Journal of
Food Bioactives
International Society for
Nutraceuticals and Functional Foods
Review
J. Food Bioact. 2025;30:19–24

Research progress on bioactive components and their activities in sea buckthorn

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DOI: 10.26599/JFB.2025.95030410
Received: May 21, 2025; **Revised received & accepted:** June 24, 2025
Citation: Gao, C., Kou, J., He, J., Yu, X., Chen, Y., Zhang, J., Kong, H., Gu, M., Zhu, X., Shang, S., Zhao, H., and Bai, L. (2025). Research progress on bioactive components and their activities in sea buckthorn. J. Food Bioact. 30: 19–24.

Abstract

Sea buckthorn (*Hippophae rhamnoides L.*) is a naturally occurring dual-use plant for both medicine and food. It contains numerous bioactive compounds demonstrating significant health-promoting effects, including anti-inflammatory, antioxidant, and blood lipid-regulating activities. China currently possesses the world's largest sea buckthorn resources. The full and rational utilization of these resources holds substantial importance for enhancing public health and stimulating local economic development. While research on the bioactive compounds and efficacy of sea buckthorn has garnered increasing attention in recent years, a systematic review of this knowledge remains lacking. This article comprehensively summarizes the rich profile of bioactive compounds in sea buckthorn and their documented health benefits. It aims to provide a foundation for the further application and development of sea buckthorn within the pharmaceutical, functional food, and related industries.

Keywords: Sea buckthorn; Bioactive components; Vitamin; Antioxidant; Anti-inflammatory.

1. Introduction

As an ecologically and economically valuable plant, sea buckthorn has garnered significant attention due to its rich natural bioactive constituents (Guo et al., 2017; Criste et al., 2020). Its potential in nutritional supplementation and disease management positions it as a multidisciplinary research hotspot. Berries and leaves are rich in bioactive compounds, constituting a valuable medicinal and edible plant resource (Wang et al., 2022; Fu et al., 2016). Sea buckthorn is gaining popularity as a functional food owing to its rich nutritional profile. Furthermore, sea buckthorn exhibits several advantageous biological traits, including tolerance to cold, drought, and poor soils (Liu et al., 2014; Luo et al., 2023). Consequently, it possesses significant ecological value in windbreak and sand fixation, soil and water conservation, and soil improvement. Specifically, its cultivation can mitigate sandstorms, enhance the ecological environment, and facilitate subsequent vegetation restoration.

Based on its significant nutritional and ecological value, China has emerged as a major global grower of sea buckthorn, with extensive cultivation concentrated in its central and western regions. The abundant sea buckthorn resources have spurred considerable research interest into its functional properties. Consequently, the bioactive properties of sea buckthorn have been extensively investigated (Wang et al., 2022; Luo et al., 2023). This article provides a comprehensive synthesis of current research advances concerning the bioactive components of sea buckthorn and their associated health benefits. It aims to facilitate and support the further valorization of this valuable plant resource.

Table 1. Main bioactive components in sea buckthorn

Type	Composition	Plant parts	Bioactivities	References
Flavonoids	Kaempferol	Fruit	Antioxidant, Lipid-lowering	Shi, 2025
	Quercetin	Fruit	Antioxidant, Anti-cancer	Liu et al., 2012
	Isorhamnetin	Fruit	Antioxidant, Anti-inflammatory	Ren et al., 2023; Wu et al., 2024
	Rutin	Fruit	Antioxidant Anti-cancer	Chen et al., 2014
	Myricetin	Fruit	Antioxidant	Li et al., 2024
	Apigenin	Fruit	Antioxidant, Lipid-lowering	Zhou et al., 2020
	Hippophaeoside	Fruit	Antioxidant, Anti-inflammatory	Wu et al., 2024; Ji et al., 2023
Vitamins	A	Fruit	Anti-inflammatory	Yan et al., 2021
	B2	Leaf	Anti-inflammatory	Liu et al., 2025
	C	Fruit	Antioxidant	Yan et al., 2021
	E	Fruit	Antioxidant, Lipid-lowering	Olas, 2016; Hu et al., 2021
	Carotenoids	Fruit	Antioxidant	Hu et al., 2021
Fatty Acids	linoleic acid	Seed	Antioxidant, Lipid-lowering	Saeidi et al., 2016; Maria et al., 2021
	linolenic acid	Seed	Antioxidant, Lipid-lowering	Bouras et al., 2017; Cui et al., 2022
	oleic acid	Seed	Antioxidant	Ren et al., 2020; Maria et al., 2021
Polysaccharides	Glucose	Fruit	Antioxidant, Anti-cancer	Zhao et al., 2024
	fructose	Fruit	Antioxidant, Anti-inflammatory	Zhao et al., 2024; Shi et al., 2024
	sucrose	Fruit	Antioxidant, Anti-inflammatory	Lin et al., 2024; Zhao et al., 2023
Amino acids	Aspartic acid	Leaf	Anti-cancer	Shang et al., 2023
	Tryptophan	Leaf	Anti-cancer	Wang et al., 2022
	Glutamic acid	Leaf	Anti-cancer, Antioxidant, Lipid-lowering	Liu et al., 2022; Sharma et al., 2018
	Arginine	Leaf	Anti-cancer, Lipid-lowering	Deng et al., 2024
	Tyrosine	Leaf	Anti-cancer, Gut microbiota modulation	Li et al., 2024; Kong et al., 2024
Others	Phenolic acids	Leaf	Anti-cancer, Gut microbiota modulation	Ge et al., 2023; Tian, 2023
	Sterols	Fruit	Anti-inflammatory, Antioxidant	Asofiei et al., 2019
	Alkaloids	Fruit	Anti-cancer, Lipid-lowering	Tang, 2022

2. Major chemical components

China accounts for over 90% of global sea buckthorn cultivation, reflecting its abundant resources (Fu et al., 2022). Sea buckthorn berries are rich in diverse bioactive compounds, primarily including flavonoids, vitamins, polysaccharides, fatty acids, phenolic acids, and minerals, show as in Table 1 and Figure 1. Among these, certain compounds have received considerable research attention due to their specific physiological functions (Chandra et al., 2018). These compounds confer antioxidant, anti-inflammatory, and glucose-regulating properties, enabling broad applications across industries (Zhang et al., 2017; Niyazi et al., 2020).

3. Research and applications of bioactive components in sea buckthorn

Based on its excellent biological activity, sea buckthorn has been widely used in the fields of food and medicine. And its biological activity relies on its rich variety of active ingredients (Xiong et al., 2022). Sea buckthorn constitutes a high-value multipurpose tree species integrating phytopharmaceutical potential, nutraceutical applications and ecological engineering significance.

3.1. *Flavonoids*

Flavonoids, as primary bioactive constituents in sea buckthorn, predominantly accumulate in its leaves at concentrations ranging from 310 to 1,238 mg/100g – significantly exceeding levels in fruits. Currently, 49 flavonoids have been isolated from sea buckthorn, mainly including quercetin, isorhamnetin, kaempferol, and their stems (Liu et al., 2012; Shi, 2025). As the main component of sea buckthorn, flavonoids demonstrates remarkable antioxidant capacity, effectively scavenging free radicals such as DPPH, superoxide anions (O_2^{-}), and hydroxyl radicals (·OH) in *vitro* (Ren et al., 2023; Zhou et al., 2020; Chen et al., 2014). Furthermore, studies have shown that flavonoids extracted from sea buckthorn leaves can enhance the vitality of PC-12 cells by preserving membrane integrity, attenuating intracellular oxidative stress, mitigating mitochondrial dysfunction, and reducing apoptotic rates (Wang

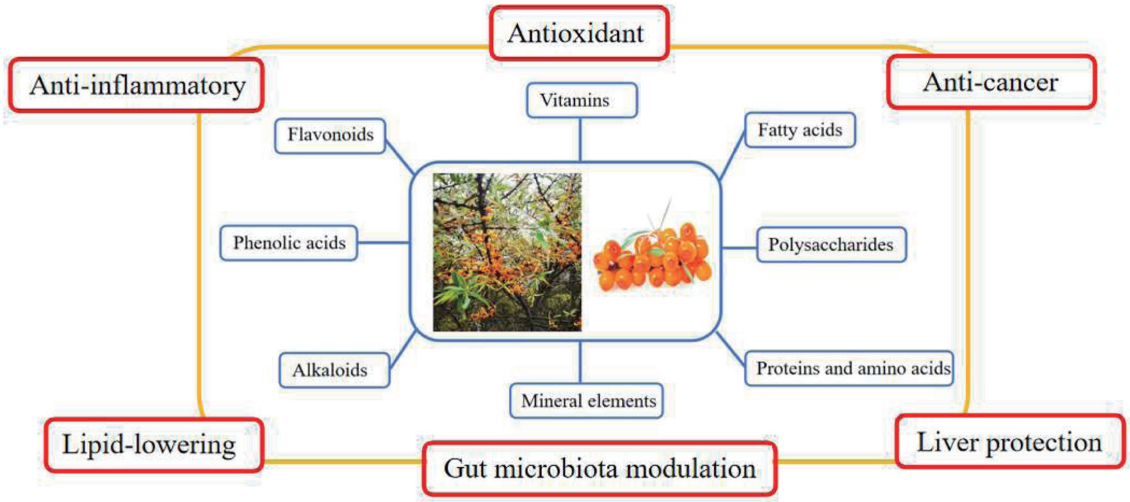

Figure 1. The main biocative components and activities in sea buckthorn.

et al., 2007; Li et al., 2024). Anti-inflammatory is one of the biological activities of sea buckthorn flavonoids. Sea buckthorn flavonoids can significantly enhance the phagocytic ability of LPS induced Raw 264.7 cells by inhibiting the release of cytokines NO and inflammatory factors IL-6, TNF - α, and COX-2 to suppress inflammation (Wu et al., 2024; Liu et al., 2025). Furthermore, due to its anti-proliferative properties, sea buckthorn flavonoids have shown great potential in anti-cancer applications. Notably, sea buckthorn flavonoids display anti-cancer potential through anti-proliferative effects via p53-mediated apoptosis (Guo et al., 2017; Rana and Gulliya, 2019). And it can also significantly inhibit the proliferation of human prostate cancer PC-3 cells and human liver cancer HepG2 cells in *vitro* by regulating the expression of Bax and Bcl-2 proteins, blocking the cell cycle (Zhao et al., 2018; Bai and He, 2021; Hao et al., 2022). Many researchers have proved that sea buckthorn flavonoids also can reduce the risk of diabetes by avoiding glucose absorption or improving glucose tolerance (Wang et al., 2022; Alqudah et al., 2023). Quercetin can reduce the ability of diabetes rats to absorb glucose, making it comparable to the absorption level of normal rats (Gao et al., 2017). Sea buckthorn flavone can significantly increase the levels of insulin and liver glycogen in ALX induced diabetes mice, and alleviate abnormal lipid metabolism, which may be closely related to cholesterol conversion and outflow (Zhu et al., 2021; Ji et al., 2023).

3.2. Vitamins

Sea buckthorn is a natural source of vitamins, rich in various vitamins, mainly including vitamin A, vitamin C, vitamin E, and vitamin F. Crucially, its vitamin C content surpasses most horticultural crops by 3- to 10-fold, attributable to the ascorbate oxidase-mediated stabilization system that minimizes oxidative degradation (Yan et al., 2021; Zhu et al., 2024; Liu et al., 2025). Vitamin A in sea buckthorn exists as provitamin A carotenoids, primarily β-carotene, which undergoes enzymatic conversion to retinol in humans. Sea buckthorn oil contains exceptionally high carotenoid concentrations, ranging from 54 to 9,265 mg per 100 g. Vitamin A sufficiency confers multisystem protection through enhanced tumor immunosurveillance, atherosclerosis prevention, improved thyroxine conversion efficiency, heavy metal chelation capacity and telomere maintenance (Yan et al., 2021; Liu et al., 2025). The high content of vitamin C endows sea buckthorn with antioxidant, lipid metabolism regulating, and immune enhancing functions. Vitamin E shows the effects of regulating cholesterol metabolism, promoting capillary proliferation, and improving cardiovascular and cerebrovascular diseases (Olas, 2016; Hu et al., 2021).

3.3. Fatty acids

All parts of sea buckthorn contain certain fatty acids, including linoleic acid, lauric acid, palmitic acid, oleic acid (Saeidi et al., 2016; Bouras et al., 2017; Ren et al., 2020). Most of them are unsaturated fatty acids that are easily absorbed by the human body, accounting for more than 70%. Sea buckthorn oil has various physiological activities and is a natural pain relieving medicine (Zielinsk and Nowak, 2017; Balkrishna et al., 2019; Maria et al., 2021). It can improve the body's immune function, promomte tissue regeneration and healing, and has good applications in the treatment of skin injuries (Cocetta et al., 2021; Cui et al., 2022). Furthermore, sea buckthorn oil has antidepressant effects and can significantly improve the mental state of the human body (Chen et al., 2023; Cui et al., 2022). The latest researches show that sea buckthorn oil has good antioxidant activity, regulating substance metabolism in the liver, alleviating liver damage caused by CCl_4, and demonstrate a good therapeutic effect on viral hepatitis (Hao et al., 2023). In addition, sea buckthorn oil promote the excretion of mercury from the kidneys and alleviate oxidative damage to the liver, and relieve liver damage in acute and subacute cadmium contaminated rats (Sheng et al., 2021; Xu et al., 2023).

3.4. Polysaccharides

One of the main components of sea buckthorn fruit is sugar and glycosides, mainly composed of glucose, fructose, and sucrose (Zhao et al., 2024; Lin et al., 2024). Researchers have found that sea buckthorn polysaccharides exhibit good antioxidant capacity in *vitro* and can effectively eliminate free radicals such as ABTS and DPPD (Liu et al., 2021; Zhao et al., 2023). Sea buckthorn polysaccharides can alleviate effect on acute liver injury induced by various drugs such as LPS in mice (Zhang et al., 2017; Marciniak et al., 2021; Zargar et al., 2022). It exerts polypharmacological effects through multiple pathways and targets (Lin et al., 2024). Therefore, sea buckthorn is expected to be developed as a new type of functional food or drug to improve liver injury. Recent investigations have established sea buckthorn polysaccharides as potent immunomodulatory agents with significant anti-inflammatory properties, garnering substantial research attention (Shi et al., 2024). Sea buckthorn fructose can activate the phagocytic function of macrophages, release pro-inflammatory factors, regulate the TLR4/MyD88/NF-κB signaling pathway, and participate in various physiological processes such as inflammatory response, oxidative stress, and immune regulation in the body (Mahahan et al., 2018; Li et al., 2019). Sea buckthorn polysaccharides can significantly enhance the immune function of cyclophosphamide induced immunocompromised mice, and increase the levels of TNF - α, IL-6, interferon - γ, and NO in spleen tissue (Ning et al., 2021). In addition, the expression of TLR4, MyD88, and p-MAPK7 can be expressed to reduce the levels of inflammatory and apoptotic factors in cells, and up regulate the expression of immunoglobulin to alleviate inflammatory reactions and exert anti-inflammatory and immune regulatory effects. Biological activities such as reducing anti-tumor, blood sugar, improving lipid metabolism disorders, and resisting obesity were observed with sea buckthorn polysaccharides (Attri and Goel, 2018; Tascioglu et al., 2021).

3.5. Proteins and amino acids

Compared with sea buckthorn fruit, sea buckthorn seeds are a high-quality plant protein resource, and have a higher protein content (Tan et al., 2018; Shang et al., 2023). Globulin, albumin, and alcohol soluble protein are the three types of sea buckthorn protein with relatively high content, which are mainly influenced by the planting area and extraction method (Liu et al., 2022; Wang et al., 2022). Sea buckthorn protein contains a rich variety of amino acids, including 8 essential amino acids for the human body, which endows it with many excellent biological activities. Studies have shown that sea buckthorn protein or its enzymatically hydrolyzed peptides have the effects of regulating blood glucose, antioxidation, and improving gut microbiota (Yuan et al., 2018; Sharma et al., 2018). Feeding sea buckthorn seed protein could reduce blood sugar in db/db diabetes mice, and this result was also verified in diabetes mice (Liu et al., 2022). Sea buckthorn protein can enhance the expression of AMP activated protein kinase (AMPK) and silent information regulator 1 in the liver by regulating the level of inflammatory factor C-reactive protein (CRP), interleukin-6 (IL-6), nuclear factor - (NF-κβ), tumor necrosis factor-α (TNF-α), thereby reducing the expression of low glucose 6-phosphatase (G-6-P), glycogen synthesis. Down regulation of hepatic glycogen synthase kinase-3β (GSK-3β) and carnitine palmitoyltransferase 1α (CPT1α) expression ameliorated insulin resistance, consequently improving hyperglycemia and polyuria in diabetic murine models (Shu et al., 2020; Deng et al., 2024; Kong et al., 2024). In addition, seabuckthorn protein can also regulate the composition and structure of intestinal flora, increase the abundance of *bifidobacteria*, *lactobacilli*, and *bacteroides*, reduce the abundance of *Clostridium globosum*, and improve diabetes symptoms (Chang et al., 2019; Kou et al., 2023; Li et al., 2024).

3.6. Other components

Sea buckthorn also contains phenolic acids, alkaloids, and mineral elements, which play important roles in promoting and maintaining overall health (Guo et al., 2017; Asofiei et al., 2019). Sea buckthorn polyphenols have been proven to have good effects in anti-cancer, improving gut microbiota, lowering blood lipids, and protecting the liver (Ge et al., 2023; Tian, 2023). And sea buckthorn alkaloids demonstrated good ability and nutritional health benefits (Ding et al., 2023). The mineral profile in sea buckthorn includes nutritionally significant levels of Ca, K, P, Mg, Na and 11 essential trace elements (Fe, Mn, I, Cu, Zn, Se, Cr, Mo, Co, Ni). These elements serve as enzymatic cofactors and metabolic modulators, particularly in energy transduction pathways (Tian et al., 2018; Tang, 2022).

4. Conclusion

As a typical medicinal and edible substance, sea buckthorn is rich in various chemical components and has multiple medicinal effects, which is in line with people's pursuit of the concept of natural and healthy food. At present, seabuckthorn has been widely used in various fields such as food, medicine, and health products. Comprehensive characterization of its phytoconstituents, particularly fruit pulpolisaccharides and leaf flavonol glycosides provides the molecular foundation for developing targeted functional products with validated health claims.

Acknowledgments

This research was supported by the National Training Program of Innovation and Entrepreneurship for Undergraduates (202310069087; 202410069245; 202510069345).

Conflict of interest

All authors declare that there is no conflict of interest.

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