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Review on nutritional composition, bioactive compounds and therapeutic properties of Hippophae rhamnoides L. (Sea Buckthorn)

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***Abstract*---**Hippophae rhamnoides L. (Sea Buckthorn) is a valuable multifunction plant largely distributed in Europe and Asia. In particular, the berries of sea buckthorn have been widely used as a food source like jam, juices, etc. The berry and seed of this plant are the main sources for its therapeutic and nutritional values. Thus, the plant has been extensively investigated for both of its nutritional and bioactive constituents. In general, the berries of this plant are rich in vitamins (C, E and K); while the ascorbic acid has been reported to be the primary vitamin, contributing to the acidic nature of the berries. Sea buckthorn berries also contain good amount of minerals like calcium and iron. On the other hand, the seed of sea buckthorn offers an excellent source of polyunsaturated fatty acids like palmitic acid, oleic acid and palmitoleic acid. Significant bioactive constituents in sea buckthorn including sitosterol, salicylic acid, tritepenoid, catechin, gallocatechin, epigallocatechin and carotenoids help in combating many diseases like cardiovascular diseases (angina), inflammation, cancer, gastric ulcer and epidermis issues. This review compiled the applications of sea buckthorn including a database of its nutritional and bioactive compounds which ultimately contribute towards the health promoting properties. As a result, these beneficial attributes have made sea buckthorn desirable source for medicinal as well as for cosmetic products.

***Keywords*---**sitosterol, palmitoleic acid, catechin, polyphenols, carotenoids.

Introduction

Hippophae rhamnoides L. commonly called sea buckthorn, sanddorn, seaberry or Siberian pineapple. It's a deciduous spiny shrub (Fig. 1) belongs to the Elaeagnaceae family (Singh et al, 2019). Sea buckthorn berries (Fig. 2) are of orange or yellow colour, circular shaped and about 3 to 8 mm in size. The detailed taxonomy of the plant is outlined in Table 1. The sea buckthorn plant naturally grows in north-western Europe, Central Asia and the northern Himalayas (Teleszko et al, 2015). While in India, it found in the zone of Ladakh, Himachal Pradesh, Uttarakhand and Sikkim. Sea buckthorn berries are mostly utilized for the local production of liquors, syrups and jams (Rop et al, 2014). All parts of this plant (especially berries and seeds) are rich in nutrients and bioactive constituents which are important for health enhancing factors. Therefore, sea buckthorn plant has been used traditionally as a remedy in many nations such as China, India, Romania, etc.

Fig 1: Sea buckthorn plant

Fig 2: Sea buckthorn berries

Table 1
Taxonomy of *Hippophae rhamnoides* L.

Kingdom	Plantae
Class	Dicotyledonae
Order	Elaeagnales
Family	Elaeagnaceae
Genus	*Hippophae*
Species	*H. rhamnoides*

Latest medicinal researches of sea buckthorn identified numerous health-promoting applications in vitro as well as in vivo (Wani et al, 2016). Therefore,

this review describes the valuable properties of *Hippophae rhamnoides* L. including its nutritional composition, bioactive compounds and health benefits.

Nutritional Properties

The nutritional attributes of sea buckthorn depend on the fruit's size, maturity, geographical region, species, climate and the method of extraction (Leskinen et al, 2010). The nutritional profile of sea buckthorn berries is briefly described in Table 2 and Table 3.

Carbohydrates

Carbohydrates are considered to be the main component in sea buckthorn berries. CHO present in sea buckthorn berries are majorly disaccharides and monosaccharides. The total amount of CHO in fresh weight is 0.48%–2.87% (Tkacz et al, 2019; Wu et al, 2016). However, the main monosaccharides are xylose, glucose, rhamnose and fructose, while the utmost representative disaccharides are sucrose and maltose.

Protein

According to Nazir and Bashir (2017), the protein in sea buckthorn berries is around 0.4% to 2.5% in fresh weight as well as the amount of free amino acid ranges in fresh weight vary from 0.77% to 2.19%. Hence, eighteen free amino acids identified in sea buckthorn and eight of these (phenylalanine, threonine, isoleucine, tryptophan, leucine, valine, lysine, and methionine) are important for health (Stobdan et al, 2013). Yet, the leading amino acid in sea buckthorn fruit pips are glutamic acid along with aspartic acid (Trineeva et al, 2015).

Lipids

Morphologically, sea buckthorn berries contain skin (8% w/w), pulp (68% w/w) and seeds (23% w/w) (García, 2019) and all consist good amount of oil. The lipid in sea buckthorn on fresh weight ranges from 1.2%–7.8%. In a study (Craciun, 2018) identified the amount of saturated, monounsaturated, and polyunsaturated fatty acids is 13.70%–42.68%, 40.73%–60.37% and 3.70%–24.62% (Craciun, 2018). However, (Dulf, 2012) evaluated the dominating fatty acids in berries pulp oil were palmitoleic (11-27%), palmitic (23-40%) and oleic (20-53%).

Table 2
Nutrient Content in Sea buckthorn Berries

Compounds			Content
Carbohydrates (%)			0.48–2.87
Protein (%)			0.4-2.5
	Free amino acid		0.77–2.19
		Aspartic acid *	0.43–55.68
		Glutamic acid*	11.76–16.48

Lipids (%)			1.20–7.8
	Fatty acid (%lipid)		8.8–11.1
	Saturated fatty acids (% Total fatty acid)		13.70–42.68
	Monounsaturated fatty acids (% Total fatty acid)		40.73–60.37
	Polyunsaturated fatty acids (% Total fatty acid		3.70–24.62
		Palmitic acid (16:0)	23-40
		Oleic acid (18:1n-9)	20-53
		Palmitoleic (16:1n-7)	11-27

*Essential Amino Acid and % lipid mean data based on sea buckthorn oil extract

Vitamins and Minerals

Sea buckthorn is a good source of vitamins like thiamine, riboflavin, pyridoxine and folic (Lu et al, 2019). However, the other vitamins rich in sea buckthorn are vitamin C, E and K. According to Pop et. al (2015), amount of α-tocopherol in sea buckthorn in fresh weight is between 43-223 mg/kg in fresh. In a very recent study Wang et. al (2021) observed that in fresh weight sea buckthorn berries vitamin K is around 90-120mg/kg (Table 3)**.** Moreover, vitamin C content in sea buckthorn is higher than the other fruits**.** The vitamin C content in sea buckthorn has an average of 7950 mg/kg in fresh weight (Hussain et al, 2014). The brief detail of vitamins and minerals in sea buckthorn berries are mentioned in Table 3. Additionally, twenty-four chemical elements are available in the juice of sea buckthorn such as, calcium, manganese, iron, boron, etc (Hussain et al, 2014). The calcium present in dried sea buckthorn is 724mg/kg similarly, the content in zinc (22.3mg/kg) as well as in copper (8.3 mg/kg) (Nour et al, 2021). Vaitkeviciene et. al (2019) studied there have also been other minerals available in sea buckthorn like, Iron (282 mg/kg DW), Manganese (16.30 mg/kg DW) and Boron (13mg/kg DW)**.**

Table 3
Vitamins and Minerals Content in Sea buckthorn Berries

Compounds		Content
Vitamins FW (mg/kg)	Vitamin E	43-223
	Vitamin K	90-120
	Vitamin C	7950
Minerals DW (mg/kg)	Calcium (Ca)	724
	Zinc (Zn)	22.3
	Copper (Cu)	8.3
	Iron (Fe)	282
	Boron (B)	13

	Manganese (Mn)	16.30

DW (Dry Weight); FW (Fresh Weight)

Bioactive Compounds

Bioactive constituents are the non-nutrient plant compounds which include health promoting properties as shown in Table 5. All the parts of sea buckthorn are rich source of large number of phytochemicals and antioxidants (Christaki, 2012).

Phytosterols

Sea buckthorn consist seventeen phytosterols. The phytosterol content in fresh weight sea buckthorn found to be 310–520 mg/kg (Hussain et al, 2014) and even higher that soybean oil. The dominating phytosterol content is sitosterol, which is between 160–330 mg/kg in fresh weight. The other phytosterols are mostly stigmastanol, campesterol, a-amyrin, and stigmastadienol.

Polyphenols

Recently Criste et. al (2020) identified that the phenolic compounds present in sea buckthorn berries and leaves, were aglycones and derivatives of cinnamic or quercetin acid**.** Total phenolic contents in sea buckthorn recalculated as gallic acid equivalents ranges from 32.93 to 1417 mg/ 100 g in fresh weight (Ivanisova et al, 2017; Rop et al, 2014). Flavonoids, tannins and phenolic acids are the major polyphenols in sea buckthorn (Guo et al, 2017).

- ***Flavonoids***
  Epicatechin, catechin, kaempferol and isorhamnetin are the major flavonoids in sea buckthorn (Fan et al, 2012). The flavonoid level in sea buckthorn berries is vary from 1680 - 8590 mg/kg FW (Heinaaho and Julkunen Tiitto, 2011) and a lot times higher than the concentration present in other high-flavonoid plants like cornelian cherry, European blackberry, , hawthorn, dog rose or blackthorn**.**
- ***Tannins***
  Tannins in sea buckthorn are of two types which are condensed and hydrolysable tannins. These are available in larger amount in sea buckthorn roots, green berries, seeds, stems and flowers (Michel et al, 2012).
- ***Phenolic acids***
  In the plant's immune system, phenolic acids considered to be the most essential compound (Daško et al, 2012). In sea buckthorn, gallic acid in free 10 form is leading with variable concentration appeared in berries (16.9 mg/kg) and leaves (79 mg/kg). While, the other phenolic acids of sea buckthorn observed in minor concentration of ferulic acid, p-coumaric acid and caffeic acid (Bittová et al, 2014). Salicylic acid is the main phenolic acid present in the berries sea buckthorn and the content is between 21- 47 mg/kg depends on the variety. Aside from salicylic acid, sea buckthorn berries also contain gallic acid in minor content (1 - 4.6 mg/kg).

Carotenoids

Carotenoids are mostly found in the soft parts of the fruit, which give them a distinctive orange-yellowish colour. In sea buckthorn berries 15−55% of all compounds of this group is β-carotene (Teleszko et al, 2015). Since, sea buckthorn berries are high in carotenoids as well as up to eighteen different carotenoids observed in the oil of sea buckthorn with the carotenoids owning provitamin A activity (sintexanthin, β-cryptoxanthin, β-zeacarotene, β-carotene and γ-carotene) along with lutein. The oil of sea buckthorn has been a primary subject in terms for health benefits, due to its higher concentration of carotenoids especially zeaxanthin (Preedy, 2014). Pop et. al (2015) identified the total concentration of carotenoids in sea buckthorn which was cultivated in Romania, only on average 172 mg/kg in fresh weight which is equivalent to around 860 mg/kg dry weight of berries. While observing various species, Ranjith et. al (2016) observed that *H. rhamnoides* berries made higher concentration of carotenoids as compared to *H. salicifolia* and *H. tibetana*.

Table 4
Bioactive compounds in sea buckthorn

Compounds		Content
Total Phytosterol (mg/kg)		310–520
	Sitosterol (mg/kg)	160–330
Total Phenolic compounds (mg GAE/100 g)		32.93–1417
	Flavonoids (mg/kg)	1680-8590
	Phenolic acids (mg//kg)	16.9
Total Carotenoids (mg/kg)		172

Therapeutic Properties

Nutritional and bioactive compounds are rich in sea buckthorn as they may affect inflammatory disorders, carcinoma, CVD, gastric ulcer and epidermis problems.

Anti-inflammatory

Chinese and Tibetian natives have been widely using sea buckthorn as a medicine for treating inflammatory disorders. Many studies have showed that it's capable of promoting immunomodulatory and anti-inflammatory activities (Suryakumar and Gupta, 2011). The chief bioactive constituents in sea buckthorn which are responsible for curing inflammatory disorders are antioxidants like carotenoids, flavonoids, vitamin E and ascorbic acid (Sayegh et al, 2014). In addition, the oil of sea buckthorn seed is rich in omega-3 fatty acid which helps in promoting anti-inflammatory property as well as insulin-sensitizing (Fatima et al, 2012). A clinical test was performed by Pentelescu et. al (2014) targeting at acute gingivitis which implied that sea buckthorn maybe used for treating gingivitis through increased immune response and improved gingival tissue. A few presences of mitogens in sea buckthorn activate lymphocyte-proliferation (Patel et al, 2012).

Anti-carcinogenic

Polyphenols in sea buckthorn can prohibit the polyphenols mutation of carcinoma cells, like human breast cancer cells as well as hepatocellular carcinogenic cells (Wang et al, 2021). Especially, berries of sea buckthorn having a potential of anticancer activity. Chemo preventive potential of sea buckthorn was evaluated in mice by Padmavathi et. al (2005) and the results showed that *Hippophae* berry extract stimulated activities of both phase II and antioxidant enzymes in the mouse liver. Studies have also been found that sea buckthorn decreased tumor incidence of skin and forestomach papilloma genesis in mice. Yasukawa et. al (2009) revealed 3 phenolic compounds, epigallocatechin, gallocatechin, tritepenoid and catechin, ursolic acid from the active fraction of the 70% ethanol extract displayed significant anti-cancer activity.

Cardiovascular risk reduction

Reduction of CVD risk is one of the most essential health beneficial activities of sea buckthorn. Since, sea buckthorn is rich in flavonoids like aglycones, quercetin and isorhamnetin, many researchers have tested the effect of various edible parts of sea buckthorn like its berry, flavonoid extracts, oil and its derivatives for preventing the cardiovascular diseases (Xu et al, 2011). Many researches (Koyama et al, 2009; Larmo et al, 2009) have identified the health promoting effects of plant sterols, polyunsaturated fatty acids, antioxidants, and flavonoids which were available in berry's juice, leaves and oil of sea buckthorn.

Flavonoids in sea buckthorn flavonoids improve function of by lowering blood viscosity and scavenging free radicals. There are many other health beneficial effects of sea buckthorn on CVD as they help in lowering the blood sugar level, cholesterol level and pressure level (Xu et al, 2011). It contains good antioxidant activities that's why it could be used for improving blood pressure along with lipids, in order to prevent and treat CVD symptoms like angina, to reduce free radical levels and prevent atheroma too (Zakynthinos and Varzaka, 2015). Numerous studies have revealed that particularly oil and juice of sea buckthorn have a positive effect on cardiovascular functions as well as lowering the cholesterol levels (Bal et al, 2011). Therapeutic properties of sea buckthorn on CVD have been showed in various animal and clinical trials. For instance, patients took 10 mg sea buckthorn flavonoids extract thrice a day for six weeks revealed decreased cholesterol and improved cardiovascular system (Zakynthinos and Varzaka, 2015).

Gastroprotective

Berries and seeds of sea buckthorn have indicated a potential importance in treating the mucous membranes which include gastro-intestinal disorders, ulcers as well as vaginal problems (Bal et al, 2011). The anti-ulcerogenic effect of a hexane extract from *Hippophae rhamnoides* was tested on indomethacin and stress induced ulcer models. As a result, hexane extract from sea buckthorn was found to be active in preventing gastric injury (Suleyman et al, 2001).

Epidermis health

Traditional utilization of sea buckthorn oil helps in the healing of skin injuries and skin conditions which is also agreed with the data of modern clinical and preclinical studies (Suryakumar and Gupta, 2011). Sea buckthorn oil is effective in preventing and treating many skin diseases like Sjogren's syndrome, atopic dermatitis, and elasticity of skin because of the presence of unsaturated fatty acids, phytosterols tocopherols and carotenoids (Larmo et al, 2014). In their study (Marsiñach and Cuenca, 2019) revealed sea buckthorn oil may had clinical properties for skin conditions like atopic dermatitis, dry eye and acne due to the presence of omega-6 fatty acids (γ-Linolenic acid and Linoleic acid). Studies have been indicated that omega-7 (palmitoleic acid) was also available in the oil of sea buckthorn which is beneficial for wound healing and regeneration of skin in the epidermis (Zielińska and Nowak, 2017). Furthermore, sea buckthorn can also facilitate cell migration, eliminate damaged protein, remodel the granulation tissue and regulate the activity of some growth factors through increasing the expression of matrix metalloproteinase in all phases of wound recovery process (Edraki et al, 2014). Sea buckthorn oil is extensively used alone or in many other forms like topically applied for burns, infections, ulcerations and scalds (Chandra et al, 2018).

Table 5
Summary of Therapeutic Properties

Compounds	Health Benefits
Flavonoids, vitamin C and vitamin E	Promotes healthy immune system function.
	Supports healthy cardiovascular function as well as lowering the blood sugar and blood pressure levels.
	Assists in the process of healthy cellular rejuvenation.
	Fights cell-damaging free radicals.
Omega 3, 6 & 7	Promotes healthy skin.
	Supports health of cardiovascular system.
Carotenoids	Supports anti- inflammatory activity.
	Zeaxanthin promotes health of eyes.
Phenolic compounds (catechin, gallocatechin, epigallocatechin and tritepenoid)	Promotes anti- carcinogenic properties.

Toxicity and Safety

Sub chronic toxicity and efficacy study of sea buckthorn oil revealed no significant changes in many haematological, physiological, biochemical (creatinine, uric acid, urea, ALT, ALP and AST) and histopathological parameters in 3 groups of New Zealand white rabbits (0.5, 1, and 1.5 ml/kg body weight) with no mortality in any of the treatment groups (Rashid et al, 2011). Zhao et. al (2017) identified that sea buckthorn oil extracted from whole berry through a supercritical carbon dioxide method during 90-days toxicity study in rats indicated no adverse effects after oral administration. Additionally, in a very latest

study by Wen et. al (2020) pregnant rats were treated with 4.68, 2.34, and 1.17 g/kg oil from gestation 7 to16 days and no treatment-related maternal toxicity or embryotoxicity was found. However, the info about safety and toxicity of sea buckthorn or its derivatives for dietary consumption by humans is still very lacking. Overall, the current results implied that sea buckthorn is not toxic for potential human consumption in food or as a dietary supplement.

Conclusion

Sea buckthorn plant has been extensively used as a traditional remedy in many nations like China, Nepal, India, Pakistan, Romania, Germany, Russia, etc. The berries of sea buckthorn offer good amount of nutrients such as essential amino acid (aspartic and glutamic acid), monounsaturated fatty acid, vitamins (C, E, K) and minerals (calcium, iron, zinc). Also, the major bioactive compounds present in sea buckthorn are sitosterol, salicylic acid, carotenoids, catechin, kaempferol, isorhamnetin, etc. Due to its excellent source of nutrients and bioactive constituents the plant has various therapeutic attributes as they help in fighting against cancer, inflammation, cardiovascular, gastro-intestinal disorders and epidermis problems. Thus, sea buckthorn could be utilized as a promising source of functional and therapeutic food for the consumption of human. Although, a future scope is really required for exploring the mechanism of sea buckthorn nutritional and phytochemical constituents along with the incorporation of cost-effective food products.

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