Seabuckthorn Research Guide – A Review

Overview

Seabuckthorn is a spiny shrub that possesses berries with high nutritional content. Seabuckthorn has been used in traditional Chinese medicine and current research is now beginning to understand and support the traditional uses. Seabuckthorn has several environmental uses, including preventing and controlling soil erosion and land desertification. There are many medicinal uses of seabuckthorn berries and leaves. Most of the research focuses on the health benefits relating to cancer, cardiovascular disease, the immune system, liver cirrhosis, gastric ulcers, and many benefits for the skin. This research review focuses on both environmental and health applications of seabuckthorn baseed on the current research available.

Introduction

Seabuckthorn (*Hippophae rhamnoides L.*, Elaeagnaceae) has been used in traditional Chinese medicine since the Tang Dynasty, going back more than 1000 years. The genus name *Hippophae* is classical Latin for "shining horse," ('Hippo' - horse and 'phaos' - to shine) a name that was given in ancient times after it was found that feeding the leaves to horses improved their health and made their hair shiny (Lu 1992). In 1977, seabuckthorn was officially listed in the Chinese Pharmacopoeia by Ministry of Public Health as a traditional medicine and more than ten different drugs have been developed from seabuckthorn. Seabuckthorn gets its name from its habit of growing near the sea, and from the possession of many spines or thorns that are reminiscent of some buckthorn species (of the genus Rhamnus).

Seabuckthorn is known in different languages as: Shaji (Chinese), Duindoorn (Dutch), Sanddorn (German), Olivello Spinoso (Italian), Oblepicha (Russian), Tyrni (Finnish), Espino de Mar, Falso Espino, Espino Amarillo (Spanish), Havtorn (Swedish).

The Plant

Seabuckthorn is a deciduous and usually spiny shrub with yellow or orange berries that last most of the winter (Bailey and Bailey 1978). It reaches 6 ½ - 13 feet (2-4 m) in height in natural habitats and has brown or black rough bark and a thick grayish-green crown (Rousi 1971). The leaves are a very distinct pale silvery-green. It is dioecious, (separate male and female plants) with male plants producing brownish flowers, which produce wind-distributed pollen. The flowers do not produce nectar which eliminates pollination by insects. The female plants produce orange berries. The berries are round to almost egg-shape, and up to 3/8 inch (1 cm) long. Berries can weigh between 4-60 grams (g) per 100 berries.

Seabuckthorn berries remain on the bushes all winter, unlike most fruits that fall off the plant at maturity, until eaten by birds. Seabuckthorn berries have a unique, strong flavor. They are known to be quite acidic and not very sweet with a mild but characteristic aroma close to that of pineapple. The sourness in seabuckthorn arises from organic acids, primarily malic acid.

Seabuckthorn needs a period of 4-5 years from the appearance of the first shoots from the seeds to the beginning of fruit and peaks at the 7-8th year of plant life, remaining productive for 30 years with intermittent pruning. An orchard planting can yield 10 tones of berries per hectare (2.471 acres).

Seabuckthorn develops an extensive root system rapidly and is therefore an ideal plant for preventing soil erosion (Lu 1992) as well as land reclamation. This is because of its ability to fix nitrogen and conserve other essential nutrients, wildlife habitat enhancement, and farm stand protection (Li and Schroeder 1996). Seabuckthorn is predominantly distributed in temperate regions. It is, however, highly adaptable to varying and extreme conditions, including temperatures

ranging from -43 to 40 ºC, drought, high altitudes, salinity, alkalinity, and inundation.

Seabuckthorn's natural distribution area includes China, Mongolia, India, Nepal, Pakistan, Russia, Great Britain, France, Denmark, Netherlands, Germany, Poland, Finland, Sweden and Norway. More than 90% of the world's seabuckthorn resources can be found in China, where seabuckthorn is mainly planted for soil and water conservation purposes. In China, fruit is harvested from over one million ha (2.5 million acres) of wild seabuckthorn and almost 300,000 ha (750,000 acres) of cultivated plants.

The seabuckthorn industry has been thriving in Russia since the 1940's when scientists there began investigating the biologically active substances found in the berries, leaves, and bark. The first Russian factory for seabuckthorn product development was located in Bisk. These products were utilized in the diet of Russian cosmonauts and as a cream for protection from cosmic radiation (Delabays and Slacanin 1995; Xu et al. 2001).

Environmental Value

Seabuckthorn has been developed into a major resource for China. The main organization overseeing and promoting its utilization is the China Research and Training Centre on Sea Buckthorn, which has given rise to the International Center for Research and Training on Sea buckthorn (ICRTS).

China is one country that is severely affected by progressive land desertification. On losses of soil and water, the indicated degraded areas from water erosion alone are 1.79 million sq. km, with 5 billion tons of soil lost every year nationwide. With desert lands and desertification, the area of non-producing land has reached 3.67 million sq. km. which accounts for 38% of the land base of China. Seabuckthorn has played a significant role in preventing additional desertification and controlling soil and water loss. Seabuckthorn can withstand severe weather and has the ability to take root even in poor soils, because it can fix nitrogen directly from air through the nodules in its roots. By comparison tests, seabuckthorn covered areas have 75% less soil loss by water erosion, 80% less runoff, and 85% less wind erosion than the barren lands.

The planting and maintenance of seabuckthorn is encouraged by the local people who can earn income from harvesting the fruits (and other parts of the plant). It was noted by ICRTS that there have been several successful establishments of seabuckthorn. Jianping County was once a place of green mountains and clean water. Over time, logging had led to a forest coverage rate of only 1.9% and serious land degradation**.** The semi-arid climate, frequent disasters such as floods, droughts, storms and the degraded natural environment had made Jianping County one of the poorest areas in China. After having validated seabuckthorn as the most competitive species in this harsh environment for the purpose of controlling water losses and soil erosion, a total of 67,000 hectares of seabuckthorn forest were planted in the County. The establishment of seabuckthorn plantations created the largest seabuckthorn forest in the world. This helped to increase the vegetation cover from 4% in the 1950s to 34% in the 1990s. Run-off and soil erosion were reduced by 90% and 70%, respectively. Fodder, fuel wood and berries contribute to local economic development. Several wild animal species have found a habitat, including pheasant, hare and fox.

Another successful project has also taken place in the Loess Plateau of northern China. This area had very low vegetation cover and exhibited severe signs of environmental degradation, including an eroded area equal to the area of Iraq. Estimates put the annual top soil losses at 1,600 million tons. Downstream effects include an annual accumulation of sediments in the Yellow River of 400 million tons. Seabuckthorn also has economic potential for people in this area. It now covers more than 200,000 hectares in the Loess Plateau, with the return of wildlife to the Plateau. From the 360 bird species known to live in the region, 51 entirely depend on seabuckthorn as food and 80 are relatively dependent upon seabuckthorn. For

many of the other animal species seabuckthorn is an important source of food or provides shelter.

Seabuckthorn is also becoming prominent in Canada. In Canada, seabuckthorn is proving to be highly beneficial for enhancement of wildlife habitat, farmstead shelter belts, erosion control, and land reclamation.

The largest concentration of seabuckthorn plants is the result of a habitat improvement initiative at the Rafferty wildlife mitigation project, located near Estevan, Saskatchewan. Since 1989, over 50,000 seabuckthorn shrubs have been planted. The population is estimated to have grown significantly since then through colonization by suckering.

Constituents

In addition to seabuckthorn's capacity for natural resource protection, there is recent interest in seabuckthorn due to the fact that the berries are considered amongst the most nutritious and vitamin-rich fruits found. The berries contain more than 100 different kinds of nutrients and bio-active substances. Its vitamin content is much higher than in any other cultivated fruit or vegetable. The berries are rich in vitamins, carotenoids, flavonoids, minerals, essential oils, and essential fatty acids. Potassium is the most abundant of all the elements investigated in berries or juice. Both fructose and glucose account for about 90% of the total sugar content. Low levels of the sugar alcohols mannitol, sorbitol, and xylitol have also been found in the berries. Seabuckthorn berries are also a rich source of several amino acids. Up to 18 different amino acids have been detected. Of these, eight free amino acids (threonine, valine, methionine, leucine, lysine, trytophan, isoleucine, and phenylalanine) are essential for the human body.

The fruit has high contents of pulp oil and oil soluble bioactive compounds, such as tocopherols, tocotrienols, carotenoids, and plant sterols. The leaves of seabuckthorn also contain considerable protein (averaging 15%). The exact composition varies with the origin, climate, and method of extractions.

The following constituents are some that have been found in the fruit:

Constituents of Seabuckthorn Fruit (per 100 grams fresh berries)	
Vitamin C	200-1,500 mg (typical amount: 600 mg)
Vitamin E (mixed tocopherols)	Up to 180 mg (equal to about 270 IU)
Carotenoids, including beta carotene, lycopene, zeaxanthine	30-40 mg
Fatty acids (oils); the main unsaturated fatty acids are oleic acid (omega-9), palmitoleic acid (omega-7), palmitic acid and linoleic acid (omega-6), and linolenic acid (omega-3); there are also saturated oils and sterols (mainly β-sitosterol)	6-11% (3-5% in fruit pulp, 8-18% in seed); fatty acid composition and total oil content vary with subspecies
Flavonoids (mainly isorhamnetin, quercetin glycosides, and kaempferol)	100-1,000 mg (0.1% to 1.0%)

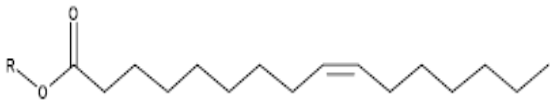
Vitamin C concentrations in seabuckthorn fruit range from 100-300mg/100g fruit, which is higher than strawberry, kiwi, orange, tomato, carrot, and hawthorn (Bernath and Foldesi 1992; Lu 1992). Comparatively, orange juice contains about 35-40 mg/100 g of fruit.

Seabuckthorn yields two different oils: seed oil (about 0.5% of the whole berry) and the pulp oil (2-3% of the whole berry) (Yang 2001). The fatty acids found in the seed oil are common, including high levels of oleic, linoleic and linolenic acid. The fruit pulp oil is much more interesting because it contains 16-54% palmitoleic acid (9-*cis*-hexadecenoic acid), which is only found in high levels in very few sources (Yang 2002). The fruit residue, which includes the outer peel, is rich in the colorful carotenoids and vitamin E, while the seed has the highest level of the unsaturated fatty acids and sterols.

The oil components from several samples have been analyzed as follows (Zeb 2004):

Ingredient	Seed Oil	Pulp Oil	Fruit Residue Oil
Vitamin E	207	171	300-600
Vitamin K	110-230	54-59	-
Carotenoids	30-250	300-870	1280-1860
Total acids	11	38	-
Total flavonoids	-	-	550
Total sterols	1094	721	-
Unsaturated Fatty Acids	87%	67%	70%
Saturated Fatty Acids	13%	33%	30%
Palmitoleic acid	-	16-54%	-
Oleic acid	32.8%	-	-
Linoleic acid	21.7- 42%	-	
Alpha-linolenic acid	Up to 39%	-	-
Palmitic acid	26.3%	-	-

Palmitoleic Acid



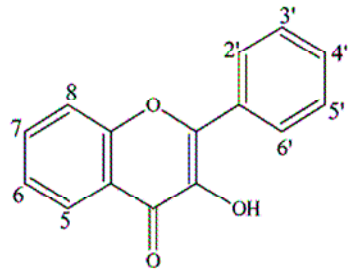
Palmitoleic acid can be found in almost any oil of animal or plant origin, although usually in very low concentrations. The most available source of palmitoleic acid is in macadamia nut oil, which contains 17-34% (Cummings 1999). Human epidermal lipid contains up to 20% palmitoleic acid (Yang 2003). Seabuckthorn has been shown to have 16-54% palmitoleic acid.

Flavonoids

Flavonoids are compounds found in fruits and vegetables and are know to have several biological effects in the body. Seabuckthorn has been shown to contain several important flavonoids.

Important flavonoid compounds in seabuckthorn (Zhao 1997):

Chemical Formula
Isorhamnetin-3-O- galactorhamnoside
Isorhamnetin-3-O-glucoside
Isorhamnetin-3-O-glucorhamnoside
Isorhamnetin-5-O-glucoarabinoside
Isorhamnetin-3-Oglucoglucoside
Isorhamnetin-7-O-rhamnoside
Isorhamnetin
Isorhamnetin-3-O-gluco-7-Orhamnoside
Myricetin
Quercitin-3-O-rutin
2,4-dihydroxy-chalcones-2-Oglucoside
Quercitin
Isorhamnetin-3-O- galactoside
Isorhamnetin-3-O-gluco-(166) Glucoside
Quercitin-3-O-glucoside
Quercitin-7-O-rhamnoside
Quercitin-3-methyl ether
Kaempferol



Kaempferol 5=7=4'=OH

Quercetin 5=7=3'=4'=OH

Myricetin 5=7=3'=4'=5'=OH

Health Applications

Many health claims are associated with seabuckthorn. Vitamin C in seabuckthorn, together with tocopherols and tocotrienols, has a strong antioxidant effect (Kallio 2002). The berries seem to have preventive effects against cardiovascular diseases, mucosa injuries, and skin problems, possibly through the enhancement of cell membrane regeneration (Kallio 1999; Yang 2002). External uses of seabuckthorn include treating a wide variety of skin damage, including burns, bedsores, eczema, and radiation injury. Each of these health benefits with be reviewed below, focusing on the key research available in each of these areas.

Antioxidant: Oxidative stress is an outcome of the over production of reactive oxygen species (ROS) that overwhelms the antioxidant capacities of the cell (Meydani 1995). An antioxidant is a substance (such as beta-carotene, vitamin C, and vitamin E) that inhibits oxidation or reactions promoted by oxygen and peroxides and help to protect the body from the damaging effects of free radicals.

A free radical is a reactive atom or group of atoms that has one or more unpaired electrons. Free radicals are produced in the body by natural biological processes or introduced from outside (as in tobacco smoke, toxins, or pollutants) and that can damage cells, proteins, and DNA by altering their chemical structure.

In a cell, mitochondria are the major site of oxidative stress because of some leakage of electrons during ATP production and also due to inefficient machinery for repair of mitochondrial DNA. For repair of nuclear DNA and recovery of many intracellular organelles energy is the most important requirement. In a cell, mitochondria are the most important source for energy generation. Therefore, any antioxidant that manifests a radioprotective effect should also protect mitochondria. Protection of the mitochondrial system can have far reaching significance in the prevention and recovery of free-radical-induced chronic disease, such as arteriosclerosis, arthritis and several neurological disorders (Goel 2005).

Diets rich in fruits and vegetables are reported to protect against certain forms of cancer believed to be due to their ability to prevent oxidative damage (Block 1992). The dietary intake of flavonoids from fruits and vegetables has also been shown to be inversely related to coronary heart disease mortality (Hertog 1993; Hertog 1995). These atherosclerotic diseases are explained as a consequence of damage to human low-density lipoprotein (LDL) by reactive oxygen species (ROS). In many in vitro experiments, phenolic compounds have been shown to inhibit the oxidative damage of LDL. Because of their antioxidant characters, flavonoids and phenolic acids are able to reduce free radical formation and to scavenge ROS. (A phenolic compound is a generic term for any compound similar in structure to a phenol - an organic compound with one or more hydroxyl groups attached to an aromatic or carbon ring).

Naturally occurring polyphenols found in fruits and vegetables are among of the main sources of antioxidants in our diets and thus have numerous biological activities. Growing evidence of the role of free radicals and antioxidants in health and aging has focused great interest on these compounds because many clinical studies support the fact that consuming fruits and vegetables is beneficial to prevent age-related diseases, cancers, heart diseases, *etc.* These protective effects are considered, in large part, to be related to various antioxidants contained in plants.

Seabuckthorn berries contain high contents of natural antioxidants including:

- ascorbic acid (vitamin C)
- tocopherols (vitamin E)
- carotenoids
- flavonoids - isorhamnetin, quercein, kaempferol
- catechins
- proanthocyanidins
- chlorogenic Acids

Several studies have quantified the antioxidants available in seabuckthorn and demonstrated the antioxidant benefits of these compounds found in seabuckthorn.

One study indicates that ascorbic acid and proanthocyanidins are the major hydrophyllic antioxidants of seabuckthorn juice (Rosch 2003). Compounds identified include: ascorbic acid, gallic acid, protocatechuic acid, catechin, epicatechin, proanthocyanidins, querectin, and isorhamnetin. Of flavonols identified, isorhamnetin 3-O-glycosides were the most important representatives quantitatively. Besides proanthocyanidins, further quantitatively important phenolic compounds of seabuckthorn juice are isorhamnetin 3-*O*-glycosides, but contribute little to the total antioxidant activity of the juice because they only show limited radical scavenging properties. Phenolic compounds such as quercetin 3- O-glycosides, catechins, and hydroxybenzoic acids with a catechol structure exhibited good antioxidant capacities, but their concentration in seabuckthorn juice was small. Ascorbic acid was shown to be the major antioxidant in seabuckthorn juice. Because of its high concentration of 1.22 g/L, it contributes approximately 75% to total antioxidant activity.

To determine the immunomodulatory and antioxidant properties of seabuckthorn, an alcoholic extract of leave and fruits were used (Geetha 2002). The extracts were found to inhibit

chromium-induced free radical production, apoptosis, DNA fragmentation and restored the anti-oxidant status to that of control cells. The leaf and fruit extracts improved the antioxidant defense system of the cells by increasing the intracellular GSH levels and inhibiting ROS production. In addition, these extracts also were able to arrest the chromium-induced inhibition of lymphocyte proliferation, indicating that the extracts also have immunodulating activity. These observations suggest that the alcoholic extracts of leaves and fruits of seabuckthorn have marked cytoprotective properties, which could be attributed to the antioxidant activity.

Summary of Key Antioxidant Studies

Health Benefit	Part of Plant	Type of Study	Reference
Antioxidant Activity	Juice	*In vitro*	Rosch 2003
Antioxidant in CHD	Juice	Human	Eccleston 2002
Reducing fat and antioxidant	Oil	Human	Yang 2002
Immuno-modulatory	Oil	Rat	Geetha 2002
Antioxidant in CHD	Juice	Human	Rice-Evans 1994

Cancer

It has been estimated that 30-40 percent of all cancers can be prevented by lifestyle and dietary measures alone (WCRF/AICR 1997). Protective elements in a cancer prevention diet include selenium, folic acid, vitamin B-12, vitamin D, chlorophyll, and antioxidants such as the carotenoids (α-carotene, β-carotene, lycopene, lutein, cryptoxanthin) (Steinmetz 1996). Modern nutrition research strongly indicates that a diet rich in fruits and vegetables protects against cancer. There is a great interest currently to identify plant products that can be used in cancer chemoprevention that would prevent tumor initiation and promotion. Drug metabolizing, detoxifying, and antioxidant enzymes are important cellular defenses against carcinogenesis.

Based on research findings, it is thought that due to the antioxidant proprieties of seabuckthorn, it may have chemopreventive and antitumorigenic efficacy. Research has also shown that the constituents present in the whole extract manifest radioprotection by several mechanisms, like free-radical scavenging, metal chelation, chromatin compaction and hypoxia induction (Goel 2003; Kumar 2002). It has also been reported to provide protection to whole mice, various tissues, cells and cell organelles against lethal irradiation. The research in this area is limited and most of the research has been animal studies.

One study using *Hippophae rhamnoides* tested the possible cancer chemopreventive potential in mice (Padmavathi 2005). The study showed that *Hippophae* fruit extract stimulated activities of both phase II and antioxidant enzymes in the mouse liver. The fruit extract also had a positive effect on all antioxidant enzyme, these include SOD (superoxide dismutase), CAT (catalase), GPX (glutathione peroxidase), GR (glutathione reductase), and GSH (glutathione S-transferase). There was also a dose-dependent decrease in the lipid peroxidation, indicating reduced levels of cellular oxidation processes. The study also found that seabuckthorn reduced tumor incidence of skin and forestomach papillomagenesis in mice.

In another study, five types of flavonols were isolated from seabuckthorn and identified (Hibasami 2005). The proliferations of human promyelotic leukemia HL-60 cells were inhibited as the concentrations of these flavonols were increased. The order of the extent of growth inhibition by the flavonols at a concentration of 20 microM is as follows: pentamethylquercetin > syringetin > isorhamnetin > quercetin > kaempherol > myricetin. Apoptotic morphological changes of the nucleus, including chromatin condensation were induced in the HL-60 cells treated with quercetin, kaempherol and myricetin, respectively, but not in the cells treated with the other flavonols. These findings suggest that growth inhibition by quercetin, kaempherol and myricetin, respectively, results from the induction of apoptosis by these flavonols. The other flavonols (pentamethylquercetin, syringetin and isorhamnetin) having methoxy (-OCH3) group inhibited more strongly than the above 3 flavonols without induction of apoptosis in the HL-60 cells. These findings suggest that mechanisms of growth inhibition by pentamethylquercetin, syringetin and isorhamnetin are different from the apoptosis caused by quercetin, kaempherol and myricetin.

Another study used the whole extract of the fresh berries of *Hippophae rhamnoides L.* (RH-3) and tested its effects on mitochondria isolated from mouse liver (Goel 2005). Superoxide anion, reduced (GSH) and oxidized glutathione (GSSG) levels, NADH-ubiquinone oxidoreductase (complex I), NADH-cytochrome c oxidoreductase

(complex I/II), succinate-cytochrome c oxidoreductase (complex II/III), mitochondrial membrane potential (MMP), lipid peroxidation (LPx) and protein oxidation (PO) were determined for RH-3-mediated radioprotective manifestation. Pre-irradiation treatment of mice with RH-3 (30 mg kg(-1,) i. p.; single dose; -30 min) significantly inhibited the radiation-induced increase in superoxide anions, GSSG, thiobarbituric acid reactive substances (TBARS), complex I, complex I/III activity and MMP maximally at 4 h ($P < 0.05$). This treatment inhibited the oxidation of proteins ($P < 0.05$) at all the time periods studied here. This study suggests that pre-irradiation treatment of mice with RH-3 protects the functional integrity of mitochondria from radiation-induced oxidative stress. The results of this investigation suggest that RH-3 conferred protection to mitochondria in-vivo against radiation-induced oxidative stress and therefore could be helpful in the prevention and treatment of several free-radical ailments associated with oxidative stress, including radical ionizing radiation-induced damage.

Summary of Key Cancer Studies

Health Benefit	Part of Plant	Type of Study	Reference
Chemoprevention	Pulp	Mouse	Padmavathi 2005
Chemoprevention	Pulp	Mouse	Padmavathi 2005
Protection against radiation	Whole extract	Mouse	Goel 2005
Non-specific immunity	Oil	Rat	Geetha 2002
Prevent Nicotine Oxidative Stress	Juice	Rat	Suleyman 2002
Protection against radiation	Oil	Rat	Agrawala 2002
Protection against radiation	Oil	Rat	Goel 2002
Anti-cancer	Oil	Rat	Xu 1994
Immunological anti-tumor	Oil	Rat	Yu 1993
Anti-mutagenic	Oil	Mouse	Neresian 1990
Non-specific immunity	Oil	Rat	Zhong 1989

Cardiovascular

There is increasing evidence to support the hypothesis that free radical-mediated oxidative processes contribute to atherogenesis (Eccleston 2002, Ivanov 1973). Research (*in vitro*) has shown that antioxidant nutrients have the ability to affect cell response and gene expression. Seabuckthorn is a rich source of antioxidants both aqueous and lipophilic, as well as polyunsaturated fatty acids, which may provide cardiovascular benefits.

In the first study, the objective was to characterize the antioxidant profile of seabuckthorn juice (SBJ) and to evaluate its effect on plasma lipids, LDL oxidation, platelet aggregation and plasma soluble cell adhesion protein concentration (Eccleston 2002). Twenty healthy male volunteers were given either a placebo or seabuckthorn juice for 8 weeks. Additional daily intakes of vitamin C, alpha-tocopherol, beta-carotene and flavonoids through seabuckthorn juice supplementation were 462, 3.2, 1.0 and 355 mg respectively. Results of the study found that seabuckthorn juice affects the risk factors (plasma lipids, LDL oxidation, platelet aggregation and plasma soluble cell adhesion protein concentration) for coronary heart disease in humans due possibly to the high antioxidant levels.

In another study, patients with ischemic heart disease were given total flavonoids of seabuckthorn, 10 mg, 3 times daily for 6 weeks (Chai 1989; Yang 2002). The patients had a decrease in cholesterol level and improved cardiac function. They also they had fewer anginas than those receiving the control drug. No harmful effect of seabuckthorn flavonoids was noted in renal functions or hepatic functions. The mechanism of action may include reduced stress of cardiac muscle tissue by regulation of inflammatory mediators.

Studies have also show that the major factors leading to the atherosclerosis are the lipid oxidation damage and anti-oxidation treatment could significantly inhibits the atherosclerosis formation and the incidence of coronary heart disease have a close relation with HDL cholesterol (Salahat 2002). This was observed in 230 abnormal blood fat cases and 190 cases with all information, among them 102 cases were selected as treatment group (dried *Hippophae* emulsion) and 92 cases as the control group (Yang 1995). All patient were treated for 12 consecutive weeks and the blood fat were checked at 4, 8, 12 weeks after treatment. The results showed that 4 weeks after treatment, the dried *Hippophae* emulsion could decrease the total cholesterol in the blood, the arteriosclerosis index [(TC-HDL)/HDL] and increase the high-density lipoprotein (HDL). After treatment, TC decreased average 19.2%, (TC-

HDL)/HDL decrease average 28.2% and HDL increase average 18.1%, eight weeks after treatment, the triglycerides content decreased significantly, average decreasing 20.1%. This study suggests that dried *Hippophae* emulsion could adjust the abnormal blood fat and have anti-oxidation function.

Summary of Key Cardiovascular Studies

Health Benefit	Part of Plant	Type of Study	Reference
Arterial thrombosis	Oil	Mouse	Cheng 2003
Cardiovascular Disease	Oil	Rat, Human	Rosch 2003
Coronary Heart Disease	Juice	Human	Eccleston 2002
Cardiovascular Disease	Oil	Rat, Human	Sadek 1999
Cardiovascular Disease	Oil	Rat, Human	Tabassum 1998
Cardiovascular Disease	Oil	Rat, Human	Zhao 1997
Cardiovascular Disease	Oil	Rat, Human	Xu 1994
Coronary Heart Disease	Juice	Human	Rice-Evans 1994
Artherosclerosis	Oil	Human	Ivanov 1973

Immune

The immune system is a complex system that is responsible for distinguishing us from everything foreign to us, and for protecting us against infections and foreign substances. The immune system is composed of many interdependent cell types that collectively protect the body from bacterial, parasitic, fungal, viral infections and from the growth of tumor cells. The cells of the immune system work together with different proteins to seek out and destroy anything foreign or dangerous that enters our body. There are a wide variety of immune cells, each with its own strengths and weaknesses. Some seek out and devour invading organisms, while others destroy infected or mutated body cells.

Research indicates that seabuckthorn may be able to strengthen the immune system. One *in vitro* study focused on the possible immunomodulatory properties of seabuckthorn (Geetha 2002). Alcoholic extracts of leaves and fruits of seabuckthorn were found to inhibit chromium-induced free radical production, apoptosis, DNA fragmentation and restored the antioxidant status to that of control cells. The leaf and fruit extracts improved the antioxidant defense system of the cells by increasing the intracellular GSH levels and inhibiting ROS production. In addition, these extracts also were able to arrest the chromium-induced inhibition of lymphocyte proliferation, indicating that the extracts also have immunodulating activity. These observations suggest that the alcoholic extracts of leaves and fruits of seabuckthorn have marked cytoprotective properties, which could be attributed to the antioxidant activity.

Summary of Key Immune Studies

Health Benefit	Part of Plant	Type of Study	Reference
Immuno-modulatory	Oil	Rat	Geetha 2002

Liver

Liver cirrhosis is a common chronic hepatic injury caused by chronic hepatitis B, ethanol consumption and metabolic disorders, etc.

In a recent clinical study, seabuckthorn was used in cirrhotic patients to determine its effect on the changes of fibrotic parameters, improvement of liver function and whether it could be used as a therapeutic antifibrotic agent (Gao 2003). The study indicates that seabuckthorn may help prevent progression of liver fibrosis, due to the vitamin A content and precursors and their role in the progression of liver fibrosis. Seabuckthorn may be a hopeful drug for prevention and treatment of liver fibrosis, but further well controlled clinical trials are required.

Summary of Key Liver Studies

Health Benefit	Part of Plant	Type of Study	Reference
Treatment of liver fibrosis	Oil	Human	Gao 2003
Treatment of chronic hepatitis	Oil	Human	Huang 1991
Treatment of liver fibrosis	Oil	Human	Cheng 1990
Protective effect of liver injury	Oil	Human	Zao 1987

Skin

Seabuckthorn seed oil contains a high content of two essential fatty acids, linoleic acid and α-linolenic acid (Chen 1990), which are precursors of other polyunsaturated fatty acids such as arachidonic and eicosapentaenoic acids. The oil from the pulp/peel of seabuckthorn berries is also rich in palmitoleic acid and oleic acid (Chen 1990). Palmitoleic acid is a component of skin.

Palmitoleic acid is a monounsaturated oil and is a highly effective antioxidant. It is a component of skin fat. It has highly emollient qualities and slight sunscreen properties. Palmitoleic acid is found in tropical oils such as macadamia nut, sesame seed, and seabuckthorn. Research has shown palmitoleic acid to be an important topical agent in treating burns and healing wounds. This fatty acid can also nourish the skin when taken orally if adequate quantities of seabuckthorn or its oil are consumed. This is a useful method for treating systemic skin diseases, such as atopic dermatitis. Seabuckthorn oil is currently used alone or in various preparations topically applied for burns, scalds, ulcerations and infections.

Abnormal levels of fatty acids have been recognized in the plasma, skin, adipose tissue and breast milk of atopic dermatitis patients compared to healthy controls. Research has shown that the efficiency of incorporation and metabolism of dietary linoleic and a-linolenic acids strongly affects the essential fatty acid status of the human body.

A clinical study tested the effects of seabuckthorn oil on atopic dermatitis patients (Yang 1999). Forty-nine patients were randomly divided into three groups taking orally ten oil capsules (5g oil) of seabuckthorn seed oil, pulp oil or paraffin oil per day for a period of four months. The fatty acid compositions of plasma phospholipids and neutral lipids of the patients were analyzed before, after one month and at the end of the treatment. Skin biopsies were taken from sixteen patients, and the fatty acid compositions of skin glycerophospholipids were analyzed before and after the treatment. Supplementation of the seed oil significantly increased the proportion of α-linolenic acid in plasma neutral lipids and total n-3 fatty acids in plasma phospholipids and neutral lipids. Increases in the proportion of α-linolenic acid, linoleic acid and eicosapentaenoic acid in plasma phospholipids by the seed oil treatment were close to significant ($0.05 < p < 0.1$). The pulp oil treatment increased the proportion of palmitoleic acid and lowered the proportion of pentadecanoic acid in both plasma phospholipids and neutral lipids. Seed oil treatment slightly increased the level of docosapentaenoic acid (22:5n-3) and decreased the level of palmitic acid (16:0) in skin glycerophospholipids. These results indicate a higher efficiency of incorporation and metabolism of α-linolenic acid than linoleic acid and a relatively stable fatty acid composition of skin glycerophospholipids.

In another study, thirty-two cases were treated, 19 were males, 13 were females; the oldest was 78 years old, the youngest was 1 year and two months old. Twenty-eight cases of scalds were caused by various reasons and four cases were gas burning; among them 12 cases were degree I burning, 18 cases were degree II light burning, 2 cases were degree II serious burning. In 14 cases, the burnt area were 5% and 10 cases were under 10%, 1 case was 15% and 4 case were above 20%. In 28 cases, they were treated with Hippophae seed oil directly after burning and in 4 cases they were treated in another hospital first and then transferred and treated with Hippophae seed oil. It established that Hippophae seed oil had functions like improve the human immunity, remove blood stasis and promote blood circulation, anti-inflammation and pain relieve, increase the tissue regeneration etc. and had magic effects in treating burns and scalds. This medicine is easy to use and reliable in the effectiveness without any side effect and could widely use in clinical treatment of burns and scalds (Yang 2003; Mingya 1994).

Summary of Key Skin Studies

Health Benefit	Part of Plant	Type of Study	Reference
Skin disease	Oil	Rat	Geetha 2002
Atopic Dermatitis	Oil	Human	Yang 2000
Atopic Dermatitis	Oil	Human	Yang 1999
Atopic Dermatitis	Oil	Human	Yang 1999
Atopic Dermatitis	Oil	Human	Yang 1999
Skin disease	Oil	Rat, Human	Mingyu 1994
Skin burning	Oil	Human	Zhao 1994

Other
Seabuckthorn has been shown to have additional health benefits for gastric ulcer, healthy mucus membranes, and neurotoxicity protection.

Gastric Ulcers
Hippophae is traditionally used in the treatment of gastric ulcers, and laboratory studies confirm the efficacy of the seed oil for this application (Zhou 1998, Xing 2002). Its functions may be to normalize output of gastric acid and reduce inflammation by controlling pro-inflammatory mediators.

One study was looking to identify new compounds with more potency against ulcers and few side effects than traditional drugs (Suleyman 2001). The antiulcerogenic effect of a hexane extract (HRe-1) obtained from the ripe fruit of seabuckthorn (*Hippophae rhamnoides*) was investigated on ulcer models produced by stress and indomethacin. Seabuckthorn was found to be active in preventing gastric injury. It was observed that the number of ulceration areas was prominently decreased in the seabuckthorn group. It is evident from the data that the number and areas of ulcerative zones of the seabuckthorn group was lower than that from rats treated with the other drugs. Seabuckthorn contains α, β, γ, carotenoids, vitamins B, C, E, riboflavin, folic acid and tannins. The cumulative effects of these vitamins on the prevention of mucosal injury and the fact that some vitamins are needed for metabolic events to occur in a normal manner may explain why seabuckthorn is active in preventing gastric injury. In conclusion HRe-1 obtained from *H. rhamnoides* has a reliable usage in folk medicine and should be investigated further for its potential as an antiulcerogenic drug.

Several additional animal studies have also shown the seed oil of *Hippophae rhamnoides* has protective effects against gastric ulcers. One study showed the *Hippophae rhamnoides* at doses of 2.5 mL/kg and betasitosterol beta-D-glucoside at relatively small doses of 12 mg/kg had a significant protective effect on acetic acid-induced chronic gastric ulcers in rats and mice (Jiang 1988). Another study using a hexane extract of *Hippophae rhamnoides* seeds on gastric ulcers in rats and rabbits showed positive benefits as well (Mironov 1989).

Neurotoxicity
Lead (Pb) is a highly neurotoxic agent that particularly affects the developing central nervous system. Exposure to low levels of Pb has been associated with behavioral abnormalities, learning impairment, decreased hearing, and impaired cognitive functions in humans and in experimental animals. Because oxidative damage is also involved in Pb toxicity, we examined parameters of oxidative stress in the brain from mice chronically exposed to the metal. In this study, we used behavioral and neurochemical experiments to determine the protective effects of HRL against the neurotoxicity induced by lead.

One study examined the effect of *Hippophae rhamnoides* L. (HRL) juice on lead-induced memory impairment and neuronal damage in the brains of adult mice (Xu 2005). Kunming mice were exposed to lead acetate 10 mg/kg body weight for 20 d. Twenty percent and 40% HRL prevented the lead-induced decrease in step-through latency. In the water maze test, the swimming time was lengthened in mice treated with lead acetate, but this time was decreased in mice that received 20% and 40% HRL. The malondialdehyde (MDA) levels were increased in lead treated mice, which were reduced by 20% and 40% HRL in dose-dependent manner. The activities of acetylcholinesterase (AchE) and monoamine oxidase-A and -B were significantly increased in the lead-treated group, which were decreased by 40% HRL but not by 20% HRL. The levels of norepinephrine, serotonin, and 5-hydroxyindole acetic acid were decreased significantly in the lead-treated mice, and the decreases were antagonized by 40% HRL, except for than in dopamine, but 20% HRL had no effect on this change. These data suggest that the different doses of the HRL juice protect against the lead acetate-induced deficits in learning and memory and changes in neurobiochemical parameters.

Summary of Key Studies

Health Benefit	Part of Plant	Type of Study	Reference
Neurotoxicity Protection	Juice	Mice	Xu 2005
Gastric Ulcer	Oil	Rat	Xing 2002
Gastric Ulcer	Oil	Rat	Suleyman 2001
Gastric Ulcer	Oil	Rat	Zhou 1998
Gastric Ulcer	Oil	Rat	Suleyman 1997
Gastric Ulcer	Oil	Rat	Nuzov 1991

Conclusion

Fruits and vegetables are among of the main sources of antioxidants in our diets and offer a wide variety of benefits and protection based on their numerous activities. Research supports the role fruits and vegetables have in providing protection from cancers, heart diseases, and many age-related diseases. Free radicals are thought to be involved in the development of many of these diseases. The benefits of a diet high in fruits and vegetables may provide protection from these diseases due to the role antioxidants have in providing protection from the damage caused by free radicals. Research is now beginning to suggest that seabuckthorn may offer several health benefits due to the fact that the berries are considered amongst the most nutritious and vitamin-rich fruits found. Seabuckthorn berries are a source of valuable chemicals including vitamin C, micro and macronutrients, sugars and organic acids and oil. Additional research is needed in further understand the benefits seabuckthorn may play in the prevention and treatment of many diseases.

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