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Product Development of Sea Buckthorn

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INTRODUCTION

Sea buckthorn (*Hippophae rhamnoides* L., Elaeagnaceae) is a hardy, deciduous, dioecious, and usually spinescent shrub (Rousi 1971). It reaches 2–4 m in height in natural habitats and bears yellow or orange-red berries, referred to as "Siberian pineapple" in Russia, because of its taste and juiciness (Abartene and Malakhovskis 1975). The natural habitat of sea buckthorn extends widely in China, Mongolia, Russia, and most parts of Northern Europe. It is a unique and valuable plant currently cultivated in various parts of the world, including Canada (Li and Shroeder 1999). It can withstand extreme temperatures from –43° to 40°C and is considered to be drought resistant. However, irrigation is needed in regions receiving less than 400 mm (16") of rainfall annually (Li and Shroeder 1996). Sea buckthorn develops an extensive root system rapidly, and is therefore an ideal plant for soil erosion control (Lu 1992), land reclamation because of its ability to fix nitrogen and conserve other essential nutrients, wildlife habitat enhancement, and farm stand protection (Li and Schroeder 1996).

Sea buckthorn is mentioned in the writings of ancient Greek scholars such as Theophrastus and Dioscorides. Sea buckthorn was known as a remedy for horses, and leaves and young branches were added to fodder, to induce rapid weight gain and a shiny coat, and in fact, the generic name *Hippophae* means shining horse (Lu 1992). Sea buckthorn has been used for centuries in both Europe and Asia for food and pharmaceutical purposes (Bailey and Bailey 1978; Li and Schroeder 1996).

The information on nutritional and medicinal value of sea-buckthorn is relatively new in North America. The medicinal value was recorded as early as the 8th century in the Tibetan medical classic *rGyud Bzi*. Recently, sea buckthorn has become the source of important medicinal and nutritional products in Eurasia and its nutritional and medicinal values is being noticed and explored in North America (Li 1999).

The sea buckthorn industry has been thriving in Russia since the 1940s when scientists there began investigating the biologically active substances found in the berries, leaves, and bark. The first Russian factory for sea buckthorn 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). The Chinese experience with sea buckthorn fruit production is more recent, although traditional uses date back many centuries (Lu 1992). Research and plantation establishment were initiated in the 1980s. Since 1982 over 300,000 ha of sea buckthorn have been planted in China. In addition, 150 processing factories have been established producing over 200 products.

Recently, sea buckthorn has been recommended for orchard-type cultivation in Canada. As a relatively new cultivated crop, some important characteristics which need improvement in the future are yield, fruit size, thornlessness, fruit quality, and early maturity. Knowledge of mechanical harvesting, and crop management techniques including soil fertility, cultivation techniques, pruning, and pest, disease, and weed controls, and nitrogen-fixing ability are also needed urgently (Li and Schroeder 1999).

SEA BUCKTHORN CULTIVATION

Sea buckthorn normally is transplanted or directly seeded in the fall or spring. It grows best in deep, well drained, sandy loam soil with ample organic matter. In arid or semiarid regions, water must be supplied for establishment. Soil acidity and alkalinity, except at extreme levels, are not limiting factors, although it thrives best at pH 6 to 7. Sea buckthorn is sensitive to severe soil moisture deficits, especially in spring when plants are flowering and young fruits are beginning to develop. Sea buckthorn, like other crops, requires adequate soil nutrients for a high yield with better quality berries. It responds well to phosphorus fertilizer (T.S.C. Li unpubl. data). Nitrogen fertilization can adversely affect root nodulation and it delays the development of nodules after inoculation with *Frankia* (Akkermans et al. 1983; Montpetit and Lalonde 1988; Bosco et al. 1992).

Recommended plant spacing for sea buckthorn varies, regions with lower land values and bigger machines may consider larger spacing. In British Columbia, 1 m within the row and 4 m between rows was recommended. Rows should be oriented in a north-south direction to provide maximum light. The ratio of male to female plants is important for maximizing fruit set. Recommendations for male : female ratios vary with plant density and region. In British Columbia, with an orchard planting of 2500 trees/ha, a 1 male : 6–8 females ratio is considered adequate. Sea buckthorn flowers are wind pollinated. Moderate pruning is required to maximize yield and reduce yearly fluctuations. The crown should be pruned annually to remove overlapping branches, and long branches should be headed to encourage lateral shoot development. Weed control is very important in sea buckthorn planting, especially for promoting growth of newly planted seedlings (Li and Schroeder 1999).

RESEARCH AND DEVELOPMENT

Pacific Agri-Food Research Centre of Agriculture and Agri-Food Canada at Summerland, British Columbia began sea buckthorn research a few years ago. The objective is to develop technology for commercial sea buckthorn production and value-added products in North America. Production problems include thorniness, harvest difficulties due to lack of abscission of berries which are firmly attached to the branches, tree size, establishment of a pruning system, disease, insect and pest control, and the need for a mechanical harvester.

Thorniness

Almost all *Hippophae* species start to develop thorns (2–5 cm) on two- or three-year-old plants. This characteristic is undesirable if harvesting is done by hand. Testing for new selections without thorns are underway in combination with selection for fruit size, yield, nutraceutical value, and oil content.

Berry Persistence

The transformation of the raw sea buckthorn berry into a sophisticated product requires appropriate harvest, transportation, holding, and storage procedures. Berries persist on the branches all winter due to the absence of an abscission layer and firm berry attachment to the fruiting branch has enormous difficulties for harvest. The total labor cost estimated for harvesting a sea buckthorn orchard of 4 ha was 58% of the total cumulative production costs over 10 years (Schroeder et al. 1996).

Studies are underway to determine if ethephon [(2-chloroethyl) phosphonic acid], an ethylene generator which reduces berry removal force in sour cherries and many other fruit crops, will be effective in sea buckthorn. Preliminary results indicated that ethephon can reduce berry removal force marginally if it was applied 10 days before havest.

Tree Size Control

Shrubs of most of the *Hippophae* species can reach 2–4 m in height and require a proper pruning system to maintain manageable height and shape.

Diseases, Insects, and Pests

At the present time, few pests or diseases on sea buckthorn have been reported. The most damaging insect is green aphids, rose leaf roller, gypsy moth, gall tick, comma-shaped scale, fruit fly, and caterpillars. Diseases reported on sea buckthorn are verticillium wilt, fusarium wilt, damping off, brown rot, and scab. The pests which cause damage to sea buckthorn include deer, birds, mice, and rats. However, since sea buckthorn is a new cultivated crop, there are no registered pesticides or fungicides. Research is underway in Canada to find the best chemical and organic control measures.

Harvesting

Prototype harvesters, available commercially in Germany, are based upon the principle of cutting off the fruit branch (Gaetke and Triquart 1992; Olander 1995). Since sea buckthorn sets fruit on second year wood, harvesting by this method means that a harvest can be obtained only every other year which is economically unsuitable for most of the farmers in North America.

In some countries, sea buckthorn is harvested in the winter after berries have frozen, however, the loss of moisture and vitamins involved with waiting for the first seasonal freeze may be unacceptable in some circumstances and flavor is unacceptable. In Canada, the most successful methods of mechanical harvesting have involved shaking the individual branches of the shrub *in situ* to dislodge the berries, without any damage if the berries are not overripe, causing them to fall into a catcher placed around the base of the tree.

Postharvest Handling and Storage

Sea buckthorn berries when overripe carry a strong musky odor with rancid taste, detectable even in the field. Washing may reduce or change the odor (Beveridge et al. 1999). To avoid this problem, berries must be harvested at the correct stage, quickly transported to the processing plant, and be cooled immediately to temperatures around 4° to 6°C to retard growth of microorganisms

If the berries are to be stored more than a few days, they should be frozen, preferably by individual quick freezing techniques. The berries are thawed and processed to products as required on demand. Juice extracted by pressing or centrifugal techniques must be stored under refrigeration and requires pasteurization and freezing for long term storage. Alternatively fruit may be processed into pasteurized or sterilized finished products and stored in that form at room temperature. The shelf life even of sterilized product is limited but improved in refrigerated storage.

CHEMICAL COMPOSITION AND SOME PHYSICAL PROPERTIES

Juice

The fruit of the sea buckthorn plant weighs between 270 and 480 mg and averages 350 mg depending upon cultivar and maturity (Li 1999). Pressing these berries yields 60% to 85% juice. Juice yield of 67% has been reported derived from centrifugal methods (Heilscher and Lorber 1996). The juice is very high in organic acids as reflected in the high levels of titratable acidity, and has a low pH (near 2.7). Quantitatively the most important organic acid is malic acid, but there several other minor acids have been reported (Beveridge et al. 1999). Protein levels are fairly high for a fruit juice and this probably explains the fact that sea buckthorn juice is a cloudy or opalescent product.

Vitamin C content has been reported as high as 600 mg/100 g of fruit. Vitamin E content is 160 mg/100 g of fruit (Bernath and Foldesi 1992). Pulp and seeds contain triglyceride oils with important medicinal value such as superoxide dismutase activity in mice, which enhance the activity of NK cells in tumor bearing mice (Dai et al. 1987; Chen 1991; Degtyareva et al. 1991).

Oil

There are two sources of oil in sea buckthorn fruit: the seed which contains 10%–15% (w/w) oil and the pulpy fruit parts surrounding the seed which contains 29%–48% oil (T.S.C. Li, unpubl. data). Both pulp and seed oils from sea buckthorn vary in vitamin E content depending on whether derived from seed oil (64.4 to 92.7 mg/100 g seed), juice oil (216 mg/100 g berry), or from the pulp after juice and seed removal (481 mg/100 g berry). Carotenoids also vary depending upon the source of the oil.

The seed oils are highly unsaturated with up to 73% or more of the fatty acids making up the oil being linoleic or linolenic (Oomah et al. 1999). Pulp oil is more saturated with about 38% of the fatty acids being palmitic, and 14%–50% of the fatty acids being palmitoleic acid. The difference between seed and pulp oil seems to lie in the relatively high content of C_{16} fatty acids in the pulp oil and the relatively high proportion of C_{18} fatty acids in the seed oil.

Phytosterols

Phytosterols are plant sterols with structures related to cholesterol and which are capable of lowering plasma cholesterol on consumption by humans. Elevated blood cholesterol is one of the well established risk factors for coronary heart disease and lowering this indicator can presumably impact heart disease incidence (Thurnham 1999). Phytosterols are the major constituents of the unsaponifiable fraction of sea buckthorn oils. The major phytosterol in sea buckthorn oil is sitosterol (β-sitosterol), with 5-avenasterol second in quantitative importance. Other phytosterols are present in relatively minor quantities. The total quantity of phytosterol is quite high in sea buckthorn and may exceed soybean oil by 4–20 times. It was reported that the total sterol content, varied between subspecies and collection sites, in the seeds, fresh pulp/peel, and the whole berries were 1200–1800, 240–400, and 340–520 mg/kg, respectively (Yang et al. 2001). Clearly, as a source of dietary sterol, sea buckthorn is worthy of further consideration.

PROCESSING AND PRODUCTS

There, potentially, is a wide array of products possible from sea buckthorn fruit for use as food, fresh fruit, nutraceuticals, pet foods, cosmetics, and skin preparations for improving the health and appearance of the skin.

Juice Extraction

If fresh pressed juice is allowed to stand one or two days it will separate into three phases: an upper floating particulate phase, a center liquid portion, and a sinking particulate sediment. This separation is undesirable from a consumer point of view (Kleinschmidt et al. 1996)

If pulp oil is left in the juice, it will result in the formation of an oil layer on the juice surface, creating an oil ring that remains on the package surface after the juice is removed. This oil ring remaining on the package is unsightly and undesirable. Centrifugal reduction of the juice oil content below about 0.1% will eliminate the floating oil problem. As the oil is removed by the disk stack centrifuge, the coarse sediment will be sedimented to the bottom of the bowl and can be removed automatically by the dislodging mechanisms present in the centrifuge (Beveridge et al. 1999). Alternatively the crushed berries or extracted juice may be treated with a preparation containing pectinmethylesterase (PME) (Lui and Lui 1989), or perhaps treated with one of the many commercially available hydrolytic enzyme preparations.

For preservation purposes, it is necessary that the juice be sterilized/pasteurized. High-temperature-short-time (HTST) processes of 80°–90°C for several seconds are preferred (Liu and Lui 1989). This is because the juice is somewhat delicate and will sustain a loss of flavor and develop an off-flavor if heated beyond the conditions indicated. Furthermore, vitamin C is destroyed by heating so maximum retention is promoted by HTST processing.

The juice turns brown after about 6 months at 15°–20°C, and this browning is reduced under non-oxidative conditions. Reducing storage temperatures to 4°C prolongs storage life (Zhou and Chen 1989) and enzymes and sunlight are important sources of browning initiation.

Normally, sea buckthorn juice is an opalescent, to very turbid juice depending upon the amount of suspended solids remaining after centrifugation. However, ultra filtration may be used to remove all particulate and produce a clear juice (Bock et al. 1990; Heilscher and Lorber 1996). The ultra filtration membrane can have a molecular weight cutoff of 100,000 or more and the process produces an oil-free permeate and an oil-rich retentate which can be utilized for production of pulp oil rich in vitamin E and a solid material rich in carotenoids which may be used as an isolation source for the pigment or as a dietary supplement.

Oil Extraction

Sea buckthorn offers two possibilities for oil extraction. Pulp oil exists in the juice pulp and is isolated as a cream layer by centrifugal technology. The usual methods for manufacturing oil commercially require countercurrent (usually) extraction of the oil bearing material, seed or pulp, with an organic solvent, commonly hexane (Weiss 1963, 1970).

Increasingly, consumers are demanding fewer residues in their foods. Newer extraction techniques such as supercritical fluid extraction (SCE) especially carbon dioxide under high pressure can be used to reduce oil residues. Sea buckthorn oil may be a secondary product since it is a specialty oil used in medicine, as a nutraceutical supplement, and in cosmetics (Beveridge et al. 1999).

Pigment

A pigment termed "sea buckthorn yellow" can be extracted from sea buckthorn waste material. The waste material could be the press cake remaining after juice extraction or the sediments remaining after centrifugation. In one process the pigment is extracted with low concentrations of alcohol (Chen et al. 1995; Liu et al. 1989) after concentrating the suspension to 11°–13° Brix. The waste material is spray dried to yield a yellow powder. It contains flavones but also, carotene and vitamin E. Supercritical CO_2 has also been used to extract a yellow coloring material from sea buckthorn waste. Pressure had the greatest influence on extraction with yields increasing with extraction pressure. A yield of 64% total carotenoids was achieved under processing conditions of 60 MPA, 85°C (Messerschmidt et al. 1993).

Teas

Sea buckthorn leaves contain nutrients and bioactive substances. These include flavonoids (Chen et al. 1991), carotenoids, free and esterified sterols, triterpenols, and isoprenols (Goncharova and Glushenkova 1996). Numerous products can be made from the air dried leaves including teas and tea powders.

Animal Feed

One potentially large market for sea buckthorn, are nutraceutical products for animals. The large volume of “waste” material from sea buckthorn, such as leaves, fruit, pulp, and seed residues from juice and oil extraction, could be developed into a value-added product. Sea buckthorn leaves contain approximately 15% protein and berry and seed residues still contain valuable chemical substances at low concentrations.

CONCLUSIONS AND FUTURE PROSPECTS

Sea buckthorn is a unique and valuable new field crop currently being domesticated in Canada. The berry and seed are the main sources of its nutritional and therapeutic values. These beneficial effects have made sea buckthorn products, especially its oils, desirable for medicinal and cosmetic purposes. Sea buckthorn products and materials, mostly imported from China, range from oil, juice, tea, and food additives to candies, jellies, cosmetics, and shampoos. In North America, a sea buckthorn industry has yet to be developed. However, with recent emerging interest and increasing plantings, sea buckthorn will play a significant part in the future nutraceutical market.

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