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Seabuckthorn (*Hippophae rhamnoides*): A repository of phytochemicals

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Abstract
An increased evidence of positive effects of phytochemicals in disease prevention has lead to scientific analysis of many plant materials for their bioactive constituents. Sea buckthorn (SBT) is known to be a good source of antioxidants and other bioactive components which have been found to exert positive effects on human health. A number of pharmacological activities such as cytoprotective, anti-stress, immunomodulatory, hepatoprotective, radioprotective, anti-atherogenic, anti-tumor, anti-microbial and tissue regeneration have been reported in seabuckthorn. Bioactive compounds present in Seabuckthorn may serve as good ingredients for development of functional foods.

Keywords: *Hippophae rhamnoides,* seabuckthorn, hepatoprotective

1. Introduction
Seabuckthorn (*Hippophae rhamnoides*) is a dioecious, nitrogen fixing, wind pollinated, thornywillow-like shrub (Jeppsson, 2009) [22]. The plant has been reported to grow in low humid (15%), alluvial gravel, wet landslips and various soil conditions. It is found on hills, gully tops, and riverside with brown rusty-scaly shoots (Basistha, 2001, Young and Kallio, 2002, Raj *et al*., 2011) [4, 9, 23, 27]. Leaves are alternate, narrow and lanceolate, with a silver-graycolour. The male bud consists of four to six apetalous flowers, which produce wind-distributed pollen whereas, the female bud usually consists of one single apetalous flower with one ovary and one ovule. The female plants produce berry-like fruit, 6‑9 mm in diameter, soft, juicy and rich in oils. The ripe berries are drupe-like and orange/red in colour, consisting of a single seed surrounded by a soft, fleshy outer tissue. Seeds are dark brown, glossy, ovoid to elliptical in shape and 2.8-4.2 mm in size (Bartish *et al*., 2002) [23]. It is able to grow and survive well with low precipitations (300 mm), in soils with pH 9.5 and 1.1% saltswhich makeit possible to be planted even in marginal soils. Natural distribution area for sea buckthorn include China, Mongolia, India, Nepal, Pakistan, Russia, Latvia, Romania, Great Britain, France, Denmark, Netherlands, Germany, Poland, Finland, Sweden, Norway and Canada. In general, the global distribution pattern of Sea buckthorn show that the plant is concentrated mostly in the cold regions.

2. Phytochemistry
The whole plant (fruits, roots, leaves, and stem) is economically important.SBT berries have been proved to be a rich source of antioxidants due to presence of flavonols such as, rutin, quercetin, myricetin, kaempferol, is orhamnetin (Hibasami *et al*., 2005) [19], tocopherols and tocotrienols (Kallio *et al*., 2002) [9, 23] and carotenoids. Moreover, various extracts of sea buckthorn are also known to exhibit marked antioxidant activity (Suleyman *et al*., 2001; Chauhan *et al*., 2007) [30, 6]. Bioactive substances whichmainly include flavonoids, carotenoids, free and esterified sterols, triterpenols, and isoprenols have also been reported in SBT leaf extract. The leaves are an equally rich sourceof important antioxidants including carotene, vitamin E, catechin, elagic acid, ferulic acid and folic acid. The polyphenolic compounds such as tannin fraction was isolated from leaves and the active components were hydrolysable gallo- and ellagi-tannins of monomeric type which includes strictinin, isostrictinin, casuarinin, casuarictin (Shipulina *et al*., 2007) [29]. Bioactive phenolic constituents, such as quercetin-3-O-galactoside, quercetin-3-O-glucoside, kaempferol and isorhamnetin were quantified in aqueous and hydroalcoholic SBT leaf extracts by RP-HPLC (Upadhyay *et al*., 2010) [32]. Oil from sea buckthorn contains several bioactive components such as vitamin E, vitamin K, carotenoids, and β-70 sitosterol (Zeb, 2004) [38]. Recent studies have shown that oil extracts obtained from the berries of sea buckthorn are rich in monounsaturated fatty acids (MUFA) (Yang *et al*., 2001) [33, 34], tocopherols, tocotrienols (Kallio *et al*., 2002) [9, 23], carotenoids, and other bioactive compounds. The leaves of sea buckthorn are rich in kaempferol-3-O- β-D-(6″ -O-coumaryl) glycoside, 1-feruloyl- β-D-glucopyranoside, isorhamnetin-3-O-glucoside, quercetin-3-O- β-D glucopyranoside, quercetin-3-O- β-D-glucopyranosyl-7-O- α-L-rhamnopyrano side, and is orhamnetin-3-O-rutinoside. Studies on SBT suggested that nine fractions, four monomeric flavan-3-ols, catechin, epicatechin, gallocatechin, and epigallocatechin, along with two dimeric procyanidins, catechin (4 α-8) catechin and catechin (4 α-8) epicatechin, can be obtained from the extracts of sea buckthorn seeds (Fan *et al*., 2007; Kim *et al*., 2011; Upadhyay *et al*., 2010) [10, 24, 32]. Various SBT phytoconstituents along with medicinal properties are presented in table 1.

Table 1: Major-phytochemicals in Sea buckthorn and their medicinal properties (Suryakumar & Gupta, 2011).

SBT Phytoconstituent	Medicinal properties	References
Tocopherols	Acts as antioxidant, minimizes lipid oxidation, helps to relieve pain	Kallio *et al*. (2002) [9, 23].
Carotenoids	Acts as antioxidant and helps in collagen synthesis and epithelialization	Andersson *et al*. (2009)
Vitamin K	Prevents bleeding; promotes wound healing; anti-ulcer effect	Jamyansan and Badgaa (2005)
Vitamin C	Acts as antioxidant and sustain cell membrane integrityAccelerates collagen synthesis	Kallio *et al*. (2002) [9, 23].
Vitamin B complex	Stimulate cell repair and nerve regeneration	Jamyansanand Badgaa (2005)
Phytosterols	Improves microcirculation in the skin, anti-ulcer, anti-atherogenic, anti-cancer, regulate inflammatory process	Yang *et al*. (2001) [33, 34].
Polyphenolic compounds	Antioxidant, cytoprotective, cardioprotective, wound healing	Upadhyay *et al*. (2010) [32].
Polyunsaturated fatty acids (PUFA)	Immunomodulatory, neuroprotective, anti-tumor	Yang *et al*. (2001) [33, 34].
Organic acids	Lower the risk of heart attack and stroke, anti-ulcer, wound healing, anti-arthritic	Yang *et al*. (2001) [33, 34].
Coumarins & triterpenes	Control of appetite, sleep, memory and learning	Grey *et al*. (2010) [16].
Zinc	Strengthen the blood circulation, anti-tumor Aids in cell proliferation, acts as a cofactor for enzymes, and enhancesutilization of vitamin A	Gupta and Singh (2005) [15, 16].

3. Role in health promotion

An array of pharmacological effects of SBT have been reported which include antioxidant, immunomodulatory, anti-atherogenic, anti-stress, hepatoprotective, radioprotective and tissue repair (Suleyman *et al*., 2001; Geetha *et al*., 2002; Goel *et al*., 2002; Xing *et al*., 2002; Gao *et al*., 2003; Gupta *et al*., 2005; Basu*et al*., 2007; Chawla *et al*., 2007; Sagguand Kumar, 2007; Upadhyay *et al*., 2010) [30, 14, 15, 33, 17, 18 7, 32]. SBT is used in Russia and Indian Himalayanregion, for treatment of skin diseases, jaundice, asthma, for gastro-intestinal treatment, as laxative and for treatment of rheumatism (Gupta and Singh, 2005) [17, 18]. A number of studies conducted on different parts of the planthave shown cardiovascular effects, effect on atherosclerosis and platelet aggregation, effect on diabetes, anti inflammatory effect, antitumor effect, effect on clinical diseases of the liver, anti-visceral obesity, antiulcerogenic effect, effect on adverse stressfulsituations, etc. Alcoholic leaf extract of sea buckthorn (70% ethanol) has been analyzed to inhibit hypoxia-induced cytotoxicity, mitochondrial integrity, reactive oxygen species (ROS) production, and DNA damage better than vitamin C (Narayanan *et al*., 2005) [25]. Sea buckthorn leaf extract acts as an immunosuppressant during the acute phase of inflammation by selectively inhibiting T-cell activation as a treatment against adjuvant-induced arthritis in rats (Ganju *et al*., 2005) [11].

Protective effect of SBT preparation on cardiovascular diseases are known and well documented in Tibetan traditional medical literature. Studies on human and animals have been carried out to evaluate the effect of flavonoids of SBT on cardiovascular diseases, as some flavonoid compounds are known to have positive ionotropic effects. Flavonoids in SBT fruit and leaves are well known to improve the functioning of cardiovascular system. Seven different kinds of flavonoids, extracted from the leaves and fruit, constitute the total flavonoid content of *Hippophae* (TFH). Among them, the main components are isorhamnetin and quercetin. TFH treatment exhibited protective effects on myocardial ischemia and reperfusion, tumours, oxidative injury and aging (Eccleston *et al*., 2002) [9]. An *in vitro* study conducted by Cheng *et al* (2003) [8, 12] on flavonoids of SBT have shown to reduce the production of pathogenic thromboses. Flavonoids from SBT protected endothelial cells from oxidized low-density lipoprotein induced injuries via regulation of LOX-1 and eNOS expression (Bao and Lou, 2006) [2]. The antihypertensive effect of total flavones extracted from seed residues of SBT have been reported in chronic sucrose fed rats by regulating its insulin and angiotensin II levels have been conducted by Pang *et al*. (2008) [26].

The hepatoprotective activity of SBT leaves and seed oil was evaluated using CCl_4 induced hepatic damage in animals (Geetha *et al*., 2008; Hsu *et al*., 2009) [13, 20], & both alcoholic SBT leaf extract and seed oil ameliorated CCl_4-induced liver injury which was further supported by both histological and biochemical findings.

Seabuckthorn contains epigallocatechin and ursolic acid that exhibits anti-inflammatory effects and is used in the treatment of diarrhoea, gastrointestinal, and dermatologic disorders (Yasukawa *et al*., 2009). The extracts obtained from leaves and branches of sea buckthornbeing rich in flavonoids, tannins, and triterpenes (Kallio *et al*., 2002) [9, 23], are used to treat colitis and enterocolitis in humans and animals (Tsybikova, *et al*., 1983) [31].

4. Conclusion

Seabuckthorn has gained popularity among researchers due to its immense functional and valuable ingredients that exert relatively impressive effects in improving human health. Seabuckthorn comprises of many valuable ingredients which can be explored for the production of many novel, health promoting products. However, there are many knowledge gaps which need to be covered so that, the bioactive components present in SBT may be used in different food formulations for the development of seabuckthorn based functional foods. Studies on safety aspects of seabuckthornare in earlier stages. However, the clinical trials till date mark it safe for human consumption. Without any doubt, the future holds great promise for SBT bio-actives.

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