FRACTIONATION AND PROCESSING OF SMALL FRUITS FOR
APPLICATIONS IN FUNCTIONAL FOODS AND NUTRACEUTICALS

Progress Report for April 21, 2010 – April 15, 2011
A Research and Development Project
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Submitted to:
Manitoba Rural Adaptation Council
c/o Kristin Yaworski-Lowdon
700 - One Research Road
Winnipeg, MB R3T 6E3
Ph: (204) 982-4795
Toll free: 800-216-9767
Fax: (204) 982-4794

Prepared by:
Alphonsus Utioh*, Meeling Nivet, Ramachandran Gopal,
Daniella Alejo, Prabal Ghosh, Paulyn Appah

*To whom correspondence should be addressed to. Email: Alphonsus.Utioh@gov.mb.ca

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ACKNOWLEDGEMENT AND DISCLAIMER

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EXECUTIVE SUMMARY

Seabuckthorn, dwarf sour cherry and blue honeysuckle (haskap) are emerging berry crops in western Canada. Seabuckthorn is the second highest rated ‘superfruit’ after goji berries because it contains exceptional amount of key nutrients (vitamins A, C, E) and antioxidants (carotenoids, polyphenols). Sour cherry is known for its anthocyanins (antioxidants) content. Haskaps contain higher phenolic compounds than blueberries, sweet in taste and easy to grow. In order to take advantage of the nutritional and health benefits of these small berry crops grown in western Canada, it is essential to develop processing technologies and find applications for these berries and their fractions in functional foods and nutraceuticals.

The goal of this project was to develop processing and fractionation technologies for total utilization of the selected prairie fruits and develop innovative value-added products using whole fruits and their fractions for commercialization. Seabuckthorn leaves were processed into bulk tea and research was initiated on the development of a ready to drink beverage. Complete chemical analyses were conducted on the whole fruits and seabuckthorn leaves. The fruits were fractionated into puree, juice, skins/pulp and seed, and where applicable, the seed and pulp were stored for extraction of seed and pulp oils. The fruit juices were evaluated for the development of a beverage blend for specific health benefits. Research on osmotic dehydration (sugar-infusion) of the fruits was conducted.

This interim report summarizes the findings of the research to date. In this report, the word “fruit” and “berry” are used interchangeable. Osmotic dehydration results have shown that a blend of osmotic solution of liquid honey and apple juice to a °Brix of 50, produced the most desired product based on the sensory attributes. The fruits were pre-treated by blanching to improve the permeability of the fruit skin for osmotic solution. Processes were developed for fractionation of the fruits and a processing flow chart was established for future reference. Saskatoon berries were notably high in calcium (97.6 mg/100 g) followed by blackcurrant (60.2 mg/100 g) and then chokecherries (25.9 mg/100 g). Seabuckthorn showed the highest vitamin A content (301.3 RE/100 g) and vitamin C content (149 mg/100 g). Only seabuckthorn showed any appreciable amount of vitamin E (6.22 mg/100 g). Blackcurrant had the highest level of potassium (2900 µg/g) followed by chokecherry (2700 µg/g), saskatoons (2200 µg/g) and seabuckthorn (1900 µg/g). The beta-carotene content of seabuckthorn was highest among the fruits (3013 IU/100 g). As expected, the sugar content of the fruits was highest in saskatoon berries (17 g/100 g) and lowest in seabuckthorn (2.4 g/100 g).
Anthocyanins and total polyphenols content of the fruits were also analysed. Blackcurrant showed the highest anthocyanins content (306 mg/100 g) and total polyphenols (385 mg/100 g). The total anthocyanin content of seabuckthorn was negligible (< 1 mg/100 g). The total polyphenols values for other berries were as follows: saskatoons (346 mg/100 g), sour cherry (142 mg/100 g), chokecherry (131 mg/100 g), and seabuckthorn (89 mg/100 g).

The analysis of seabuckthorn leaves showed ORAC value of 80325 μmol TE/100 g, total flavonoids of 7500 mg/100g and total polyphenols of 9638 mg/100 g.

Preliminary results of this study have shown that saskatoon berries, chokecherries, blackcurrant, sour cherries and seabuckthorn have the potential to be used as ingredients in the functional food and nutraceutical industry. These research findings provide new information and could be used as a marketing tool for the Prairie fruit growers and processors.

The research was carried out in collaboration with Prairie Fruit Growers Association to ensure industry relevance of the findings. Financial support was provided by Manitoba Rural Adaptation Council and Alberta Horticultural Congress.
1.0 INTRODUCTION

This report provides an update of the work completed to date (April 15, 2011) at the Food Development Centre (FDC) on the project entitled “Fractionation and Processing of Small Fruits for Applications in Functional Foods and Nutraceuticals” jointly funded by the Manitoba Rural Adaptation Council (MRAC), Alberta Horticultural Congress (AHC) and Prairie Fruit Growers Association (PFGA). The report is prepared according to MRAC reporting format to list key achievements under each activity as per Part V of the Agreement.

The overall objectives of the project are to develop processing and fractionation technologies for total utilization of the selected prairie berries and develop innovative value-added products using whole berries and their fractions for commercialization.

This is a collaborative project with FDC in Portage la Prairie; Food Processing Development Centre in Leduc; Saskatchewan Food Centre and University of Saskatchewan. FDC, as the lead research organization, signed a contract with PFGA on June 21, 2010 for the purpose of conducting the research on their behalf.

Based on the approved work plan, the project team at FDC has been working on the following major components of the project work:

- develop processing and fractionation technologies for total utilization of berries;
- determine chemical and nutritional profile of whole berries and their fractions;
- develop value-added products using whole berries and their fractions; and
- develop technology and knowledge transfer plans of the processes and products for commercialization.

2.0 KEY ACHIEVEMENTS

2.1 Literature Review

The purpose of the literature review was to gather any information available on the selected fruits, chokecherries, sour cherries, saskatoons, seabuckthorn, haskap and blackcurrants to help in experimental design for the project. Fractionation technologies were reviewed. A detailed report of the literature review is being prepared for the final report of this project. A summary of some of the findings for each fruit is presented in this report.
Chokecherry (*Prunus virginiana* L.)

Chokecherry (*Prunus virginiana*) is a member of the Rose family and native to North America. Chokecherries are single-seed, dark red-purple in colour and typically mature during the fall of each year. The seeds, twigs, barks and leaves of chokecherry plant contain cyanide, which upon digestion by humans and livestock releases poisonous hydrocyanic or prussic acid (Dinstel, 2008, Anonymous, 2010). The stems are diuretic. Therefore, care must be taken to process chokecherry by removing its seeds or not crushing the seeds during juice extraction (Dinstel, 2008). The flesh portion of the fruits is safe to consume.

Some physio-chemical properties of the fruits are pH, 3.8-4.2; soluble solids, 16.4-19.5°B; total solids, 31.5-38% (Zatylny et al., 2005). Green (2007) reported that citric acid (471 mg/100 g fruit) is the most prominent organic acid in chokecherries followed by malic (189 mg/100 g fruit) and succinic acids (142 mg/100 g fruit). Dinstel (2008) reported that chokecherries are good source of dietary fibre (68% of the RDA), vitamin K (37% of RDA), manganese, potassium and vitamin B6.

*Aronia melanocarpa* (black chokecherry) has attracted scientific interest due to its deep purple, almost black pigmentation that arises from dense contents of phenolic phytochemicals, especially anthocyanins. Total anthocyanin content in chokeberries has been reported as 1480 mg per 100 g of fresh berries, and proanthocyanidin concentration is 664 mg per 100 g. (Wu et al. 2004 and 2006). Both values are among the highest measured in plants to date. Their findings were also confirmed by Li et al. (2008) for Manitoba fruits when measuring the total antioxidant capacity by ORAC assay.

Analysis of anthocyanins in chokecherries has identified the following individual chemicals (among hundreds known to exist in the plant kingdom): cyanidin-3-galactoside, epicatechin, caffeic acid, quercetin, delphinidin, petunidin, pelargonidin, peonidin and malvidin. All these are members of the flavonoid category of antioxidant phenolics. Li et al. (2008) reported extremely high levels of caffeic acid, up to 6455 mg per kilogram of the fruit powder. Li reported that caffeic acid levels decreased in the order: saskatoon berry > wild blueberry > red strawberry > raspberry > seabuckthorn.
Juice from chokecherries is astringent and not sweet, but high in vitamin C and antioxidants. The juice can be used to make concentrates, jellies, syrups, purees, sauces, beverages, jams and wine. The juice would be well suited to juice blends for colour and marketed for their antioxidant properties. The juice can be concentrated for ease of transportation and storage.

**Seabuckthorn (Hippophae rhamnoides L.)**

Seabuckthorn (Hippophae rhamnoides L.) is a hardy deciduous shrub with yellow or orange fruits and has been used for food in both Europe and Asia for centuries (Yang, & Kallio, 2002a). It is currently domesticated in many parts of the world like China, Russia, Mongolia, Kazakhstan, India, Nepal, Pakistan, Afghanistan, Hungary, Romania, Switzerland, Germany, France, Britain, Finland, Sweden, Norway and Canada. With the application of modern analytical techniques, almost all parts of the plant (fruits, leaves and bark) are shown to have a unique composition emphasizing its potential as a dietary and medicinal supplement (Li, Beveridge, & Drover, 2007).

The component and uses of the plant part are shown in Table 1. Research has indicated that extracts isolated from the bark of seabuckthorn may inhibit tumour growth and there are reports that it has successfully treated gingivitis (Xu, Xie, Pan, Yang, Wang, Cenkowski, Hydamaka, & Rao, 2006). The leaves of the seabuckthorn plant also contain many nutrients and bioactive substances (Guan, Cenkowski, and Hydamaka, 2005). Leaves harvested from the male plant can be used to produce tea, tea extracts, tea powder and animal feed (Li, 2007). The extensive root system of seabuckthorn plant offers environmental benefits in soil conservation and land reclamation.

<table>
<thead>
<tr>
<th>Plant Part</th>
<th>Component</th>
<th>Uses</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>Pulp, seed, juice</td>
<td>Food, drinks, pharmaceuticals</td>
<td></td>
</tr>
<tr>
<td>Pulp</td>
<td>Oil</td>
<td>Pharmaceuticals, cosmetics, pigment</td>
<td></td>
</tr>
<tr>
<td>Seeds</td>
<td>Oil</td>
<td>Pharmaceuticals, cosmetics</td>
<td></td>
</tr>
<tr>
<td>Leaves</td>
<td>Sterols, flavonoids, carotenoids</td>
<td>Pharmaceuticals, cosmetics, teas</td>
<td></td>
</tr>
<tr>
<td>Bark</td>
<td>Hippophan (5-hydroxytryptamine), proanthocyanidins</td>
<td>Pharmaceuticals</td>
<td></td>
</tr>
<tr>
<td>Roots</td>
<td></td>
<td>Soil conservation, land reclamation</td>
<td></td>
</tr>
</tbody>
</table>
Chemical Composition

Fruits contain many bioactives including vitamin C, vitamin E, flavonoids and carotenoids. Seed and pulp contain oils which are known for their fat-soluble vitamins, plant sterols and essential fatty acids. The vitamin C content of seabuckthorn ranges from 150 to 2500 mg per 100 grams of fruits. The vitamin C content is dependent on the varieties (Yang, & Kallio, 2001), plant location, maturity of the fruits, harvesting time, altitude of growing environment and processing method, and is among the highest in the plant kingdom. Health Canada’s recommended daily intake (RDI) of vitamin C for an adult is 60 mg/day, which means an average Canadian only needs to consume 2.4 - 40 grams of the fruit to meet the vitamin C requirement. Seabuckthorn is known for its high content of α-tocopherol (vitamin E) in its seed oil. An average adult only needs to take about 5 g of seabuckthorn seed oil to meet the daily vitamin E requirement. Tocopherol is recognized as the natural antioxidant in the human body. It is believed that high levels of tocopherol minimize skin oxidation which helps to maintain skin integrity and reduce skin toughening and wrinkling. Seabuckthorn oils are also believed to have a biological protective capacity. The tocopherols and carotenoids can trap and reduce the formation of UV-B induced toxic products in skin cells. Due to these UV-B absorptive properties, seabuckthorn oils may be used by industry as a natural sun screen (Yang, & Kallio, 2006).

Other unique constituents of seabuckthorn are relatively high amount of unsaturated fatty acids, especially high amount of ω-3 fatty acid in its seed oil. The ratio of omega-6 to omega-3 is 1:1. The palmitoleic acid (ω-7) in the pulp oil is known to be the highest in the plant kingdom to date (Yang, & Kallio, 2002b). Table 2A and 2B show the unique constituents in the seabuckthorn fruit or oils. High amounts of carotenoids, flavonoids, and sterols in seabuckthorn contribute to the unique colour and antioxidant capacity of the fruits. The palmitoleic acid and carotenoid contents found in seabuckthorn oils are claimed to promote healing of skin burns and relief other skin ailments such as eczema and dermatitis. While high organic acid content contributes to the unique tart flavour of the fruits, and presents beverage development challenge to food developers.

Table 2A: Unique constituents of seabuckthorn fruit

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipids:</td>
<td></td>
</tr>
<tr>
<td>Unsaturated: oleic acid (ω-9), palmitoleic acid (ω-7), palmitic acid and linoleic acid (ω-6), and linolenic acid (ω-3), Saturated Sterols (mainly β-sitosterol)</td>
<td>6 - 15% of seed</td>
</tr>
<tr>
<td>Carotenoids, including β-carotene, lycopene, zeaxanthin</td>
<td>30 - 40 mg/100g of fruits</td>
</tr>
</tbody>
</table>
Flavonoids (e.g., mainly isorhamnetin, quercetin glycosides, and kaempferol) | 10 - 1000 mg/100g of fruits
---|---
Organic acids (malic and quinic acids) | 3.5 - 4.4 (% malic acid)

Table 2B: Unique constituents of seabuckthorn fruit

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Amount (per 100 g of fruit or oil)</th>
<th>Recommended Daily Intake (RDI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin C</td>
<td>500 - 1,000 mg (700 mg)</td>
<td>60 mg (&lt; 10 g of fruit)</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>Up to 200 mg (300 IU)</td>
<td>8 - 10 mg (5 g of oil)</td>
</tr>
<tr>
<td>Folic acid</td>
<td>Up to 0.08 mg</td>
<td>0.18 - 0.2 mg (250 g of fruit)</td>
</tr>
</tbody>
</table>

Haskap (Lonicera Caerulea L.)

Haskap (Lonicera caerulea) berries are native to Russia, Japan and Canada. The word Haskap means “lot of little things on top of the branches” in the Ainu language. Haskap is also known by the following names as blue honeysuckle, edible honeysuckle, honeyberries, hashup, haskap, or hasukappu. The plants can withstand very low temperatures like -40 to -50°C while the flowers can withstand up to -8°C.

The flesh or pulpy part of the fruit is dark-purple, juicy and aromatic. It tastes sour to sweet and the fruit texture is soft to firm. The fruit contains about 20 seeds and the seeds are similar to tomato seeds in shape and colour, but the size of the seed is similar to that of kiwi fruit and it may not be noticeable while eating.

In Canada, Dr Bob Bors of the University of Saskatchewan has been involved in Haskap breeding research since 1998, and has worked on Siberian, Russian and Japanese cultivars. Borealis and Tundra varieties are considered the best for commercial production. It has been reported that the Tundra variety fruit is almost 50% larger than other varieties available in Canada, which is suitable for individually quick frozen (IQF) processing. These fruits are suited for mechanical harvesting, making commercial production attractive.

Haskap is rich in Vitamin C (40-70mg/100g). It has a high content of ascorbic acid from 28.56 up to 86.96 mg/100gm, potassium 10,175 to 14,764 mg/kg and anthocyanins from pomace 6.245- 17.36 g/kg. Dry matter content of haskap berries were reported as 14.42 to 20.27%. Sugar content ranged from 4.3 to 12.8% (Jurikova et al, 2007). Soluble fibre content of the berries was found to be 14.8%. Organic acid content for the berries is 12.2% (Svarcova et al, 2007).
A variety of food products can be made from Haskap such as puffed snacks, jam and jellies, candy, chewing gum, ice-cream, yogurt, pies, fruit cake, berry bars, tea, flavoured noodles, soft drinks, canned and frozen fruit, juice, wine and they can also be eaten fresh.

**Sour cherry (Prunus cerasus L.)**

Sour cherry fruit is round or heart-shaped, glabrous drupe with long pedicels. The pit is generally smooth and encloses a single seed. Sour cherries are typically bright red in colour. The world production of sour cherries is 1.36 Mt (FAOSTAT, 2009). Russia is the largest producing country followed by Poland, Turkey and Germany. Canada produces around 7518 Mt of sour cherries on an annual basis (FAOSTAT, 2009). The mass of each sour cherry fruit ranges between 2.5 and 3.2 g. Total soluble solids ranges between 16 and 25°Brix.

Sour cherries are rich in phytochemicals such as anthocyanins and flavonoids. Phytochemicals act as antioxidants and also regulate enzyme metabolitic activities, modulate nuclear receptors, gene expression and sub-cellular signalling pathways, and repair DNA oxidative damage (Seeram, 2000). Sour cherries contain a large amount of anthocyanins which possess strong antioxidant and anti-inflammatory activities. Anthocyanin concentrations in sour cherries range from 569 to 858 mg/L. Bušić et al. (2008) reported that sour cherries offer high antioxidative activity due to the presence of higher concentration of anthocyanins. Anthocyanins content is approximately 30% higher in enzymatically treated juices compared to heat treated juices. Approximately 58% loss of anthocyanins was reported during storage of sour cherry nectars at 20°C for six months. Will et al. (2007) also reported that juice colour depends on both anthocyanins and polyphenols, which act as co-pigments. Therefore, reduction in anthocyanins due to processing does not entirely change the colour of the juice.

Commerically sour cherries are processed into purees, concentrates and juices. Sour cherries contain little pectin; hence, it is easy to extract its juice (Will et al., 2007). Purees are used in pastries, confectionary or dairy industry; juices or concentrates serve as source of fruit nectars and fruit beverages. IQF (individually quick frozen) sour cherries and dehydrated sour cherries in sweetened and unsweetened forms can also be produced.
Saskatoon berries are native to southern Yukon and the Northwest Territories, the Canadian prairies and the northern prairie states of the United States (Mazza 1986). Saskatoon berries belong to the Rosaceae family and Amelanchier genus. Saskatoon berry varieties include Honeywood, Northline, Martin, Smoky and Thiessen. The mature fruit is a purple berry like pome, 1-1.5 cm in diameter and contains 1-5 very small seeds. The physico-chemical properties of saskatoon berries are: total solid content, 19.9-27.9%; soluble solids, 14.0-20.1%; pH, 3.65-4.18; Titratable acidity, 0.291-0.631 % of malic acid (Zatynly et al., 2005a,b). The berries typically taste like a blend of cherries, blueberries, plums and almonds. Mazza (1982) noted that saskatoons are an excellent source of manganese, magnesium and iron and a relatively good source of calcium, potassium, copper and carotene (Table 6). Saskatoon berries were reported as a better source of calcium than red meat, vegetables and cereals as they supply 11% of the recommended dietary allowance (RDA). They are a good source of iron supplying 22.3% of the RDA (Mazza and Cottrell, 2008). Saskatoon berries are a good source of manganese, which is beneficial for bone health. According to Prairie Berries Inc. of Keller, Saskatchewan, 100 g saskatoon berries provide almost 70% of daily recommended intake.

Saskatoon berries are rich in antioxidants which scavenge free radicals and inhibit intracellular oxidation (Green and Mazza, 1986; Hu et al., 2005). According to Hosseinian et al. (2007), the antioxidant capacity of whole saskatoon berry measured by the oxygen radical absorbance capacity (ORAC) is 449.4 mg/100 g in the methanol fraction (equivalent of Trolox). This value is similar to chokecherry (479.5 mg/100 g) and much higher than strawberry (190.75 mg/100 g), raspberry (167.6 mg/100 g), wild blueberry (331.5 mg/100 g) and seabuckthorn (135.7 mg/100 g) (Hosseinian et al., 2007). Mazza (1986, 2006) reported the presence of about 13 phenolic compounds in saskatoon berries with total phenolics ranging between 405 and 498 mg/100 g in Smoky and Northline varieties. Total polyphenol content in saskatoon berries ranges between 535.45 and 801.37 mg of gallic acid equivalent per 100 g fresh weight (Bakowska-Barczak and Kolodziejczyk, 2008).

Saskatoon berries can be processed for bakery products such as pies, muffins, biscuits, breads and cakes; beverages such as juice, tea, cider, beer, wine and liqueur; preserves such as jam, jelly, sauce, pie filling, syrup, salad dressings; dried products such as powder, infused berry, fruit leather, snacks or trail mixes; sweets such as chocolate coated, maraschino type or gelatin type; and other foods such as meat stuffings, soups and cheese flavourings (Mazza, 2006).
Saskatoon berries contain one to five tiny seeds containing 9.44-17.01% oil. Bakowska-Barczak (2009) reported that saskatoon berry seed oil is a potential dietary source of tocopherols, sterols and unsaturated fatty acids and could offer good oxidative stability properties.

**Blackcurrant (Ribes Nigrum)**

Blackcurrant is the edible berry of a shrub, which usually grows to 1 to 2 meters and is native to Northern/Central Europe and Asia. The berry has a black colour, a calyx at the top and a rather glossy skin and it contains several seeds. The taste of blackcurrant is very sweet but also astringent. The leaves are deeply lobed. The white flowers are rather small and grow in short clusters. During summer, the familiar small, shiny, dark purple (almost black) berries are formed. All parts of the plant, but especially the young buds, have a strong and typical blackcurrant fragrance.

Blackcurrants are very rich in phytonutrients, antioxidants, vitamins, essential fatty acids and minerals. In particular, blackcurrants are known for their high content of Vitamin C (a powerful antioxidant), GLA (Gamma-Linoleic Acid, a rare Omega-6 essential fatty acid) and potassium. They have been reported to have twice the potassium of bananas, four times the vitamin C of oranges, and twice the antioxidants of blueberries. They contain many anthocyanins, which are very potent antioxidants and are responsible for the colour of blackcurrants. In addition, blackcurrant seed oil contains 47% linoleic (18:2n6), 14% alpha-linolenic (18:3n3), 12% gamma-linolenic (18:3n6), and 2.7% stearidonic (18:4n3) acids.

Blackcurrants are often used to make jellies, jams, added to desserts or as an ingredient in sauces and dips. Commercially, blackcurrants are commonly used to make cordial, liqueur, added to ice-cream and are found in juice form (e.g., Ribena). Other applications include leaves being used to improve the taste and colour of Vodka, and it is also a common ingredient in beverages in the UK, where it is mixed with cider to form "Cider and Black" and is also added to beer (Guinness).

### 2.2 Conventional Drying and Osmotic Dehydration of Whole Berries

The main objective of this activity is to develop suitable processes for the preservation of the selected small fruits for further utilization in food products. Drying of fruits and vegetables is one of the most time and energy consuming processes in the food industry. To reduce the processing time, thus facilitating and accelerating the dehydration process,
a number of obstacles must be overcome. The main challenge for this type of fruit preservation is the outer layer of the fruit, which is the skin. The skin impedes water transfer from the interior of the fruit to its surface; thus, slowing the drying process whether in conventional or osmotic dehydration.

Two pre-treatment methods for the fruits were chosen for investigation: blanching and hot/cold water dip. In this reporting period, only steam blanching was investigated. Chemical treatments of the fruits were not considered as these fruits are known for their health promoting benefits. Liquid Honey (70*Bx) and a mixture of liquid honey and apple juice (50*Bx) were chosen as the osmotic solutions (natural sweeteners) to maintain the health characteristics of the fruits.

Preliminary work has been completed on saskatoon berries at a laboratory scale. Frozen berries were supplied by Anthony Mintenko, Fruit Crops Business Development Specialist (BDS) with Manitoba Agriculture Food and Rural Initiatives (MAFRI), Crop Knowledge Centre. The berries were stored in FDC freezer until ready to be used. Several trials were conducted to investigate the ratio of berries to osmotic solution, concentration of osmotic solution and the infusion time.

The frozen berries were pre-treated by washing in cold water to remove extraneous materials. The washed berries were steam blanched in a steamer (laboratory steamer) to remove or break the waxy surface and enhance the effectiveness of the osmotic dehydration process. The blanched saskatoon berries were immersed in the osmotic solution at three different ratios of fruit to osmotic solution (1:1, 1:3 and 1:5) for a predetermined amount of time (6, 18 or 24 hours). The infused berries were drained and dried in laboratory Hobart oven. Detailed results for this section of the project are shown in Appendix A.

A ratio of 1:5 (fruit to osmotic solution) resulted in a better tasting, fruity and sweeter product. A mixture of honey and apple juice was preferred over honey alone as a medium for infusion because of the fruity flavour balance it conveyed to the saskatoon berries.

Saskatoon berry samples infused for six hours were considered by sensory panellists as the most preferred for sweetness and flavour retention. These osmotic infusion parameters will be studied further for saskatoon berries to obtain dry berries suitable as snacks or for use in breakfast cereals.
Further work on pre-treatment prior to osmotic dehydration will be carried out using a hot/cold water shock (skin cracking) and steam blanching at a pilot plant scale. Two drying temperatures (60 and 70°C) will be studied. The infusion and drying parameters used for saskatoons will be later used as a starting point for the osmotic dehydration of seabuckthorn, blackcurrants and sour cherries.

2.3 Fruit Fractionation and Processing

The objective of the whole berry fractionation is to ensure total utilization of all parts of the berries. The established process was found to be suitable for all the selected berries except for chokecherries. As noted in the literature review, chokecherry seeds contain cyanide forming compounds; therefore, research for a juice processing method without breaking the seeds was initiated.

All berries except seabuckthorn were supplied by Anthony Mintenko, Fruit Crops BDS with MAFRI, Crop Knowledge Centre. FDC purchased seabuckthorn fruits from a Manitoba grower. The fruits were kept frozen at FDC until used.

Figure 1: Fruit Processing/Fractionation Flow Chart
2.4 Fractionation Process

FDC developed an integrated process for the berry fruits as shown in Figure 1. All berries were fractionated to produce a puree, skin (with pulp) and seeds. The puree was further clarified to produce clear juice by centrifugation. Research has begun on the development of fruit powder from the puree, and research is also underway to develop fruit leather using blended fruit purees. Further research is planned for the extraction of fruit puree without the addition of water.

The skin and seeds from saskatoon and seabuckthorn berries were separated by air-drying and sifting through an appropriate sized screen. The skin (dried pulp) was stored and will be incorporated in a nutritional bar development. The seeds of saskatoon berries and the seeds, skins and pulp from seabuckthorn will be used for oil extraction and results will be included in the final report.

2.5 Product Prototype Development

This activity was designed to investigate the applications of the whole berries and their fractions into value-added and novel products. The products included a berry beverage with enhanced nutritional quality, a fruit energy bar high in protein and fibre, and fruit leather. Seabuckthorn leaves were also dried and milled into bulk tea leaves from which a steep base was made and will be used for further prototype development of a ready to drink beverage.

*Development of Seabuckthorn Bulk Tea*

Fresh male seabuckthorn leaves (cv. *Sinensis*) were provided by Anthony Mintenko, Fruit Crops BDS with MAFRI, Crop Knowledge Centre. The leaves were stored frozen at FDC until used.

There are two basic technologies employed in drying of seabuckthorn leaves: convection air drying and freeze drying. Convection air drying is the most basic yet effective and commonly used in the industry; hence, this technology was used in this process. Typically, equipment such as a forced-air tray dryer is used for convection air drying. Freeze drying, or lyophilization, is another drying technology but not commonly used for seabuckthorn leaves for economic reasons.

FDC studied the drying, milling and steeping of seabuckthorn leaves for the development of a tea extract. Detailed experimental design and results are attached in Appendix B.
Frozen seabuckthorn leaves were washed with cold water and drained. A cabinet type dryer (Proctor and Schwartz-062, SCM Corporation, Philadelphia, PA, USA) was used at 50°C for drying trials. The wet leaves were spread on perforated drying trays and placed in the dryer. Drying times were established by monitoring moisture content at various time intervals. The total drying time was four hours and the final moisture content ranged from 8.72 – 9.72%. Figure 2 shows the process for seabuckthorn tea processing.

**Milling Dried Seabuckthorn Leaves**

Milling seabuckthorn leaves was performed using a Fitzpatrick Communitron Hammer Mill with a round perforated screen (9.53 mm pore size). Sifting of the ground leaves was performed using a RoTap RX-29 Sieve Shaker equipped with several sieves. Particle size distribution was measured from 10 trials. The total percentage of usable material (>0.35 mm and <2 mm) represents 80% of the total weight of the dried ground leaves while the majority (around 66%) of the total usable material ranges between 0.35 and 0.85 mm.

The weighted mean particle size (WMPS) was 0.93 mm; this is in the range of commercial tea particle size (0.4 to 2 mm).

**Steeping of Seabuckthorn Tea**

The dried tea leaves from the selected sizes were steeped in hot water. The factors evaluated in steeping trials were steeping time (10, 15, 25 minutes), temperature (80 or 90°C), and ratio of leaves to water (10, 14, and 30 g per litre of water). The extract was analyzed chemically and physically for pH, colour and total titratable acidity (TA). Sensory analysis was performed by four trained panellists to select the combination of factors that resulted in the most palatable product.

It was noticed that pH levels did not differ among samples although acidity changes were detected by sensory analysis; therefore, titratable acidity (expressed as g malic acid/100 g) was introduced as another attribute for evaluating the seabuckthorn leaf extracts in order to establish the differences among samples.

Colour changes were observed and confirmed by analytical results between concentrations, but only slight differences were found at different steeping times. Darker tones were perceived by the sensory panellists at higher concentrations and higher temperatures. This was reflected in the colour measurements with a decrease in luminosity (L*) and yellow tones (b*). Lower and upper limits for the different factors studied were identified. Leaves steeped for five minutes lacked flavour, whereas leaves
steeped for 25 minutes resulted in a bitter tea extract. A ratio of 1:100 (leaves to water) was determined to be a suitable concentration and produced a flavourful extract. Of the two steeping temperatures evaluated, the sensory panellists preferred samples at 80°C.

A steeping time of 10 to 15 minutes with leaves to water ratio of 1:100 g/ml and temperature of 80°C were selected as the most suitable steeping conditions.

Figure 2: Process flow chart for the development of seabuckthorn tea base

Development of Fruit Leather

In the development of fruit leather, puree fractions of the selected berries were used. The fruit fractions included a blend of the seabuckthorn, saskatoons, blackcurrant and sour cherry in equal amounts. This approach was used to ensure utilization of all berries, and take advantage of their unique nutritional and health benefits. Appendix E details the prototype development work completed in this reporting period.

The fruit leather formulation included the study of sweeteners, and other ingredients to obtain the desired texture and flavour. The processing steps for the fruit leather is shown in Figure 3. The fruit leather mixture was dried at 60°C for five hours to obtain water
activity ($a_w$) of $\leq 0.51$ and moisture content of 19.26%. An $a_w$ of 0.51 or below is desired to prevent the proliferation of spoilage organisms. The selected berry puree blend produced dark coloured leather with a pleasant fruity flavour and a dry leathery texture. Further work will be carried out to confirm the processing parameters and product quality.

![Process flow chart for fruit leather](image)

**Figure 3: Process flow chart for fruit leather**

### 2.6 Nutritional Analyses

Nutritional and chemical analyses were subcontracted to SGS Laboratories in British Columbia, Canada; Eurofins Scientific, Inc. and Covance Laboratories in the USA. The ORAC and total phenolics analyses were subcontracted to Canadian Centre for Agri-food Research in Health and Medicine (CCARM).

The nutritional analyses of the fruits were carried out and the results are attached in the Appendix C. Saskatoon berries were notably high in calcium (97.6 mg/100 g) followed by blackcurrant (60.2 mg/100 g) and then chokecherries (25.9 mg/100 g). Seabuckthorn showed the highest vitamin A content (301.3 RE/100 g) and vitamin C content (149 mg/100 g). Only seabuckthorn showed any appreciable amount of vitamin E (6.22 mg/100 g). Blackcurrant had the highest level of potassium (2900 µg/g) followed by chokecherry (2700 µg/g), saskatoons (2200 µg/g) and seabuckthorn (1900 µg/g). The beta-carotene
content of seabuckthorn was 3013 IU/100 g. As expected, the sugar content of the fruits was highest in saskatoon berries (17 g/100 g) and lowest in seabuckthorn (2.4 g/100 g).

Anthocyanins and total polyphenols content of the fruits were also analysed. The results are presented in Appendix D. Blackcurrant showed the highest anthocyanin content (306 mg/100 g) and total polyphenols (385 mg/100 g). The total anthocyanin content of seabuckthorn was negligible (< 1 mg/100 g). The total polyphenols values for other berries were as follows: saskatoons (346 mg/100 g), sour cherry (142 mg/100 g), chokecherry (131 mg/100 g) and seabuckthorn (89 mg/100 g).

The analysis of seabuckthorn leaves showed ORAC value of 80325 μmol TE/100 g, total flavonoids of 7500 mg/100 g and total polyphenols of 9638 mg/100 g. These results are considered relatively high according to Dr. Chris Siow of the Canadian Centre for Agrifood Research in Health and Medicine (CCARM).

### 3.0 OBSTACLES/SUCCESSES DURING THE REPORTING PERIOD

This research project is progressing well after a slow start because of the difficulties in obtaining fruits. Due to the poor growing season, it was not possible to obtain samples of haskap for the research during this reporting period.

#### 3.1 Key Successes

Some of the key successes of the project during this reporting period include:

- Development of seabuckthorn bulk tea with very high ORAC, total flavonoids and total phenolics values. A Manitoba company has expressed interest in commercializing this tea along with its other tea products.
- An article “Seabuckthorn Leaf Tea – A Healthy Choice” was prepared and submitted to Prairie Fruit Growers Association for publication in Prairie Garden Magazine.
- The fruit fractionation methods developed in this project has been transferred to develop seabuckthorn puree for Manitoba and Saskatchewan companies. The Manitoba Company is in the process of commercializing the puree.
- This research project was presented at the Canada-China partnership seminar on processing of small fruits in Portage la Prairie in July 2010.
- A further awareness of small fruits has been created through participation in the Saskatoon Berry Council of Canada. The project information has been shared with
North American Bio-Extracts – a research company on fruit extracts. North American Bio-Extracts has agreed to share its fruit oil technology once developed.

- A BC company is working with FDC to develop seabuckthorn sports drinks which could include a blend of other small fruits.

3.2 Obstacles

There were some challenges during this reporting period and they include:

- Difficulties in finding accredited laboratories to carry out some of the phytochemical analyses in Canada. Mostly USA laboratories were used for these analyses.

- Toxicity analyses at CCARM were delayed for the seabuckthorn leaves and an alternative laboratory was not identified in this reporting period.

- Analytical costs were much higher than estimated in the proposal as it became necessary to expand the tests in order to compare the potential of the fruits in functional food applications.

- Challenges in extracting chokecherry puree and juice to eliminate any seed breakage. This necessitated the acquisition of a new equipment to research other techniques for the extraction.

- Prabal Ghosh, one of the project team members, started paternity leave in February 2011 which affected the timeframe for osmotic dehydration activities.

- Renovation and construction is underway at FDC, which limits access to the pilot plant to conduct research.

4.0 PROJECT TIMELINES AND BUDGET

There are two key activities not yet initiated in the project: the evaluation of a new drying technology at the University of Saskatchewan and the evaluation of high pressure processing on fruit juice at Food Processing Development Centre in Leduc. These activities are planned for the next reporting period. The fractionation research started ahead of schedule due to the delay of drying activities at the University of Saskatchewan. Other activities are within the project timelines.

According to the scheduled work, the project is expected to be completed within schedule.
There are cost over-runs on certain activities, particularly in the chemical analyses. There is a need for re-allocation of activity costs to keep the overall project within budget.

5.0 FUTURE ACTIVITIES

The next reporting period will focus on conducting research trials to confirm some of the analytical results and initiating work at University of Saskatchewan and Food Processing Development Centre in Leduc. Specifically, the following activities will be carried out:

- Finalization of the development of seabuckthorn tea beverage
- Continuation of osmotic dehydration on the remaining berries
- Development of fruit based bar
- Development of fruit leather
- Development of fruit juice blend with specific health benefit
- Evaluation of fruit drying using University of Saskatchewan technology
- Evaluation of high pressure processing on fruit juice quality
- Participation in a conference to present research findings
- Preparation of final report

6.0 PROJECT CONTACT INFORMATION

Alphonsus Utioh, M.Sc., P.Eng.
Manager, Research & Development
FOOD DEVELOPMENT CENTRE
P.O. Box 1240, 810 Phillips Street
Portage la Prairie, Manitoba, R1N 3J9
Phone: (204) 239-3179
Toll-free: 1-800-870-1044 (in Canada)
Fax: (204) 239-3180
Email: alphonsus.utioh@gov.mb.ca
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OSMOTIC DEHYDRATION OF WHOLE BERRIES

Progress Report for April 21, 2010 – April 15, 2011

Submitted to:
Manitoba Rural Adaptation Council
c/o Kristin Yaworski-Lowdon
700 - One Research Road
Winnipeg, MB R3T 6E3
Ph: (204) 982-4795
Toll free: 800-216-9767
Fax: (204) 982-4794

Prepared by:
Meeling Nivet, Prabal Ghosh, Ramachandran Gopal,
Daniella Alejo, Alphonsus Utioh

April, 2011
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1.0 INTRODUCTION

Berries such as blackcurrants, chokecherries, saskatoons, seabuckthorn, dwarf sour cherry and blue honeysuckle (Haskap) are abundantly grown in the Prairie Provinces of Alberta, Saskatchewan and Manitoba. These berries are high in vitamins, minerals and antioxidants such as anthocyanins and polyphenols. The aim of this part of the project is to find applications for the berries and position the fractions as ingredients for the development of marketable value-added products. The project will encourage growers and small and medium-size enterprises (SMEs) involved in the value-added and innovation chain to take the advantage of the potential offered by small berries to expand their production and processing capacities to strengthen their competitive advantage.

Osmotic dehydration consists of diffusion of sugar in a countercurrent mass transfer against water movement. As water is flowing out of the fruit due to the osmotic pressure difference, sugar solution is flowing into the fruit (Figuerola, 2007). The process is usually carried out by immersing or infusing the fruits in concentrated solutions such as sucrose, lactose and glycerol among others. The selection of the brine or osmotic agent depends on its cost, molecular mass and sensorial characteristics of the product to be dehydrated (Osorio et al., 2007). In fruit preservation, it is common to use sucrose or other sweeteners because browning is reduced and the sweet taste of the fruit is reinforced.

2.0 OBJECTIVE

The objective of this part of the project is to study and optimize the conditions during osmotic dehydration of whole berries in natural sweeteners.

3.0 MATERIALS AND METHODS

Fresh-Frozen berries (blackcurrants, chokecherries, saskatoons, seabuckthorn and dwarf sour cherry) were obtained from Anthony Mintenko, Fruit Crops BDS with MAFRI, Crop Knowledge Centre. The berries were stored in the walk-in freezer at FDC for further processing.

Liquid honey (Beemaid®) was purchased as it is a natural sweetener to enhance the sweetness of berries. It also helps to retain the moistness of the end product as humectants. Unsweetened apple juice (SunRype) was also used to reduce the cost and °Brix of honey.
3.1 Preliminary trials

Preliminary trials were carried out to investigate honey as a natural osmotic medium for dehydration of saskatoons, seabuckthorn, sour cherries and blackcurrant berries. All berries were infused in honey at a ratio of 1 part of fruit per 2 parts of honey for 18 hours, followed by drying for 10 hours. These trials were not reported in the results section as they were designed as a preliminary study to observe the behaviour of the berries undergoing the osmotic dehydration process.

3.2 Osmotic dehydration of berries

Currently, only saskatoon berries have been extensively studied. Optimum conditions will later be applied to the rest of the small fruits. Figure 1 shows the general process for osmotic dehydration used for the berries. At this point, the fruit infusion was studied without the drying stage. Successful osmotic conditions will later be applied in the drying process.

![Flowchart](image)

Figure 1: Process flow chart for osmotic dehydration of Saskatoon berries

3.2.1 Pre-treatment

Two pre-treatments were chosen for investigation: blanching and cracking of fruit skin. In this stage of the project, only steam blanching was studied. Berries were placed in a perforated tray and washed in cold tap water in order to remove extraneous materials such as twigs, stems and leaves, and were later washed with chlorinated water (200ppm) for one minute. The washed berries were steam blanched in a steamer for two minutes to rupture
the cell wall of the saskatoon waxy skin to enhance the effectiveness of the osmotic dehydration process, this process has been previously reported as an effective pre-treatment before osmotic dehydration of cherries (Torreggiani et al., 1987).

3.2.2 Infusion

Two osmotic agents (brines) were evaluated. Honey (70°Bx), and a mixture of honey and apple juice at a ratio of 1:1 (50°Bx). The washed berries were immersed in the brines at three different ratios fruit: brine (1:1, 1:3 and 1:5) for a predetermined amount of time.

3.2.3 Draining/Filtering

After the desired infusion time, berries were drained or filtered with a strainer to remove excess sweetener. The final product was stored at 4°C before conducting sensory and chemical analyses.

3.3 Analysis of infused berries

Three different properties of the fruits were measured: pH, °Bx, and titratable acidity (TA) after the infusion process. The infused fruits were crushed with a mortar and pestle in order to effectively measure all attributes. The pH was evaluated using an Accumet XL50 pHmeter (Fisher Scientific, USA). Brix were measured using a Mark II Plus refractometer (Riechert, MY USA). Titratable acidity was measured according to AOAC method 942.15 (titratable acidity of fruit products).

Sensory analysis was performed by four trained panellists. Flavour attributes (sweetness, fruitiness, tartness and freshness) as well as texture were evaluated and rated in a 1 to 5 scale, where 5 is extreme high level and 1 is a non existing flavour.

4.0 RESULTS AND DISCUSSION

The first stage on the production of osmotic dehydrated saskatoon berries was the determination of the berry sweetness achieved after the infusion process.

4.1 Infusion in Honey

Table 1 shows the analytical attributes of saskatoon berries immersed in honey at the three different ratios for 6, 18 and 24 hours. The pH level remained stable regardless of infusion conditions. It can be observed in Figure 2 that Brix increased with increasing concentration of honey as well as with increasing infusion time. Titratable acidity (TA, expressed as malic acid) decreased with increasing infusion time, due to the migration to the brine, which was
confirmed with increasing acidity of the honey over time. After six hours infusion time, the acidity and Brix levels started to stabilize, meaning that most of the sweetness transfer from honey to the fruit was done in the first six hours. Further infusion trials will not be carried out for more than six hours, as the changes in sweetness are lesser after 18 hours. Similar dehydration times (maximum six hours) for cherries have been reported by Torreggiani et al. (1987).

Table 1: Analytical results of saskatoon berries infused with honey

<table>
<thead>
<tr>
<th>fruit : honey</th>
<th>infusion time (hours)</th>
<th>pH</th>
<th>°Bx²</th>
<th>TA (g malic acid/100mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 : 1</td>
<td>6</td>
<td>3.93</td>
<td>25.6</td>
<td>0.4154</td>
</tr>
<tr>
<td>1 : 3</td>
<td>6</td>
<td>3.98</td>
<td>27.6</td>
<td>0.3685</td>
</tr>
<tr>
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<tr>
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<td>3.97</td>
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</tr>
<tr>
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<td>29.6</td>
<td>0.1943</td>
</tr>
<tr>
<td>1 : 3</td>
<td>24</td>
<td>3.95</td>
<td>34.4</td>
<td>0.1876</td>
</tr>
<tr>
<td>1 : 5</td>
<td>24</td>
<td>3.96</td>
<td>33.3</td>
<td>0.2077</td>
</tr>
</tbody>
</table>

= a Brix, b Titratable Acidity

Figure 2: °Bx and titratable acidity of saskatoon berries infused in honey

Noticeable differences were found in the outer appearance of the berries. Generally, higher wrinkling of the skins occurred in higher infusion times. It was determined that higher concentration of honey in the system produced a berry with less wrinkles and therefore more plumpness. Figure 3 shows the most important flavour attributes that were analyzed. Very similar flavour tones were found in samples infused for 18 and 24 hours, which lead the
sensory panel to eliminate 18 and 24 hour infusion for economical purposes. Berries infused in a ratio of 1:5 for six hours were selected as the best trial because of their sweetness, fruitiness and lower wrinkling.

![Figure 3: Sensory attributes of saskatoon berries infused in honey](image)

### 4.2 Infusion in Honey + Apple Juice

Considering reducing the cost of the brines used for infusion, apple juice was used as a medium for diluting honey and imparting tartness to saskatoon berries. A mixture of 50% honey and 50% apple juice (50°Bx) were used as osmotic agent.

From previous results of infusion of saskatoon berries in honey or apple juice, it was determined to eliminate 18 and 24 hours infusion, since they produce similar results to six hours with a higher cost. This trial was performed for only three and six hours total infusion time.

Table 2 and Figure 4 show the analytical results of the berries after the determined infusion time. Samples infused for three hours had similar Brix values regardless of fruit to brine ratio, whereas after six hours the Brix increased noticeably.

The migration of acidity from the saskatoon berries to the brine was higher in samples infused for six hours, but acidity levels in all samples were within the same range.
Table 2: Analytical results of saskatoon berries infused with honey + apple juice

<table>
<thead>
<tr>
<th>fruit : brine</th>
<th>infusion time (hours)</th>
<th>pH</th>
<th>°Bx</th>
<th>TA (g malic acid/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 : 1</td>
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</tr>
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<td>6</td>
<td>4.06</td>
<td>25.2</td>
<td>0.3015</td>
</tr>
<tr>
<td>1 : 5</td>
<td>6</td>
<td>4.08</td>
<td>24.3</td>
<td>0.2881</td>
</tr>
</tbody>
</table>

Figure 4: Sensory attributes of saskatoon berries infused in honey + apple juice

After sensory evaluation of berries infused in the mixture of honey and apple juice, it was confirmed that a ratio of 1:5 fruit to brine produced a sweeter, more pleasant product (Figure 5). Berries infused for three hours were less sweet and flavourful. A ratio of 1:1 for six hours resulted in a palatable product, but the plumpness of samples with 1:5 ratio was preferred due to an improved appearance.
5.0 CONCLUSIONS

Both osmotic agents, honey alone and a mixture of honey and apple juice, are suitable mediums for osmotic dehydration of saskatoon berries at room temperature for the production of dried fruits.

A ratio of 1:5 fruit to brine resulted in a better tasting, fruity and sweeter product, regardless of the osmotic agent. A mixture of honey and apple juice was preferred as a medium for infusion because of the flavour balance it conveys to the saskatoon berries. Six hours infusion was the best time for saskatoon berries in terms of sweetness and flavour absorption, and it is also a feasible time for scaling into a commercial process.

6.0 NEXT STEPS

The most successful combination of factors will be carried out into the drying process for saskatoon berries. Two temperatures (60 and 70°C) will be studied. The same infusion parameters will be used as a starting point for the osmotic dehydration of seabuckthorn, blackcurrants and sour cherries.
REFERENCES


APPENDIX B

DEVELOPMENT OF SEABUCKTHORN TEA EXTRACT

Progress Report for April 21, 2010 – April 15, 2011

Submitted to:
Manitoba Rural Adaptation Council
c/o Kristin Yaworski-Lowdon
700 - One Research Road
Winnipeg, MB R3T 6E3
Ph: (204) 982-4795
Toll free: 800-216-9767
Fax: (204) 982-4794

Prepared by:
Meeling Nivet, Prabal Ghosh, Ramachandran Gopal,
Daniella Alejo, Alphonsus Utioh

April, 2011
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1.0 INTRODUCTION

Tea is made from an extract from the Camellia Senesis plant, is a popular, refreshing beverage and an integral part of consumer culture. Consumers currently look to tea for a refreshing experience and is appreciated for its unique ability to refresh, relax and revive. Tea is filled with antioxidants: polyphenols, flavonoids, and catechins. These antioxidants are known to prevent free radical damage that can lead to cancer (Rufle, 2008). Black tea, green tea, Oolong tea and white tea are the four main types of teas. There are also other varieties like herbal, flavoured and scented.

**Black Tea** is the most popular tea all over the world and is made from the young tea leaves and the buds. The leaves and buds are completely fermented or oxidized after they have been dried. Black tea has a strong, bitter flavour. Some different types of black teas are Orange Pekoe, and Earl Gray. **Green Tea** comes from the same plant as black tea, Camellia Senesis. It is even made from the same leaves as the black tea. The difference is that green tea does not go through a fermenting process. Instead the leaves are steamed after they are dried. Green tea has a grassy flavour. **Oolong tea** only is partially fermented. This gives the tea a smoother taste that is not as strong as black tea and curbs the grassy flavour of green tea. **White tea** was once reserved for royalty in China and has only been available outside of China for a few years. The leaves are also from the Camellia Senesis plant. The leaves are picked only twice a year at a very young stage just before the buds are beginning to open. The leaves are then partially fermented in a similar manner to the Oolong tea. **Herbal teas** are made from flowers, leaves, roots or seeds of plants and generally do not contain leaves of the Camellia Senesis plant. Some examples of herbal teas are chamomile, mint and Jasmine. The benefits of the herbal teas vary based on the herbs included.

The seabuckthorn leaves are typically air dried to develop different products such as tea, tea powder and extract for use in nutraceuticals and cosmetics. Air dried seabuckthorn leaves are high in protein (up to 25%). Seabuckthorn leaves are rich source of two major flavonoids such as isorhamnetin and quercetin, carotenoids, free and esterified sterols, triterpenols, and isoprenols (Goncharova and Glushenkova, 1996; Geetha et al., 2002). Geetha et al. (2002) reported that seabuckthorn leaves possess anti-viral and antimicrobial activity and have protective activity against cytotoxicity. Seabuckthorn tea is non toxic as reported by the Defense Research Development Organization of India. Seabuckthorn tea is not only a good tasting beverage but it also contains important health promoting attributes.
The purpose of this research was to prepare seabuckthorn leaves for tea extraction suitable for preparing a refreshing beverage. The seabuckthorn leaves were dried and steeped to obtain a tea extract. The research did not include either fermentation or steaming of the dried leaves.

2.0 MATERIALS AND METHODS

2.1 Raw Material

Fresh-frozen seabuckthorn leaves cv. Sinensis were obtained from Anthony Mintenko, Fruit Crops BDS with MAFRI, Crop Knowledge Centre and were stored in the walk in freezer at FDC. The frozen seabuckthorn leaves were washed in cold tap-water to remove dirt and other debris prior to usage.

2.2 Process Flow Chart for drying and milling of tea leaves

Figure 1 shows the process flow chart of seabuckthorn drying. The process included drying, milling, particle size determination and final blending.

The following equipment was used during drying and milling of tea leaves:

- Drying: Tray Dryer (Procter)
- Milling: Fitzpatrick Comminutor Hammer mill (Screen size 0350)
- Sieving: RoTap RX-29 Sieve shaker

2.3 Drying

Air-tray drying technique was used for the preparation of dried seabuckthorn leaves for steeping. The leaves were spread very thinly on trays and placed on racks inside a drying chamber where the heat is applied and the vapours are removed. Drying was carried out at 50°C for four hours. The mass loss of the tray samples were noted after every hour of drying. Dehydration occurs mostly from convection (Earle, 1983).
Figure 1: Process flow chart for the development of dried, ground seabuckthorn tea leaves

2.4 Milling of Dried Seabuckthorn Leaves

A hammer mill (*Fitzpatrick Comminutor Hammer Mill*) was used to grind the dried seabuckthorn tea leaves to reduce its particle size. Different screen sizes were used in the milling trials to identify a suitable screen size to collect the tea leaves. Approximately, 1.12 kg dried seabuckthorn leaves were grinded using a 0.375 inch screen size. The screen size used was selected based on preliminary analysis in order to minimize the losses.

2.5 Particle Size Determination

Particle size determination of the grounded seabuckthorn leaves was carried out using a Rotap equipped with a series of sieves. The mean diameter of the particles was determined according to the following equation.

\[
WMPS = \sum_{i=1}^{n} MF_i \left( \frac{SO_i - SO_{i-1}}{2} \right)
\]

Where:
- \(MF_i\) = Mass fraction retained in sieve \(i\);
- \(SO_i\) = Sieve opening (in mm) in sieve \(i\); and
- \(n\) = Number of sieves including the pan

2.6 Seabuckthorn Tea Steeping/Infusion

A tea infusion or steeping allows the natural interactions between the various components in the herbs/leaves to occur. Most of the major compound groups occurring in plants are either soluble in boiling water or will release into the water in time, due to the interactions occurring during the water extraction process.
Leaf particles (Size 0.35 to 2 mm) were mixed together and steeped to develop the tea extract. A 500 mL beaker was filled with water and placed on a hot plate. A predetermined amount of dried seabuckthorn leaves were added to the beaker when the hot water reached the desired temperature. The mixture was stirred homogeneously with the help of a magnet throughout the steeping process. However, as soon as the tea leaves were added into the water manual stirring was needed to enhance homogenized mixing. Steeped tea was filtered using a regular coffee filter. The filtered tea extract was filled into a sterilized bottle and stored in a refrigerator for further processing. Bottles were sterilized for 20 min at ~95°C prior to tea filling.

The factors evaluated in steeping trials were steeping time (10, 15, and 25 minutes), temperature (80 or 90°C) and ratio of leaves to water (10 g, 14 g and 30 g per litre of water). The extract was analyzed chemically and physically for pH, colour and total titratable acidity (TA). Moreover, sensory analysis was performed by four trained panellists to select the combination of factors that resulted in the most palatable product.

2.7 Analysis of Seabuckthorn Tea Extract

The total soluble solids (TSS) were measured in °Brix with a Mark II Plus refractometer (Riechert, NY USA). pH was evaluated using an Accumet XL50 pHmeter (Fisher Scientific, USA). Titratable acidity was measured according to AOAC method 942.15. Colour of the tea samples was determined with a Chroma Meter CR-400/410 (Konica Minolta) with D65 settings. Parameters like L* (luminosity), a* (red-green) and b*(blue-yellow) were measured.

Sensory analyses were carried out with three trained panellists in a round-table setting. Tea extracts were sweetened with regular sugar before testing to improve their astringency and palatability. The sensory ballot used is shown in Appendix 1.

3.0 RESULTS AND DISCUSSION

3.1 Drying and Particle Size of Seabuckthorn Leaves

Two drying trials were carried out. The moisture content of the dried leaves was 8.72 and 9.72% w.b. for Trial 1 and 2, respectively. Data from the weight of the leaves was monitored after one hour intervals during the process. Drying curves for Trial 1 and 2 are shown in Figure 2. The moisture loss was higher in the first hour for trial 1 but after two hours, the same trend was found in both trials and similar final moisture contents were obtained. The water activity of the dried leaves was 0.4318 @25.1°C.
Figure 2: Drying behaviour of seabuckthorn leaves

The particle size distribution is shown in Table 1. It shows a mean from 10 trials. Particles collected from sieve size #8 and 10 (>2 mm) were discarded as they contained large pieces, branches and debris. The fine particles from the pan (<0.35 mm) were also discarded due to their woody nature. The total percentage of usable material (>0.35 mm and <2 mm) represents 80% of the total weight of the dried ground leaves while the majority (around 66%) of the total usable material ranges between 0.35 and 0.85 mm.

The Weighted Mean Particle Size (WMPS) was 0.93 mm; this is in the range of commercial teas that vary from 0.4 to 2 mm.

Table 1: Particle size distribution of seabuckthorn leaves

<table>
<thead>
<tr>
<th>Sieve #</th>
<th>Opening size (mm)</th>
<th>% of dried leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2.38</td>
<td>3.94</td>
</tr>
<tr>
<td>14</td>
<td>1.41</td>
<td>10.70</td>
</tr>
<tr>
<td>16</td>
<td>1.19</td>
<td>7.74</td>
</tr>
<tr>
<td>20</td>
<td>0.84</td>
<td>15.04</td>
</tr>
<tr>
<td>35</td>
<td>0.50</td>
<td>29.93</td>
</tr>
<tr>
<td>45</td>
<td>0.35</td>
<td>16.46</td>
</tr>
<tr>
<td>pan</td>
<td>-</td>
<td>11.74</td>
</tr>
</tbody>
</table>

*Highlighted cells represent usable material
3.2 Steeping of Seabuckthorn Leaves

Preliminary trials were carried out to evaluate the suitable range of particle size to study during the steeping process. The range in particle size selected, as previously mentioned, was from 0.35 mm to 2 mm.

3.2.1 Effect of Steeping Time

In order to assess the effect of steeping time on the properties of seabuckthorn tea extract, constant ratio of leaves to water (1:100) and temperature (80°C) were selected. Steeping times were 5, 10, 15 and 25 minutes.

The sensory evaluation panel observed some flavour differences between all steeping times. The colour of the tea extract was darker with increasing steeping time. It was identified by the panel that the extract steeped for 25 minutes resulted in higher bitterness and was therefore eliminated.

3.2.2 Effect of Concentration of Seabuckthorn Leaves in Water During Steeping

From previous tests, steeping times of 5, 10 and 15 minutes were considered suitable. The three steeping times were evaluated with two ratios of leaves to water (1:100 and 1.5:100). It is visible in Table 2 that °Brix increased and acidity decreased in samples with higher concentration of leaves, but both attributes did not differ among steeping times.

It was observed that as the concentration of leaves increased. The steeped tea produced a darker colour extract with strong bitterness. Samples steeped for five minutes had a mild, watery taste and were therefore disqualified for future study. The most balanced and flavourful extracts as selected by the sensory panel were 10 and 15 minutes at a ratio of 1:100.

Table 2: Analytical results for evaluation of concentration during steeping

<table>
<thead>
<tr>
<th>Ratio Leaves-water (g/ml)</th>
<th>Steeping Time (min)</th>
<th>Steeping temp(°C)</th>
<th>TSS (°Brix)</th>
<th>pH</th>
<th>TA (Malic Acid %)</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:100</td>
<td>5</td>
<td>80</td>
<td>0.23</td>
<td>6.04</td>
<td>0.40</td>
<td>30.90  8.86  -4.22</td>
</tr>
<tr>
<td>1:100</td>
<td>10</td>
<td>80</td>
<td>0.27</td>
<td>5.99</td>
<td>0.40</td>
<td>29.82  8.36  -2.08</td>
</tr>
<tr>
<td>1:100</td>
<td>15</td>
<td>80</td>
<td>0.20</td>
<td>5.90</td>
<td>0.40</td>
<td>29.35  8.84  -1.90</td>
</tr>
<tr>
<td>1.5:100</td>
<td>5</td>
<td>80</td>
<td>0.27</td>
<td>5.83</td>
<td>0.39</td>
<td>29.42  8.92  -1.61</td>
</tr>
<tr>
<td>1.5:100</td>
<td>10</td>
<td>80</td>
<td>0.40</td>
<td>5.73</td>
<td>0.38</td>
<td>28.82  8.24  -0.21</td>
</tr>
<tr>
<td>1.5:100</td>
<td>15</td>
<td>80</td>
<td>0.40</td>
<td>5.66</td>
<td>0.38</td>
<td>28.52  8.46  -0.07</td>
</tr>
</tbody>
</table>
3.2.3 Effect of Steeping Temperature

Two steeping temperatures were evaluated (80 and 90°C). The sensory panel observed that increasing the temperature to 90°C showed an increased odour and stronger flavour and bitterness, which was confirmed by an increase in titratable acidity (Table 3). Darker tones were extracted at higher temperature and were perceived by sensory evaluation and confirmed by a decrease in luminosity ($L^*$) and yellow tones ($b^*$).

After sensory analysis, both samples steeped at 80°C were selected to move forward for beverage formulation.

Table 3: Analytical results for evaluation of steeping temperature

<table>
<thead>
<tr>
<th>Ratio Leaves-Water (g/ml)</th>
<th>Steeping Time (min)</th>
<th>Steeping Temp(°C)</th>
<th>TSS ('Brix)</th>
<th>pH</th>
<th>TA (Malic Acid %)</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$L^*$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$a^*$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$b^*$</td>
</tr>
<tr>
<td>1:100</td>
<td>10</td>
<td>80</td>
<td>0.3</td>
<td>5.74</td>
<td>0.3350</td>
<td>30.21</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>9.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.68</td>
</tr>
<tr>
<td>1:100</td>
<td>15</td>
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<td>0.3</td>
<td>5.84</td>
<td>0.3015</td>
<td>29.34</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>3.02</td>
</tr>
<tr>
<td>1:100</td>
<td>10</td>
<td>90</td>
<td>0.4</td>
<td>5.70</td>
<td>0.3685</td>
<td>28.34</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>9.17</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.44</td>
</tr>
<tr>
<td>1:100</td>
<td>15</td>
<td>90</td>
<td>0.3</td>
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<td>0.4355</td>
<td>28.11</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>9.04</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.13</td>
</tr>
</tbody>
</table>

4.0 CONCLUSIONS

FDC successfully prepared dried seabuckthorn tea leaves and optimized the steeping base that will be used for a beverage formulation.

The leaves were air dried and ground using a hammer mill. Particle size distribution was analyzed and a suitable range in sizes (0.35-2mm) was selected for utilization.

A suitable steeping time of 10 to 15 minutes with leaves to water ratio 1:100 g/ml and temperature of 80°C was selected based on analytical and sensory data.

5.0 NEXT STEPS

A seabuckthorn tea beverage will be made from the tea extract produced in this section of the project.
REFERENCES


Appendix 1

Sensory ballot for evaluation of seabuckthorn tea

| PJ #3344 | Name: ____________________________ |
| Date: ____________________________ | Sample: ____________________________ |

<table>
<thead>
<tr>
<th>Visual Appearance (colour)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Green/yellow</td>
<td>2 Yellow/brown</td>
<td>3 Brown</td>
<td>4 Dark brown</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Odour intensity</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Slight</td>
<td>2 Moderate</td>
<td>3 High</td>
<td>4 Extremely high</td>
<td></td>
</tr>
</tbody>
</table>

**FLAVOUR**

<table>
<thead>
<tr>
<th>Dryness/astringency</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 None</td>
<td>2 Slightly Dry</td>
<td>3 Moderately dry</td>
<td>4 Extremely dry</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bitterness</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 None</td>
<td>2 Slight</td>
<td>3 Moderate</td>
<td>4 Extreme</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Balance/Intensity of flavour</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Weak</td>
<td>2 Moderate</td>
<td>3 High</td>
<td>4 Extreme</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acceptance (Degree of likeness)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Dislike Extremely</td>
<td>2 Dislike</td>
<td>3 Like</td>
<td>4 Extremely like</td>
<td></td>
</tr>
</tbody>
</table>
### APPENDIX C

**NUTRITIONAL ANALYSIS OF FRESH-FROZEN BERRIES (FROM SGS LAB)**

<table>
<thead>
<tr>
<th>TEST</th>
<th>BLACKCURRANTS</th>
<th>CHOKECHERRIES</th>
<th>SASKATOONS</th>
<th>SEABUCKTHORN</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>0.6</td>
<td>0.2</td>
<td>0.5</td>
<td>2.7</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Moisture</td>
<td>80.6</td>
<td>76</td>
<td>69.5</td>
<td>79.3</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Ash</td>
<td>0.9</td>
<td>0.7</td>
<td>0.9</td>
<td>0.4</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>mg/100 g</td>
</tr>
<tr>
<td>Energy</td>
<td>77</td>
<td>94</td>
<td>121</td>
<td>95</td>
<td>Cal/100 g</td>
</tr>
<tr>
<td>Energy</td>
<td>322</td>
<td>394</td>
<td>506</td>
<td>396</td>
<td>KJ/100 g</td>
</tr>
<tr>
<td>Total Sugar</td>
<td>4.1</td>
<td>12.9</td>
<td>17</td>
<td>2.4</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.3</td>
<td>0.15</td>
<td>0.5</td>
<td>2.6</td>
<td>mg/100 g</td>
</tr>
<tr>
<td>Calcium</td>
<td>60.2</td>
<td>25.9</td>
<td>97.6</td>
<td>7.1</td>
<td>mg/100 g</td>
</tr>
<tr>
<td>Iron</td>
<td>1.3</td>
<td>0.15</td>
<td>0.6</td>
<td>0.3</td>
<td>mg/100 g</td>
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<tr>
<td>Calories from Fat</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>24</td>
<td>Cal/100 g</td>
</tr>
<tr>
<td>Total Dietary Fibre</td>
<td>9.8</td>
<td>8.9</td>
<td>8.8</td>
<td>7.2</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>15.9</td>
<td>21.7</td>
<td>27.3</td>
<td>14.6</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Vitamin A (Retinol)</td>
<td>22</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
<td>IU/100 g</td>
</tr>
<tr>
<td>Vitamin A (RE)</td>
<td>12.9</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
<td>301.3</td>
<td>RE/100 g</td>
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<tr>
<td>Vitamin C</td>
<td>137.2</td>
<td>5.5</td>
<td>7.3</td>
<td>149</td>
<td>mg/100 g</td>
</tr>
<tr>
<td>Cd</td>
<td>&lt; 0.02</td>
<td>&lt; 0.02</td>
<td>&lt; 0.02</td>
<td>&lt; 0.02</td>
<td>ug/g</td>
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<tr>
<td>Co</td>
<td>0.01</td>
<td>&lt; 0.01</td>
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<td>&lt; 0.01</td>
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</tr>
<tr>
<td>Cr</td>
<td>&lt; 0.5</td>
<td>&lt; 0.5</td>
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<td>&lt; 0.5</td>
<td>ug/g</td>
</tr>
<tr>
<td>Cu</td>
<td>1.1</td>
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<td>1</td>
<td>ug/g</td>
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<td>K</td>
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<td>2700</td>
<td>2200</td>
<td>1900</td>
<td>ug/g</td>
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<tr>
<td>Mg</td>
<td>330</td>
<td>200</td>
<td>310</td>
<td>1100</td>
<td>ug/g</td>
</tr>
<tr>
<td>Mn</td>
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<td>3.1</td>
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<td>ug/g</td>
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<td>Ni</td>
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<td>P</td>
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<td>3.1</td>
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<td>ug/g</td>
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<tr>
<td>Zn</td>
<td>2.7</td>
<td>0.9</td>
<td>2.8</td>
<td>2.7</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Protein (N X 6.25)</td>
<td>2</td>
<td>1.4</td>
<td>1.8</td>
<td>3</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Saturated Fat</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>1.1</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Monounsaturated Fat</td>
<td>0.1</td>
<td>&lt; 0.1</td>
<td>0.1</td>
<td>1.3</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Polyunsaturated Fat</td>
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<td>0.1</td>
<td>0.3</td>
<td>0.3</td>
<td>g/100 g</td>
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<tr>
<td>Omega 3</td>
<td>0.1</td>
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<td>&lt; 0.1</td>
<td>g/100 g</td>
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<td>Omega 6</td>
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<td>0.1</td>
<td>0.3</td>
<td>g/100 g</td>
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<td>Omega 7</td>
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<td>&lt; 0.1</td>
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<td>&lt; 0.1</td>
<td>0.1</td>
<td>0.3</td>
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<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>g/100 g</td>
</tr>
<tr>
<td>Beta-Carotene</td>
<td>63.1</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
<td>3013</td>
<td>IU/100 g</td>
</tr>
</tbody>
</table>

**Remarks**

< denotes none detected followed by the detection limit
### APPENDIX D

#### Analysis of dried Seabuckthorn leaves (COVANCE LAB)

<table>
<thead>
<tr>
<th>Product</th>
<th>Total flavonoids (mg/100g)</th>
<th>Total polyphenols (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seabuckthorn leaves</td>
<td>7500</td>
<td>9360</td>
</tr>
</tbody>
</table>

#### Anthocyanin and Polyphenols content of berry Juice (COVANCE LAB)

<table>
<thead>
<tr>
<th>Product</th>
<th>Total Anthocyanins (mg/100g)</th>
<th>Total Polyphenols (Gallic Acid Equivalents)(mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sour Cherry Juice-Belt Pressed</td>
<td>33.4</td>
<td>142</td>
</tr>
<tr>
<td>Seabuckthorn Juice</td>
<td>&lt;1.00</td>
<td>88.5</td>
</tr>
<tr>
<td>Saskatoons Juice-Unground Juice</td>
<td>37</td>
<td>277</td>
</tr>
<tr>
<td>Saskatoons Juice- Ground Juice</td>
<td>32.3</td>
<td>346</td>
</tr>
<tr>
<td>Chokecherry Juice (Hobart)</td>
<td>&lt;1.00</td>
<td>131</td>
</tr>
<tr>
<td>Blackcurrant Juice-Ground Juice</td>
<td>183</td>
<td>385</td>
</tr>
</tbody>
</table>

#### Anthocyanin content of fresh-frozen berries (COVANCE LAB)

<table>
<thead>
<tr>
<th>Type of Fruits (Frozen)</th>
<th>Total Anthocyanins (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sour Cherry</td>
<td>91.7</td>
</tr>
<tr>
<td>Seabuckthorn</td>
<td>&lt;1.00</td>
</tr>
<tr>
<td>Saskatoons</td>
<td>90.2</td>
</tr>
<tr>
<td>Chokecherry</td>
<td>3.88</td>
</tr>
<tr>
<td>Blackcurrants</td>
<td>306</td>
</tr>
</tbody>
</table>
Development of Prototype Fruit Leather

Progress Report for April 21, 2010 – April 15, 2011

Submitted to:
Manitoba Rural Adaptation Council
c/o Kristin Yaworski-Lowdon
700 - One Research Road
Winnipeg, MB R3T 6E3
Ph: (204) 982-4795
Toll free: 800-216-9767
Fax: (204) 982-4794

Prepared by:
Paulyn Appah

April, 2011
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EXECUTIVE SUMMARY

Seabuckthorn, saskatoon, blackcurrant, sour cherry, haskap and chokecherry are berries commonly found in the Prairies. These berries have excellent nutritional profile due to their high content of fibre, antioxidants (phenolic compounds), and micronutrients. Due to the consumers’ increased knowledge of antioxidants and desire for healthy foods, there is a growing demand for these berries.

The objectives of this research were to:

- Develop nutritious and functional fruit leather from fractionated Prairie berries.
- Focus and assess ingredients that may improve the taste and nutrient profile of the fruit leather.
- Assess the functional and nutritional properties of the fruit leather.

This report summarizes the research findings at the Food Development Centre (FDC). FDC successfully developed a prototype fruit leather formula using purees from seabuckthorn, saskatoon, blackcurrant and sour cherry. The fruit leather formula was dried at 60°C for five hours and a water activity ($a_w$) of $\leq 0.51$ and moisture content and 19.26% was attained respectively.

The fruit leather that attained moisture content of less than 19.26% did not properly release from the tray and was gummy in texture. An $a_w$ of 0.51 is below 0.60 which prevents the proliferation of spoilage organisms. Similarly, due to uneven leveling of mixture on pans, leather thickness varied slightly and affected sensory attributes.

Further work will include:

- Establishing process yields and drying times.
- Assessing the effect of process changes on the quality of the final product.
- Determining nutritional profile of fruit leather.
- Conducting a preliminary shelf life study to generate information on shelf stability.
1.0 INTRODUCTION

Better consumer awareness of the health advantages of Prairie berries has increased their demand. However, being fragile, the seasonal berries have a relatively short shelf life which limits their consumption. By improving post-harvest processing capabilities and developing value-added shelf stable products, losses will be reduced and consumption will consequently increase. In addition, it is critical to develop fractionation technologies and create innovative product applications for these fractions. As a result, the Fruit Growers Associations, industry stake holders and FDC proposed a project that was funded jointly by MRAC and other collaborators.

Fruit leather is one of the product development applications that was investigated under this project, utilizing fractionated berries from seabuckthorn, saskatoon, chokecherry, blackcurrant, haskap and sour cherry. Fruit leathers are dried snacks produced from dehydrated fruit puree. Dried fruit leather has a firm pliable texture due to water loss during drying. The fruit leather sheets are cut to desired shapes and deliver chewy flavourful sensory profile when consumed. As low-intermediate moisture food, they are relatively shelf stable.

2.0 PROJECT OBJECTIVE

The objectives of this research were to:

- Develop nutritious and functional prototype fruit leather from fractionated Prairie berries.
- Conduct a preliminary shelf life evaluation.

To accomplish these goals, the berries were fractionated at FDC using an optimized process. FDC conducts product and process development research to determine the functional properties and potential opportunities for value added food products.

2.1 Project Activities

Existing literature on fruit leather production was used to understand the various aspects of fruit leather formulation, processes, ingredient function and challenges in product/process development. Ingredient composition, quantity and processes were carefully selected and tailored to desired quality attributes. The aspects of process and product activities involved:
• Evaluating and establishing the ratio of fruit puree required to maximize the nutritive/bioactive components;
• Identifying suitable ingredients, such as; sweeteners, fillers and gums; that will improve the taste and nutrient profile of the fruit leather;
• Assessing the usage level of the ingredients in the formula;
• Assessing the functional and nutritional properties of the fruit leather;
• Optimizing the process parameters (mixing, sample thickness, and dehydration temperature and time).

3.0 DEVELOPMENT OF FRUIT LEATHER

Assessment of ingredients, formulation and processes are critical in the prototype development of fruit leather. Several ingredients were tested to assess their functionality in fruit leather development. The fruit fractions (excluding haskap and chokecherry) used in the trials were obtained from an optimized process established earlier in the project. Similarly, additional ingredients were sourced from commercial suppliers or received as samples with the exception of carrot powder which was processed and produced at FDC.

3.1 Test Methods

Fruit leather was analyzed for pH, \( a_w \), colour, moisture (rapid) and sensory attributes. The formula and process parameters were adjusted to attain desired quality attributes using methods described below (Table 1).

Table 1: Methods used to evaluate quality parameters of fruit leather

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pH</strong></td>
<td>The pH of the puree was measured with pH meter, Accumet model XL50.</td>
</tr>
<tr>
<td><strong>Water activity (( a_w ))</strong></td>
<td>Water activity was analyzed using method MFLP-66 with Aqualab model 4TE (Decagon Devices, Inc.).</td>
</tr>
<tr>
<td><strong>Colour</strong></td>
<td>Fruit leather colour was measured by Chroma meter (model CR-400, Konica Minolta Sensing Inc.) with the measure head placed directly on the fruit leather sample. The colour system ( L^* ), ( a^* ) ( b^* ) representing lightness, red-green, and yellow-blue, respectively was used.</td>
</tr>
<tr>
<td><strong>Moisture</strong></td>
<td>The moisture was analyzed using a Denver Instrument IR 30 moisture analyzer.</td>
</tr>
<tr>
<td><strong>Sensory</strong></td>
<td>Two to three FDC staff trained in basic fruit leather attributes evaluated the sensory qualities. The panelists rated samples for appearance, odour, texture, flavour balance and overall acceptability.</td>
</tr>
</tbody>
</table>
3.2 Processing Equipment
- Scale: Analytical, E0214
- Hobart Mixer (Model N-50)
- Trays, teflon coated
- Spreader
- Hobart Oven (Model HO 300E, rotating, convection)

3.3 Ingredient Selection
The following ingredients listed in Table 2 were tested during the development of the prototype fruit leather.

Table 2: List of ingredients tested during the development of fruit leather.

| Fruit Fractions | • Seabuckthorn puree  
|                 | • Saskatoon puree 
|                 | • Blackcurrant puree 
|                 | • Sour cherry puree |
| Sweeteners      | • Evaporated cane juice crystal 
|                 | • Evaporated cane juice 
|                 | • Honey 
|                 | • Vital sugar |
| Fillers         | • Apple flakes 
|                 | • Corn fibre 
|                 | • Citrus fibre |
| Others          | • Oat bran 
|                 | • Carrot powder 
|                 | • Mustard powder, de-heated |

3.4 Prototype Development
Generally, Prairie berries are not readily available in large quantities for commercial processing. Consequently, the research teams consented to working with complementary blends from the berries. Preliminary trials were conducted to characterize the physical and sensory properties of the fruit purees. In the study, fruit purees obtained from saskatoon, blackcurrant, seabuckthorn and sour cherry were evaluated for pH and sensory attributes (colour and flavour). All berries studied were similar in colour with the exception of seabuckthorn. A description of the pH, colour, and flavour is provided in Table 3.

Since seabuckthorn fruit colour was distinct from others; varying amounts were blended to evaluate potential colour changes and identify sensory issues associated the blends. Similarly, blends with varying levels of seabuckthorn were mixed, dehydrated and
evaluated for appearance and taste. Based on the results, equal amounts of purees were used to create a blend as obtaining the fruits in large quantity for commercial production could potentially impact the project outcomes.

Table 3: Physical and sensory properties of selected fruit purees.

<table>
<thead>
<tr>
<th>Fruit</th>
<th>pH</th>
<th>Colour</th>
<th>Flavour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saskatoon</td>
<td>4.01</td>
<td>Dull, deep wine red colour</td>
<td>Sour flavour</td>
</tr>
<tr>
<td>Blackcurrant</td>
<td>2.91</td>
<td>Glossy, red purple colour</td>
<td>Unpleasant odour and overpowering flavour</td>
</tr>
<tr>
<td>Seabuckthorn</td>
<td>2.90</td>
<td>Pumpkin-like orange colour</td>
<td>Tart, acidic and tangy flavour</td>
</tr>
<tr>
<td>Sour cherry</td>
<td>3.33</td>
<td>Brownish red colour</td>
<td>Tangy, slightly tart flavour</td>
</tr>
</tbody>
</table>

3.4.1 Prototype formula

Further bench top studies included dehydration of puree blends at 60°C. In the absence of fillers, the fruit leather was thin with acceptable appearance and taste. Based on these comments, a basic formula was developed to evaluate the effect of ingredients on sensory qualities.

The formula (selected ingredients) and process (mixing time, dehydration temperature and time) was controlled to determine functionality of ingredients. Texture, mouthfeel, and aftertaste were evaluated on the prototype product.

Prototype fruit leather was developed following the testing of ingredients at varying levels as described in Table 4. The processing steps involved weighing, adding dry ingredients to the puree blends, mixing, pouring on trays, levelling, and dehydrating at 60°C. The process is shown in Figure 1. The dehydrated samples were evaluated by the sensory panel.
Table 4: Range levels of added ingredients tested in the development of fruit leather and their effect on textural quality.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>% Levels</th>
<th>Effect on fruit quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit puree blends (seabuckthorn, saskatoon, blackcurrant, and sour cherry) each</td>
<td>25</td>
<td>Fruity flavour, tart / acid flavour, thin leathery texture</td>
</tr>
<tr>
<td>Evaporated cane juice</td>
<td>10 - 30</td>
<td>Reduced sweetness compared to evaporated cane juice crystals</td>
</tr>
<tr>
<td>Evaporated cane juice crystals</td>
<td>10 - 30</td>
<td>Good texture, intense fruity flavour, balanced acid / sweet flavour</td>
</tr>
<tr>
<td>Honey</td>
<td>10 - 30</td>
<td>Good texture, good initial flavour and tartness level later, not well balance flavour</td>
</tr>
<tr>
<td>Vital sugar</td>
<td>12 - 21</td>
<td>Reduced sweetness, tart, less stickiness in the mouth, reduced drying time</td>
</tr>
<tr>
<td>Apple flakes</td>
<td>3 - 15</td>
<td>Good texture, maintained fruit flavour and sweetness</td>
</tr>
<tr>
<td>Citrus fibre</td>
<td>3 - 8</td>
<td>Good binding properties but pulled down sweetness and flavour, retained fruit colour</td>
</tr>
<tr>
<td>Carrot powder</td>
<td>4 – 8</td>
<td>Cooked carrot flavour, chewy, no acid flavour, flaky</td>
</tr>
<tr>
<td>Corn fibre</td>
<td></td>
<td>Crumbly texture, very dry and powdery</td>
</tr>
<tr>
<td>Oat bran</td>
<td>3 - 8</td>
<td>Delivers nice texture, subdues fruit flavour, slight film coating on tongue</td>
</tr>
<tr>
<td>Pea fibre</td>
<td>3 - 10</td>
<td>Very dry, lacked rubbery texture, chalky mouthfeel</td>
</tr>
<tr>
<td>Mustard powder</td>
<td>1 - 5</td>
<td>Reduced surfaces stickiness, tangy mustard flavour, very strong at 2% level.</td>
</tr>
</tbody>
</table>
4.0 RESULTS AND DISCUSSIONS

4.1 Fruit Leather Quality Indices

Generally, fruit leather required the use of citrus fibre, apple flakes and sweeteners for improved textural quality and taste. Exclusion of these ingredients produced thin leathery samples that lacked cohesiveness. Desirable fruit leather texture was influenced by ingredients, the depth of mixture on trays, and dehydration conditions (temperature and time).

The data for the quality indices (colour, water activity and moisture) measured on the fruit leather are shown in Table 5. The fruit leather moisture content of 19.26% is acceptable and produced a fruity flavour and a dry, chewy texture expected of fruit leathers. The $a_w$ indicates the available water needed for microbial growth. At low $a_w$ levels of 0.51, the fruit leather will not support the proliferation of micro-organisms.
Table 5: Colour, water activity and moisture of fruit leather

<table>
<thead>
<tr>
<th>Sample</th>
<th>Colour</th>
<th>Water activity</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L*</td>
<td>a*</td>
<td>b*</td>
</tr>
<tr>
<td>Fruit leather</td>
<td>24.60</td>
<td>3.66</td>
<td>0.47</td>
</tr>
</tbody>
</table>

The visual appearances of the formula before drying (left) and dried fruit leather (right) are shown in Figure 2. The fruit leather colour appeared dark and the L*, a* and b* values are shown in table 3. In Figure 2, the fruit leather had darker visual appeal with a slightly rough surface texture than the puree mixture before drying.

![Figure 2: The visual appearance of the fruit leather mixture before drying (left) and after drying (right).](image)

4.2 Process Challenges

The processing challenges encountered during the prototype development stage were addressed but the following are still of concern:

- Depending on the type of filler/binders used in the formulation, the viscosity of the mixed puree was difficult to level on the dehydrating trays. Uneven spreading of puree resulted in variable thickness.

- Extended dehydration process degraded the fruit leather colour and the exposure to air; heat and light during drying can further negate the antioxidant benefits because of quality degradation under these conditions.

4.3 Future Activities

- Evaluate the use of flavours and fillers and their effect on taste and overall acceptability.
- Scale-up the formulation and process to batch production capacity of 5 kg. Determine the nutritional properties of the fruit leather.
• Establish process yields and drying times since they are specific to the amount of mixture / tray and drying conditions.
• Assess the effect of processing changes on the quality of the final product.

5.0 CONCLUSIONS

Based on these results, FDC successfully initiated the development of prototype fruit leather using selected puree blends. Incorporation of the blend in equal ratios was possible and provided good visual appeal and blended flavour.

The formula and process developed showed that fruit leather with acceptable sensory quality can be produced with the selected fruit purees.