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Seabuckthorn (*Hippophae Rhamnoides* L.): An Economically Important Shrub of Cold-Temperate Regions

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ABSTRACT

Seabuckthorn (*Hippophae rhamnoides* L.) is one of the ancient flowering plant species. In India, Seabuckthorn is found naturally growing in cold arid areas of Ladakh, Lahaul and Spiti, Kinnaur, Pangi, parts of Kumaun and Garhwal region and certain areas in northeastern hills of Indian Himalayan region. It can withstand extreme temperature from −40 °C to +40 °C with limited soil nutrients. It has gained global attention for its health benefits, primarily, rich metabolic profile; vitamin C being the most significant nutrient. It is a valuable source for developing and commercialisation of products such as fruit juice, tea, oil, wine and cosmetics. The primary application includes nutritional, pharmaceutical, food and feed, cosmetology and ecological restoration. This study explores the morphology, cultivation, and economic potential of Seabuckthorn, addressing its applications, toxicity, and safety concerns, and paving the way for further research. However, the species has yet to receive focused attention from scientists and conservationists with respect to its cultivation and ecological significance.

Keywords: Antioxidants; Bioactive compounds; Conservation; Flavonoids; Food application; *Hippophae rhamnoides*

1. INTRODUCTION

The global climatic change has alarmed the need of conservation and monitoring strategies to protect the rich Himalayan biodiversity. It encompasses a remarkable array of unique ecological zones; biodiversity and global climate regulation. Moreover, the Himalaya holds deep cultural and religious significance in India[1]. The expedition of wild, underutilised and endemic tree species has been a research hotspot since long. In a nutshell, the Himalaya is a living laboratory for climate science, geology, biodiversity, anthropology, and sustainable development, all at once[2]. However, the region confronts various obstacles, including population expansion, deforestation, urbanisation, and heavy construction, which leads to biotic extinctions and increasing natural calamities[3]. Protecting cultural and ecological richness of the Himalaya calls for promoting traditional knowledge and management of conservation strategies is a primary need. Empowering local communities in conservation efforts will enhance the outcome.

Several documents stated various approaches for monitoring the Himalaya and the activities within. Tierney[4], *et al.* used the combination of ecological status and biological integrity (commonly called as ecological integrity) to evaluate the structure, composition and function of an ecosystem[4]. It also takes into account, the natural and anthropogenic variations caused by any of the factors in present or in past. The development of long-term ecological monitoring system can be an efficient approach for such purpose. Negi[5], *et al.* evaluated the potential of National Mission for Sustaining the Himalayan Ecosystem (NMSHE) implemented by Indian National Action Plan for Climate Change (NAPCC). The authors found that the data generated through such systems is reliable. However, the limitation lies in the robust assessment of this data[5]. Rawat[6], *et al*. emphasises the importance of examining the correlation between species availability and forest ecosystem composition and functioning for a better understanding of forests. In the cited study, two methodologies i.e., conventional method and Plant Functional Trait (PFT) based approach can be implemented to define forest functions[6].

The research on Seabuckthorn satisfies the PFT-method by connecting its characteristics to critical forest functions. Its capacity to fix nitrogen improves soil fertility and promotes forest development[7]. Deep roots maintain the soil, reducing erosion on slopes and disturbed regions. High drought and cold tolerance enable forests to spread into hard areas[8]. Seabuckthorn berries and prickly branches

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give food and shelter increasing biodiversity. Its excellent photosynthesis helps to sequester carbon, which aids climate regulation. By evaluating these characteristics, researchers may learn how Seabuckthorn effect nutrient cycling, soil stability, biodiversity support, and ecosystem resilience, making it critical for forest ecosystem function. Besides, it is a collection of health benefits due to high anti-allergic, anti-carcinogenic, antioxidants and skin healing properties[9].

2. SEABUCKTHORN (*HIPPOPHAE RHAMNOIDES* L.): MORPHOLOGY, CULTIVATION AND ECONOMIC POTENTIAL

Seabuckthorn (family- Elaeagnaceae) is a hardy shrub that has garnered significant attention for its economic and ecological importance, particularly in cold temperate regions. Originally native to such regions of Europe and Asia, this deciduous shrub is renowned for its resilience in harsh climates and poor soil conditions. Due to its resilience, it is a useful plant for land reclamation, reforestation, and soil erosion control, giving otherwise uninhabitable environments stability and fertility[8,10]. Based on this fact, it is known as the gold mine of cold deserts[7-8]. One Seabuckthorn berry provides the recommended daily amount of vitamin C. The virtues of Seabuckthorn were known to the Greeks, who gave it the Latin name *Hippophae rhamnoides*, which translates to "shining horse." As mentioned by Gurčík et al. it is one of the greatest nutrients containing plants with more than 190 useful chemicals independently (Fig.1)[11].

This plant variety has been a research focus since 1995 with a remarkable increase in publications after 2005 (Fig. 2a) majorly in agricultural and biological sciences, biochemistry, genetics and molecular biology, environment and pharmacology (Fig. 2b).

It has gained global attention in the food and feed industries due to its remarkable nutritional and bioactive properties. The essential compounds include distinct vitamins, trace minerals and amino acids. Additionally, it has a high concentration of omega 3,6,7 and 9, as well as phytosterols. It includes beta-carotene, vitamin C, B, E and carotenoids[10-11]. In fact, it has been used in traditional Chinese medicine since ancient time to treat a variety of ailments[12-13].

2.1 Data Collection Approach

Based on a bibliometric analysis of published data obtained from the Scopus database, the main keyword "Seabuckthorn" was used to find 2,111 publications. Peer-reviewed articles, reviews, and conference papers published between a certain period (1990–April 2025) were the focus of the data collection. The inclusion criteria prioritised relevance to Seabuckthorn (*Hippophae rhamnoides*) and its applications, while excluding editorials, non-English publications, and unrelated studies. The analysis was guided by the following main research questions: (1) What are the main objectives of Seabuckthorn research? (2) How did the emphasis change over time? (3) In terms of Seabuckthorn research, which nations are at the forefront? After a keyword analysis, 13,959 indexed terms were found, 609 of which had a minimum occurrence of 10.

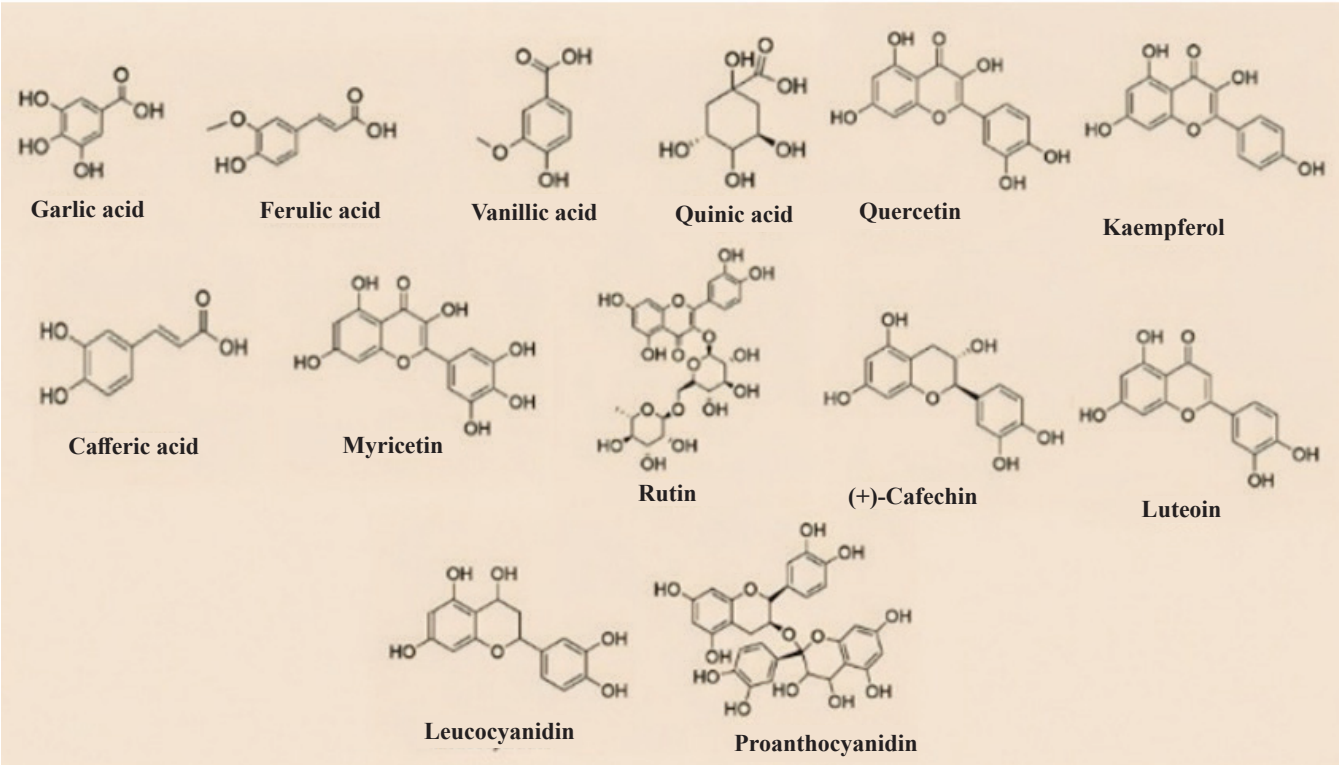


Figure 1. Some of the major bioactive compounds found in Seabuckthorn.

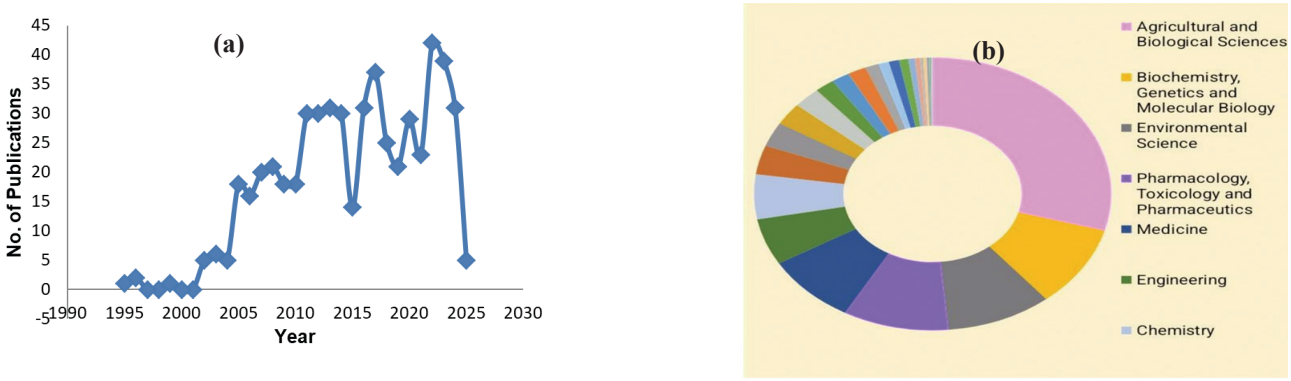
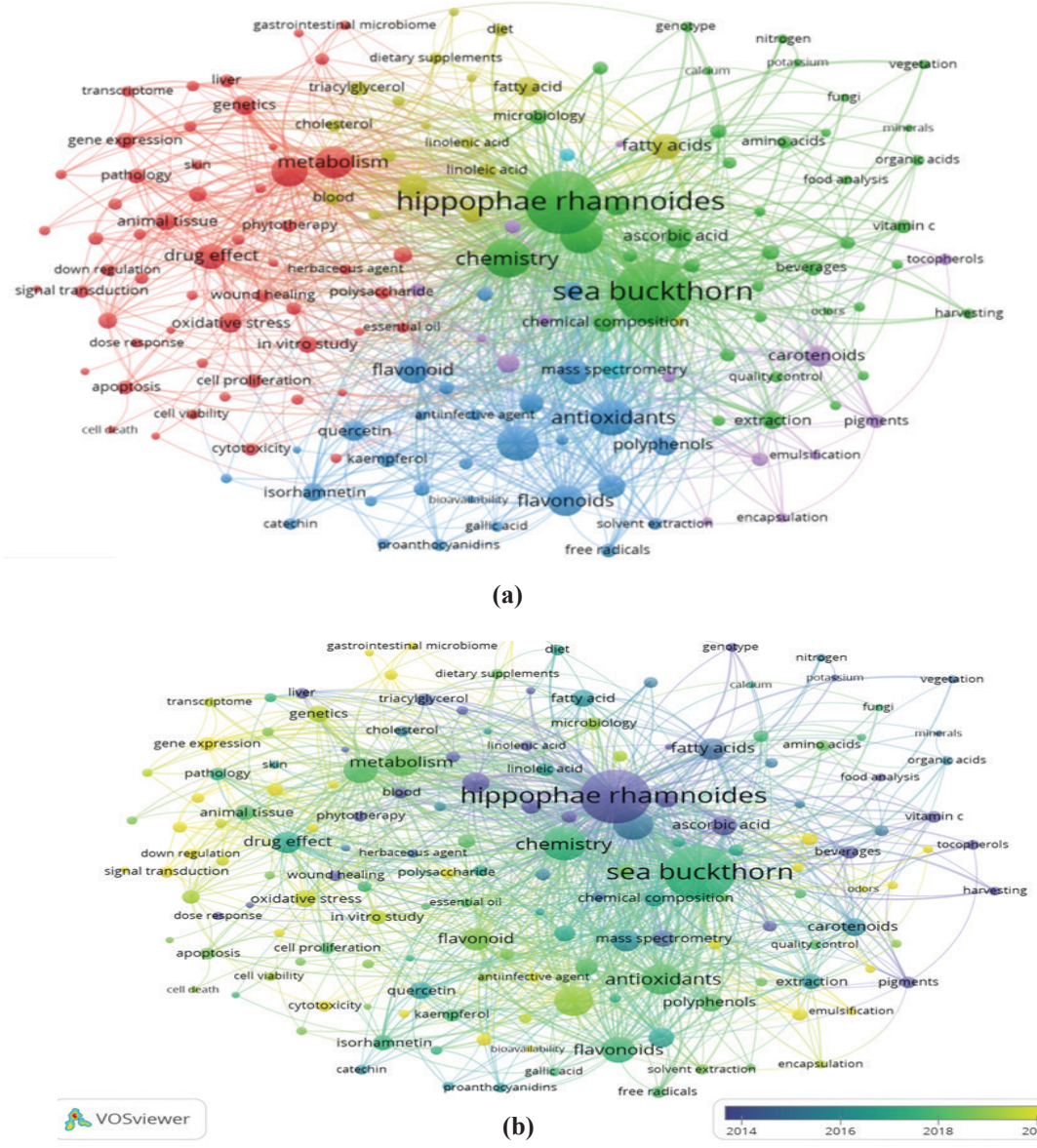


Figure 2. Research trends based on no. of publications-(a) representation of the publication in this duration, and (b) The percentage area of research in different sectors.

The most often used keywords were "chemistry", "Seabuckthorn", and "*Hippophae rhamnoides"* (Fig. 3a). Bioactive substances, therapeutic development, antioxidant and anticancer potential, signaling, nutrition, and toxicology were all the subjects of several studies. However, there were relatively fewer reports on agricultural, ecological, fermentation, and horticultural disciplines. The yearly pattern shown in Fig. 3b indicates that Seabuckthorn research began



(a)

(b)

Figure 3. Cluster map generated by VOS viewer based on the data retrieved from scopus- (a) network map evaluated the majorly used keywords by the authors, and (b) yearly distribution of Seabuckthorn- based research and review studies.

with a focus on phytocompounds, and the current trend was influenced by the identification of cytotoxicity, signaling, genetic changes, and impacts on the gut flora. In terms of Seabuckthorn research, China is the nation that publishes the most, followed by Russia, Romania, Poland, and India. However, recent studies have demonstrated the enormous potential of goods made from Seabuckthorn, making it a widely desired component of contemporary food and feed.

2.2 Morphological Characteristics

Seabuckthorn is a deciduous shrub, also known as sand thorn, sea berry, Siberian pineapple, and sallow thorn.[12,14] It is morphologically characterised as a bush to a small tree, with thorns. Ontogenetic and morphological traits, along with ecological factors like soil moisture, air humidity, soil nutrients, pH, precipitation, illumination, and temperature, are used to rank different Seabuckthorn genotypes[15]. Seabuckthorn has dioecious flowers with spherical orange-yellow fruits growing in clusters. Leaves are lanceolate with dark grey upper surface and silver grey lower surface. The branches are dense covered in stiff thorns. The stem is thorny woody with rough brownish bark. The pulp is oily and soft, containing one seed per fruit. The seeds are shiny brown with a hard coat and 2.8-4.2mm in size[16-17]. One of the most notable features of Seabuckthorns is the vibrant orange berries that are rich in vitamins, antioxidants, and essential fatty acids[18]. These berries have become a lucrative source of income for many communities living in the regions where the shrub naturally grows[8]. These characteristics and biochemical components of Seabuckthorn berries have implications for their enormous use in the food industry.

2.3 Cultivation

Seabuckthorn is cultivated in many parts of the world including China, India, Russia and many parts of Northern Europe[14]. Though, substantial research and development initiatives are underway, commercial production and promotion of Seabuckthorn remains in its early stages. Some of the common obstacles encountered by the Seabuckthorn business include a lack of understanding of its potential, a short harvest season, and high water content, which hinder farmers from cultivating the crop and impede the creation of value-added goods[8]. Despite, Seabuckthorn is commonly found growing wild in temperate valleys, riverbanks, hillsides, and mountains. It is habitable to a variety of soil textures and porosity but survives best in well-drained soils with a pH between 6.0 - 7.0. In terms of propagation, it can be grown through seeds, cuttings, root suckers and tissue culture.

Seabuckthorn is dioecious, meaning that male and female flowers are borne on separate plants. Therefore, both sets of plants must be present for fruit production. Singh[14], *et al.* recommended planting one male plant, located upwind for every 6-8 female plants to ensure adequate pollination. The authors also suggested pruning of the plant during late winter or early spring[14]. Heinäaho[19], *et al.* reported that the change in cultivation methods (land contours and mulches) exert an effect on the amount of phenols in Seabuckthorn leaves. The flat surface had considerably larger quantities of gallic acid, pentagalloyl, quercetin, astragalin A, and tannins, than the low hill surface. The plastic mulch had a lower percentage of gallic acid and tannins[19]. Seabuckthorn has been effectively regenerated utilising various organs and medium and clonal propagation by cuttings in greenhouses and fields. Nevertheless, these propagation methods are season dependent and may be inconvenient[7]. Therefore, biotechnology was found reliable in such cases. For instance, Ruan[20], *et al.* observed the appearance of dried-shrink disease, commonly in Seabuckthorn as the limiting factor for its development. To combat the issue, the authors initiated the development of clones with the disease resistance genes[20]. The utilisation of distinguished breeding strategies involving metabolite profiling and use of specific markers for efficient genotype development paved way to improved biotechnological interventions[7,21] Besides, recent developments in genetic mapping, plant genomics, and QTL analysis provide additional tools for improving our comprehension of crop diversity at the species and genomic levels. They have additionally facilitated the investigation of genetic control for significant attributes and the emergence of high-value genotypes in breeding programs[22]. However, much research focusing on the standardisation and optimisation process of Seabuckthorn domestication is still needed.

2.4 Economical Potential

H. rhamnoides has a rich history of traditional use across Europe and Asia. Originating in the Hengduan Mountains and East Himalaya, it has been used for centuries in medicine, nutritional supplements, and for soil and moisture conservation. The Seabuckthorn market is expected to develop at a Compound Annual Growth Rate (CAGR) of 10.39 % from its estimated USD 381.4 million in 2024 to USD 837.26 million by 2032. With a market share of 67.42 % in 2024, Asia Pacific led the industry, which is indicative of the plant's indigenous existence and long-standing usage in the area. In 2023, 26.6 % of the Seabuckthorn market's revenue came from dietary supplements. Between 2024 and 2031, the food and beverage category will be growing at a CAGR of 10.6 %[23]. Key export markets include Europe, Asia-Pacific, and North America. Value-added products include juices (34 %), functional beverages (11.4 %), nutritional supplements (28 %), and cosmetic items like oils and creams, which leverage Seabuckthorn's antioxidant, anti-inflammatory, and skin-repair properties. Major companies in the Seabuckthorn industry include W.S. Badger Company Inc., Seabuck Wonders, Natures Aid Ltd., WELEDA, Wellsash, Leh Berry, Natura Health Product, Erbology, SIBU, and TEREZIA COMPANY S.R.O.[24] Several products manufactured from Seabuckthorn as shown in Fig. 4 are also used for commercial purposes. The plant is so valued that it is known as "Wonder Plant" or "Golden Bush"[14]. Differenct parts of Seabuckthorn shrubs have their values as given fig. 4.

Figure 4. Seabuckthorn products.

- **Berries are useful as**

Nutraceuticals	Rich in vitamin C,E, flavonoids and omega fatty acids
Juice and syrup	Popular in health drinks, jams and sauces
Cosmetic oil	Skin care and hair care products
Pharmaceuticals	Formulations for ulcers, burns and cardiovascular support

- **Roots & Stem are useful as**

Ecological aspect	Stabilise soil, induce symbiosis, enrich nutrients thus ideal for land reclamation
Therapeutics	Bark extracts used for antitumor, anti-inflammatory and antifungal treatments

- **Seeds are useful as**

Seed soil	Rich in omega fatty acids
Nutritional supplements	Grounded into powder for capsule and medicine formation

- **Flowers are useful as**

Traditional medicine	Used in Tibetan and Mongolian healing practices for treating skin diseases and respiratory issues
Cosmetics	Used in anti-aging and skin soothing formulations

- **Leaves are useful as**

Tea production	Rich in antioxidants
Animal feed	Due to high protein content
Medicinal uses	Anti-inflammatory, antimicrobial, anti-diabetic, anticancer, antioxidant, reduced cholesterol and treat skin ailments

2.4.1 Nutritional and Medicinal Use

Seabuckthorn is a rich source of various bioactive compounds that contribute to its nutritional and medicinal properties[9,25] (Table 1).

These compounds include vitamins, carotenoids, flavonoids, fatty acids, and other beneficial substances[26]. The amount of these compounds differs with reference to other parts as mentioned in Table 2.

It is extremely rich in vitamin C that contributes to its antioxidant and immune-boosting properties[13]. As a fat-soluble antioxidant, vitamin E in Seabuckthorn helps protect cells from damage caused by free radicals. It also contains other vitamins like A, B1, B2, and K contributing to overall health and well-being[12]. A precursor to vitamin A, β-carotene is abundant in Seabuckthorn and has a significant impact on vision, immune function, and skin health[27-28]. Seabuckthorn contains other carotenoids like zeaxanthin and lutein, which are important for eye health[12]. Seabuckthorn is rich in flavonoids which offer antioxidant, anticancer, and anti-inflammatory properties that may help protect against chronic diseases[29]. Yang[30], *et al.* studied the effect of rutin and isorhamnetin on retinal pigment epithelial cells and reported the reduction of apoptosis and the amount of oxidative products[30]. Similar findings induced by Seabuckthorn proanthocyanidins were reported earlier by Ma[31], *et al.* that act as protectant during retinopathy[31].

Seabuckthorn is also a valuable source of important fatty acids viz., omega-3, 6, and 9 which are crucial for heart health, brain function, and reducing inflammation.[12] Amazingly, it is one of the few plant sources of omega-7 fatty acids, known for supporting skin health and metabolic function[10]. Other beneficial compounds include polyphenols, it possesses antioxidants and anti-inflammatory properties, which help protect against cellular damage and chronic diseases and phytosterols. These plant-derived compounds can help lower cholesterol levels and improve cardiovascular health[32]. Several researchers documented the applications of polysaccharides obtained from Seabuckthorn as a treatment to various ailments. For instance, Ma[33], *et al.* purified a novel polysaccharide capable of reducing lipid accumulation and maintaining body weight, making it feasible as a natural anti-obesity agent[33]. These can be further used for making capsule coating and other pharmaceutical products in combination to nanotechnology. Its fruit contains organic acids like malic and citric acid, which contribute to its tangy flavor and potential health benefits[26]. Seabuckthorn has several potential applications in female reproductive health, particularly related to

Table 1. The major bioactive compounds observed in Seabuckthorn and their applications.

Compound class	Key compounds	Applications	References
Flavonoids	Isorhamnetin, quercetin, kaempferol, rutin	Antioxidant, anti -inflammatory, cardiovascular health, anticancer, anti – diabetic and reducing apoptosis	Bao et al[29], Yang et al[30], Singh et al[44], Chen et al[53], Cui et al[54]
Carotenoids	Beta-carotene, lycopene, lutein & zeaxanthin	Antioxidant, precursor to vitamin A, skin health and eye protection	Andersson et al[27], Tudor C et al[28]
Phenolic acids	Gallic acid, caffeic acid, ferulic acid, p-coumaric acid	Antioxidant, anti-inflammatory, antimicrobial	Upadhyay et al[32]
Proanthocyanidins	Proanthocyanidins dimers, trimers, tetramers	Antioxidant, anti-cancer, vascular protection, protective and restorative effects in retinopathy	Ma et al[31], Wang et al[55]
Fatty acids	Omega acids, palmitoleic acid, oleic acid, linoleic acid, α-linolenic acid	Skin regeneration, anti-inflammatory, metabolic regulation	Ciesarova et al[10], Wang et al[12], Cui et al[54], Hongzhi et al[56]
Vitamins	Vitamin C, E (α-tocopherol), B-complex vitamins	Antioxidant, immune support, anti-diabetic, skin health	Mei et al[13], Shin et al[57]
Phytosterols	β-sitosterol, campesterol, stigmasterol	Cholesterol-lowering, cardiovascular protection	Cui et al[58]
Triterpenoids	Ursolic acid, oleanolic acid	Anti-inflammatory, hepatoprotective, skin health	Singh et al[44]
Polysaccharides	-	Immunomodulatory, antioxidant, anti-cancer, inhibit lipid accumulation, anti-obesity	Ma et al[33], Chen et al[59]

- = None

managing menopausal symptoms and promoting vaginal health[34]. Seabuckthorn oil has been demonstrated to reduce the thinning and drying of vaginal mucosa as a symptom of menopause[35]. These findings were confirmed by another study conducted by Yu[36], *et al.* during their study on more than 300 postmenopausal patients[36]. Thus, it can also be a suitable alternative for women who cannot tolerate estrogen treatment[37]. Seabuckthorn oil has shown curative effects against chronic cervicitis[38].

2.4.2 Food and Cosmetic Applications

Currently, Seabuckthorn is utilised in the preparation of various food and functional food products. Seabuckthorn juice and multivitamin beverages are popular drinks, leveraging the fruit's high vitamin C content and unique flavor profile. It is sometimes mixed with sweeter liquids (such as apple or grape) to offset its inherent sourness and astringency. Seabuckthorn berries are processed into jam jellies etc., offering a tangy and nutritious spread. The berries are used in pies, sauces, purees, fruit wines, liquors, and even ice cream, delivers a distinctive citrus-like flavor and brilliant orange color[12]. Kashyap[39], *et al.* reported the extraction of antifreeze chitinase from Seabuckthorn seeds attributed to reduction in ice recrystallisation potential. The phenomenon was validated through cryopreservation of green beans[39]. Feng[40], *et al.* documented that when flavonoids extracted from leaves were mixed with chitosan; they showed an efficient food preservative potential on lettuce by determining enhanced antioxidant and antibacterial effect along with film production[40]. The use of Seabuckthorn syrup as a substrate for the production of fermented vegetal soy drink along with the microbial inoculum was tested by Maftei[41], *et al.* It was found to enhance antioxidant activity, microbial growth rate and viability, water holding capacity, pH, total phenolic content and shelf life[41], Khalid[42], *et al.* prepared yogurt supplemented with Seabuckthorn pulp and found the enhancement in its antioxidant properties[42]. The plant can be used to develop functional foods targeting specific health benefits, like antioxidant, anti-inflammatory, and cardio protective effects. In some regions, the leaves, seeds, and fruit residues are used as feed material for livestock and poultry[38]. Extracts and oils from Seabuckthorn can be formulated into dietary supplements to provide a concentrated source of bioactive compounds[12]. Research suggests that including Seabuckthorn in animal feed can improve the quality of meat and eggs.

The oil extracted from Seabuckthorn contains balanced composition of fatty acids, carotenoids, and vitamins,

Table 2. Nutritional content of different parts of Seabuckthorn plant.

Nutrient	Berries (per 100 g)	Seeds (per 100 g)	Pulp/Peel (per 100 g)	Leaves (per 100 g dry matter)	Branches (per 100 g dry matter)	References
Energy	79 kcal	106–135 kcal	60 kcal	350–400 kcal	350–400 kcal	Sethunath et al[8], Ciesarova et al[10]
Moisture	81.4–81.9%	45–55%	85–90%	10–15%	10–15%	Wang et al[12]
Protein	3.12 g	18.63 g	6.89 g	15.41 g	11.62 g	Dong et al[9], Moskalets et al[15], Yu et al[18]
Fat	2.50 g	11–12.5 g	3–8 g	5.29–5.84%	5.31–5.67%	Wang et al[12], Moskalets et al[15], Jasniewska et al[38]
Carbohydrates	11.0 g	3.5–5.0 g	6.0–7.0 g	24.97 g	24.97 g	Wang et al[12], Yu et al[18]
Fiber	6.55 g	2.0–3.0 g	3.0–4.0 g	10–15%	10–15%	Dong et al[9], Ciesarova et al[10]
Vitamin C	193–400 mg	-	-	-	-	Sethunath et al[8], Dong et al[10]
Vitamin A (β-carotene)	2–170 mg	-	-	-	-	Wang et al[12], Andersson et al[27], Tudor C et al[28]
Vitamin E (α-tocopherol)	43–223 mg	-	-	-	-	Mei et al[13], Yu et al[18], Ruan et al[20]
Vitamin K1	1100–2300 µg	-	-	-	-	Dong et al[9]
Fatty Acids	SFA: 13.7–42.7% MSFA: 40.7–60.4% PSFA: 3.7–24.6% PLA: 16–54%	SFA: 8.7% MSFA: 19.4% PSFA:40.9% LA: 40.9%	SFA: 26.7% MSFA:17.1% PSFA:12.7% LA: 12.7%	NA	NA	Dong et al[9], Ciesarova et al[10], Wang et al[12], Moskalets et al[15], Cui et al[54], Hongzhi et al[56]
Carotenoids	53.1–96.7 mg	-	-	0.9 mg (lutein)	NA	Wang et al[12], Andersson et al[27]

NA = Data not available, - = None, SFA = Saturated fatty acid, MSFA = Monounsaturated fatty acid, PSFA = Polyunsaturated fatty acid, LA = Linoleic acid and PLA= Palmitoleic acid

finding its way into a plethora of beauty and health care formulations for irritated, sensitive, dry, burnt, flaky, or rapidly aging skin. It has over 100 unique compounds, including palmitoleic to γ-linolenic acid ratios that are uncommon in plants[43-44]. The polysaccharide extracted from Seabuckthorn was tested for the anti-aging effect attributed to its natural antioxidant behavior. Moreover, the purification processes employed to the crude polysaccharide enhance its potential[45], Sangeetha[46], *et al.* mentioned detailed data of the commercialised products such as body oil, serum, face oil, sunscreen, creams, lotions, and eye gel formulations developed from Seabuckthorn[46]. Many researchers have developed and patented their products; the application majorly belonged to cosmetology and pharmacology (Table 3).

2.4.3 Agricultural and Environmental Benefits

Seabuckthorn is a pioneer plant; it was among the first to invade and improve damaged soils. It is known for its ability to tolerate abiotic stresses due to several factors; one of them is the large root system aiding nitrogen fixation, hence improving soil fertility. Studies reveal that Seabuckthorn trees may fix significant amounts of nitrogen, similar to the use of artificial fertilisers, and enhance soil nutrient content when compared to bare ground. It is vital for controlling soil erosion, restoring deteriorated and wastelands, improving animal habitat, and protecting farmsteads[47]. Enescu highlighted the ecological amplitude of Seabuckthorn with major emphasis on land reclamation. It states the role of Seabuckthorns in reducing desertification, stabilisation of soil strata, and symbiosis with the surrounding vegetation and microorganisms[48-49]. Thereby, it regulates local microclimate contributing to a stable and hospitable environment for other flora and fauna. Moreover, it was found that the presence of Seabuckthorn induces the growth of other tree species than the pure population[49] proving its efficiency in forest amelioration. However, despite its rich nutritional and therapeutic potential, Seabuckthorn demands greater

Table 3. Details of the published patents involving the use of Seabuckthorn

Patent name	Application number/ Patent no.	Composition	References
Anti-inflammatory SBT compositions	US2005214394A1	Extracts of SBT leaves, berries, seeds; synergistic use with chemo drugs	James et al[60]
Skin-whitening cream	CN103432039A	SBT seed oil, rutin, mulberry pigment, silymarin	Chen et al[53]
Cancer proliferation inhibitor	JP2012025724A	Flavonoids from SBT (quercetin, kaempferol, myricetin, isorhamnetin, rutin)	Singh et al[44], Nakajima et al[61]
Anti-AIDS active compound	RU1805967C	SBT-derived substance with activity against HIV	Serafima et al[62]
Anti-inflammatory flavonoid glycoside	KR101186264B1	Quercetin-3-O-glucoside-7-O-rhamnoside from SBT fruits	Kim et al[63]
Residue extract with ACE inhibition	WO2009125071A2	L-quebrachitol enriched extract from SBT berry residues	Baoru et al[64]
Anticancer and radioprotective extract	IN217317	Ethanolic extract fractionated through various solvents; anticancer activity via cell cycle inhibition and apoptosis	Singh et al[44]
Cardiovascular formulation with flavonoids	CN103505484A	Total flavonoid fraction from SBT and linoleic acid	Cui et al[54]
Drug for viral diseases	RU2118163C1	SBT-based formulation to treat viral infections	Shipulina et al[65]
Flavonoid-based cardiovascular treatment	CN103505451A	Isorhamnetin and quercetin mixture	Cui et al[54]
Alkaloid extract for ischemia	CN101612176A	Tryptamine derivatives from SBT leaves	Xu et al[66]
Preparation method of SBT polysaccharide soft capsule	CN103494789A	SBT pomace and leaves for capsule wrapping	Hongzhi et al[56]
SBT fruit juice for diabetes	KR10170226B1	Raw juice containing fatty acids, flavonoids, vitamins	Shin et al[57]
Lipid-lowering formulation	CN103505483A	Blood lipid reducing composition- SBT oil, fatty acids, and phytosterol	Cui et al[58]
Antibacterial and antioxidant extract from SBT seeds	RU2311192C2	Methanol Soxhlet extract from seeds	Chauhan et al[67]

investigation into its environmental impact, particularly in fragile mountainous locations that are most vulnerable to human intervention[50].

3. SAFETY AND TOXICITY

Research indicates that Seabuckthorn is safe for both animal and human consumption. Studies have not identified any significant adverse effects on organ weight or biochemical and hematological parameters in animal trials, even at high doses[51]. Based on the toxicology report of the Seabuckthorn leaf extract documented by Saggu[52], *et al.* the maximum effective adaptogenic dosage of the extract was found to be 100 mg/kg body weight. However, no remarkable changes except liver and kidney were documented. The dosage pattern used in the cited study was the maximal effective dose administered for 14 days (single oral doses of 1 g/kg and 2 g/kg once daily) and 30 days (single oral dose of 100 mg/kg once daily). In conclusion, the LD50 of the extract was evaluated as more than 10g/kg[52]. Beyond its safety, Seabuckthorn offers numerous potential health benefits, including antioxidant, anticancer, anti-hyperlipidemic, anti-obesity, anti-inflammatory, antimicrobial, antiviral, dermatological, neuroprotective, and hepatoprotective activities[12]. It has also been researched for its potential in treating cardiovascular disorders and gastrointestinal

ulcers. While Seabuckthorn is generally safe, it's always advisable to consult with a healthcare professional before incorporating it into diet[51]. Further, the toxicological profiling of Seabuckthorn and related products will help strengthen its applications.

4. CONCLUSION AND FUTURE PERSPECTIVE

Seabuckthorn holds considerable promise for future development and research. The plant's inherent resilience makes it valuable for environmental applications, including soil improvement and erosion control. Simultaneously, its rich nutritional composition and potential health benefits open doors for innovation across the food, beverage, cosmetics, and pharmaceutical sectors. Companies aiming for success in the Seabuckthorn market will need to focus on strategic product innovation and development. Looking ahead, several avenues exist for expanding Seabuckthorn cultivation and its applications. One key area is expanding cultivation efforts, especially in regions where Seabuckthorn can contribute to both economic growth and environmental sustainability. China's extensive planting of Seabuckthorn since 1982 demonstrates this potential. Further, an insight on rhizosphere and microbiome of Seabuckthorn will support the healthy cultivation of the species. Besides, continued research into the active compounds within Seabuckthorn fruit and leaves can drive the creation of new product formulations and applications. Market growth is anticipated on a global scale, fuelled by increasing applications across diverse industries. Sustainable practices are also crucial, necessitating further investigation into optimising the sustainable use of Seabuckthorn. This includes ensuring that cultivation and processing methods minimize environmental impact and maximize resource efficiency. Finally, exploring novel applications of Seabuckthorn, such as in the treatment of cardiovascular diseases represents an area of untapped potential.

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