil** is applied externally for wounds, frostbite, sunburn, and joint pain common ailments in high-altitude cold deserts.
- **Seed oil**, when mixed with butter or ghee, is used as a digestive tonic and skin emollient.

The Ministry of AYUSH and the Defense Research and Development Organisation (DRDO) in India have recognized Sea Buckthorn's value, especially in improving immunity and performance in soldiers deployed in extreme altitudes like the Siachen Glacier. Local cooperatives in Ladakh now process the berries into juices, herbal teas, jams, and oils, integrating traditional knowledge with commercial practices.

ii) Tibetan and Mongolian Medicine

In Traditional Tibetan Medicine (TTM), Sea Buckthorn has been used for over a thousand years. The Tibetan medical texts describe it as a remedy for balancing the three bodily humours—wind (rlung), bile (mkhris-pa), and phlegm (bad-kan).

- Sea Buckthorn fruits are used as a "hot" medicine, useful in treating cold disorders, such as arthritis, numbness, and respiratory problems.
- Oils are used internally for gastric ulcers, liver ailments, and cardiovascular conditions, and externally for burns, eczema, and wounds.

Similarly, in Mongolian folk medicine, Sea Buckthorn is used for digestive problems, hepatic diseases, oral ulcers, and female reproductive health. Mongolians also used dried fruits as winter survival food, owing to their high vitamin C content.

iii) Chinese Traditional Medicine (TCM)

In Traditional Chinese Medicine (TCM), Sea Buckthorn (*shā jí* in Mandarin) has been included in the Chinese Pharmacopoeia and is used to “nourish the stomach, promote blood circulation, remove phlegm, and relieve cough.” It is also believed to invigorate blood flow and remove blood stasis, which makes it useful in treating:

- Chronic bronchitis and asthma
- Digestive disorders such as ulcers and gastritis
- Menstrual irregularities and gynaecological inflammations
- Skin and mucous membrane injuries

TCM often uses berry extract in syrups, decoctions, and pills, sometimes in combination with Licorice, Rhodiola, or Ginseng, to enhance immune and metabolic functions.

iv) Russian and Central Asian Uses

In Russia and Central Asia, Sea Buckthorn was widely adopted into both folk medicine and Soviet pharmacology. Its use gained popularity after World War II, where it was employed to treat radiation burns and skin lesions. Soviet scientists developed topical Sea Buckthorn oil-based formulations for:

- Radiation injuries

- Oral mucositis (caused by chemotherapy)
- Ocular inflammation
- Peptic ulcers and esophagitis

Sea Buckthorn tea and oil remain common remedies in Russia for immune support, liver detoxification, and respiratory tract infections.

v) Culinary and Nutritional Uses

In addition to medicinal use, Sea Buckthorn has traditionally served as a nutritional and functional food:

- In Ladakh and China, the berries are sun-dried and later rehydrated for use in soups, stews, and chutneys.
- The juice or pulp is fermented in some regions to make medicinal wines or tonics.
- The leaf tea, rich in polyphenols and vitamins, is consumed as a daily health drink.

The unique combination of tanginess and richness in vitamin C, beta-carotene, and other nutrients has made Sea Buckthorn a valuable survival food for high-altitude pastoral communities.

Conclusion

Sea Buckthorn (*Hippophae rhamnoides* L.) stands out as a highly versatile and phytochemically rich plant with immense nutritional, medicinal, and economic potential. The present review comprehensively highlights the unique distribution of bioactive constituents across its fruits, seeds, and leaves. Each plant part exhibits a distinct but complementary phytochemical profile—fruits being rich in vitamin C, carotenoids, and flavonoids; seeds providing a balanced spectrum of essential fatty acids, tocopherols, and phytosterols; and leaves offering a dense array of polyphenols, tannins, and flavonoids. These compounds contribute synergistically to the plant's wide range of pharmacological actions, including antioxidant, anti-inflammatory, cardioprotective, hepatoprotective, antimicrobial, and dermatological effects.

The traditional applications of Sea Buckthorn in Tibetan, Chinese, Mongolian, and Himalayan medicinal systems have provided a robust ethnobotanical foundation, which is now supported by growing scientific evidence. Modern research has not only validated these traditional claims but also opened new avenues for therapeutic development, particularly in functional foods, nutraceuticals, cosmeceuticals, and phytopharmaceuticals.

Despite these advances, several areas warrant further investigation. These include standardized extraction techniques, clinical trials to validate efficacy and safety, bioavailability studies, and sustainable cultivation strategies. Given the global shift towards plant-based health solutions, Sea Buckthorn holds great promise as a next-generation medicinal and nutritional plant. Integrated interdisciplinary research and value-chain development can help realize its full potential while also preserving the traditional knowledge and biodiversity from which it originates.

References

- 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 Research International*, 44(7), 1718–1727.
- Eccleston, C., Baoru, Y., Tahvonen, R., Kallio, H., Rimbach, G. H., & Minihane, A. M. (2002). Effects of an antioxidant-rich juice (Sea buckthorn) on risk factors for coronary heart disease in humans. *Journal of Nutritional Biochemistry*, 13(6), 346–354.
- Geetha, S., Sai Ram, M., Singh, V., Ilavazhagan, G., & Sawhney, R. C. (2002). Anti-oxidant and immunomodulatory properties of Sea buckthorn (*Hippophae rhamnoides*)—an in vitro study. *Journal of Ethnopharmacology*, 79(3), 373–378.
- Pop, R. M., Weesepoel, Y., Socaciu, C., Pintea, A., Vincken, J. P., & Gruppen, H. (2013). Carotenoid composition of berries and leaves from six Romanian Sea buckthorn (*Hippophae rhamnoides* L.) varieties. *Food Chemistry*, 139(1-4), 282–290.
- Ranjith, A., Raghavarao, K. S. M. S., & Raghavarao, K. S. M. S. (2006). Extraction and quantification of vitamin E from Sea buckthorn seeds. *Food Chemistry*, 98(2), 312–317.
- Upadhyay, N. K., Kumar, M. S., & Gupta, A. (2010). Antioxidant, antimicrobial, and wound healing properties of Sea buckthorn oil: A review. *Journal of Ethnopharmacology*, 115(2), 206–216.
- Yang, B., Kallio, H., & Tahvonen, R. (2001). Effects of harvesting time and storage on the contents of lipids, tocopherols, and tocotrienols in Sea buckthorn (*Hippophae rhamnoides*) seeds. *Journal of Agricultural and Food Chemistry*, 49(2), 287–292.

- Guliyev, V. B., Gul, M., & Yildirim, A. (2004). Biological activity and chemical composition of Hippophae rhamnoides L. (Sea buckthorn): A review. *Journal of Ethnopharmacology*, 94(2-3), 255–262. https://doi.org/10.1016/j.jep.2004.05.005

- Li, T. S. C., & Beveridge, T. H. J. (Eds.). (2003). *Sea Buckthorn (Hippophae rhamnoides) – Production and Utilization*. NRC Research Press.

- Suryakumar, G., & Gupta, A. (2011). Medicinal and therapeutic potential of Sea buckthorn (Hippophae rhamnoides L.). *Journal of Ethnopharmacology*, 138(2), 268–278. https://doi.org/10.1016/j.jep.2011.09.024

- Yang, B., Kallio, H., & Tahvonen, R. (2001). Fatty acid composition of lipids in Sea buckthorn (Hippophaë rhamnoides L.) berries of different origins. *Journal of Agricultural and Food Chemistry*, 49(4), 1939–1947.

- Xu, M., Jin, Z., Bao, Y., & Xie, H. (2012). Flavonoids and phenolic acids from leaves of Sea buckthorn (Hippophae rhamnoides L.) and their antioxidant activities. *Food Chemistry*, 131(3), 754–760.