Presented To:

Ontario East Wood Centre & Eco-Industrial Park

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MAPLE PROCESSING AND REFINING *FOR THE BIOECONOMY OF EASTERN ONTARIO*

Ontario East Wood Centre & ECO-INDUSTRIAL PARK

IN AFFILIATION WITH:

Queen's UNIVERSITY

TEAM

A Techno-Economic Feasibility Report and Marketing Study

Proposed By: ***Mary Hales, Skyler Howes, Andrew McFadden, Julia Natalie, and Tatyana Smetheram***

Maple Syrup

An Emblem of Canadian Identity

Maple Syrup - A 100% pure, natural, and traditional product that ties together the cultural fabric of Canada. The operation of maple sugaring underlines an ancestral way of life in Canada, promotes a recognizable national identity, and holds tribute to centuries of Indigenous traditions and contributions. Overtime, it has consistently been proven as a unique, natural, and pure health product with high nutritional value and digestive benefits.

Queen's University students, Mary Hales, Skyler Howes, Andrew McFadden, Julia Natalie, and Tatyana Smetheram have worked in conjunction with the Ontario East Wood Centre - an environmentally regulated complex designed for the exploration, growth, and industrialization of environmentally regulated products. The team has conducted a feasibility analysis for the processing, refinement, and development of a centralized demonstration-sized maple production facility. The proposed design, accompanied by a thorough marketing analysis, is presented with the intent to encourage Eastern Ontario to extend its market share in the maple industry. There are numerous opportunities discussed in this report that emphasize the ways in which Ontario can enter the maple market and compete with Quebec.

An economic estimate for refining the raw maple sap from sugar bushes, as well as the numerous health and environmental incentives to encourage consumers to buy a diverse range of maple products in a localized area, are justified through a detailed analysis of technical, business, and safety factors.

In an industry where Canada is the world's leading producer and exporter of maple products, the significance of Ontario's contribution to maple production is apparent. The goal of this report is to contribute to research that will enhance existing processes and highlight our country's true connection to nature, Indigenous influences, and national pride.

By employing the research, suggestions and innovative designs outlined in this report on a larger scale in Ontario - not just for one facility - significant investment opportunity and market breakthrough will become a reality. It is this collaborative effort that will help Ontario tap into its potential.

> “*Above everything, we are Canadian - Sir George Etienne Cartier*”

Contents

Queen's UNIVERSITY

Who We Are

A motivated, disciplined, and goal-oriented TEAM of Queen's students from a variety of technical backgrounds and disciplines. We are passionate about sustainable operations, and by applying our cross-functional strengths, we aim to address the various facets of your company's proposed project.

Pictured Left to Right: *Andrew McFadden, Skyler Howes, Tatyana Smetheram, Mary Hales, and Julia Natalie*

WHY IS THIS PROJECT OF IMPORTANCE TO US?

We are grateful to have had the opportunity to interact with the Ontario East Wood Centre and employ our individual areas of expertise to this province-wide endeavor. The impact of maple on the cultural fabric of Canada, and its degree of both intangible and tangible benefits, make this techno-economic feasibility study of dire importance to our TEAM. Our team is passionate about this industry and believe that it is important to support the local economy. We value the importance of Canadian heritage and hope that through this study, homage will be paid to the historical development of Canada, and that the design of an innovative commercial process to promote maple production - respectful of both environmental and aesthetic factors - be fulfilled.

CHEMICAL ENGINEERING | LIFE SCIENCE | BUSINESS

Coming from an interdisciplinary background, as a TEAM, the technical knowledge that has been applied to this report is comprehensive. A background in chemical engineering has provided the foundation for process analyses and flow diagrams, technical calculations, operational improvements, and for fundamental compositional knowledge. A contextual understanding of life science aided in the research of biological improvements and chemical process additives. Furthermore, our strength in business allowed for an in-depth marketing analysis on the produced maple products, as well as calculating the final economic value of production.

We are a team of multi-disciplinary students tasked with helping the *Ontario East Wood Centre* expand their research and promote sustainable development of Ontario's vast national resources. Our goal is to help highlight the importance of maple products in Canada and to put Eastern Ontario on the map in the world-wide maple market.

QUEEN'S UNIVERSITY AND ITS INDIGENOUS TIES

Queen's University is an institutional education centre that lies on traditional Anishinaabe and Haudenosaunee land. Before its current existence, usage, and foundation for the development of European colonies, it was historically a territory that hosted, and continues to host Indigenous peoples and their practices.The contributions and traditions of these peoples are tied to the surrounding land and this relationship to the land is continuously recognized and respected by its inhabitants.

> *Queen's University is situated on traditional Anishinaabe and Haudenosaunee Territory.*

Intangible Benefits

Ontario Market Breakthrough

Ontario's place in the maple market hierarchy will increase if new and innovative ways to refine and purify maple products are developed. These innovative processing techniques will give Ontario the upper hand in the largely dominated Quebec maple market and help us promote maple products world-wide.

National Appreciation

Being such a large part of Canada's cultural fabric, this plan will instrumentally increase consumers views on Canada as a country, and in return the views on our ancestors responsible for its introduction. This intangibly increases country pride, and historical appreciation.

Health, Safety, Well-Being

By investigating ways to improve the purity of maple products in the refining process, and researching more in depth about maple health benefits, the usability of the products by consumers will increase, and their health, safety, and well-being will flourish. This will highlight Canada's, and specifically Ontario's, important contribution to a significant market.

Project Objectives & Constraints

A feasibility design for a process to refine maple sap, and a strategy to market the resultant products was conducted. The cost of refining this raw maple sap from maple trees, as well as several health and environmental incentives to encourage consumers to purchase Eastern Ontario's diverse range of maple products, have been justified through a detailed analysis of technical, business and safety factors.

The maple industry, widely controlled by Quebec, motivates Eastern Ontario to improve, renew, and expand their techniques used to process, boil, and endorse high-quality maple products. Ontario accounts for less than 1% of Canadian maple exports with Quebec covering almost 95%! However, Ontario is home to approximately three times more maple trees than Quebec, having approximately 1.8 million hectares of maple dominant stands [32]. While testing for process feasibility, research to examine the compounds, flavours, and health benefits of the maple sap was also conducted to emphasize its nutritional importance and the influence that Indigenous peoples have had on this industry.

Project objectives and desired results have been adamantly broken down - focusing on the utilization of raw maple sap in a variety of products. These products are manufactured primarily for use as a food source but can be utilized in other normalized practices such as in the cosmetic/skin-care industry. Maple applications that have been studied and developed are outlined below.

1. SAP WATER **2. MAPLE SYRUP** **3. GRANULATED MAPLE SUGAR** **4. SUGAR SAND (NITER)**

This diverse range of maple products are created as by-products from the maple syrup production process, or by further manipulating the syrup itself. It is with this wide array of nutritious maple products and by innovating and improving the production process, that Eastern Ontario will have a chance to make a substantial mark on the Canadian maple market and optimistically in the future - the international market. Raw maple sap, extracted from maple trees in a localized sugar bush, have been used as the feed source to produce the maple products in this process, delivered from the surrounding acreage around the production facility.

BUSINESS, PROJECT, & ENGINEERING CONSTRAINTS

1. The proposed plant must support an incoming sap feed coming from 100,000 taps in a 1600 acre sugar bush (Maximum of 10,000 L of syrup/day).
2. The sugar concentration of refined maple syrup must be at a minimum 66% or 66 Brix, and at a maximum 68.9% of 68.9 Brix (the sugar content of an aqueous solution).
3. The maple products must meet Canadian regulatory requirements, under the Maple Products Regulations (MPR), the Food and Drugs Act (FDA), and the Consumer Packaging Labelling Act (CPLA). It must also meet Ontario regulations, under the Ontario Maple Syrup Regulations.
4. The sugar sand (niter) product must meet the Canadian regulatory requirements set out by the Cosmetic Regulations from the Justice Laws Website of the Government of Canada.
5. Maple syrup must be produced exclusively by concentration of maple sap and contain no additives in the final product (must be 100% pure).
6. The process must produce maple syrup and products that are clean and fit for human consumption.
7. The process must be environmentally sustainable and safe.
8. Extraction of raw sap must minimize/reduce harm to trees and saplings.
9. Monetize by-products, and find ways to re-use waste products (water) in the process.

A diverse range of technical information including current processes for manufacturing maple syrup (nature of the sap run, collection methods, evaporation, filtration, classification, and possible improvement areas), a process flow diagram for the refining process, the application of maple health benefits for marketing, an intensive policy analysis, an overview of the global maple market, and the history of the Indigenous peoples maple origins has been investigated in this report. An overview of future growth strategies and recommendations has also been underlined.

The History of the Maple Tree & Indigenous Contributions

Indigenous peoples have a rich history in collecting sap and producing syrup [1] [2] [3]. Maple sugar was used as the primary sweetener by the Indigenous peoples of Canada long before processed sugars existed. Maple syrup was also a desired commodity for many colonists [4]. Maple sap, also referred to as "sweetwater" has traditionally been used by Indigenous peoples for medicinal purposes [5]. Though traditions vary from region to region, many Indigenous communities celebrate maple sap as it is the first resource that is harvested in the spring [5]. To many communities, maple sap is representative of the beginning of a new season and to some communities, is symbolic of new life. For this reason, many Indigenous communities traditionally administered maple sap to pregnant women as a cleansing agent [5]. Indigenous people have a close relationship with the environment and traditionally value total health which reflects harmony in the body, mind, spirit, and body, mind, spirit, and heart [4]. Though Indigenous peoples have traditionally used maple sap to benefit their physical health, it is apparent from a basic understanding of Indigenous culture, that such an agent is more than just medicinal.

Traditional Collection

Traditionally, trees were tapped 2-3 feet above the ground using hand tools; sap was collected in either buckets or bags that needed to be emptied periodically [9] [10]. The sap was then manually taken back to the sugar shack [9][10]. Moving forward to present day, trees are now tapped and connected to a tubing system (tap lines) that can span entire forests before coming together in one main line that goes directly to the sugar shack. A pump is used to create a light vacuum within the tap lines that gently guides the sap away from the tree. Incorporation of a pump into the tree tapping process, increases yield on days where sap production is low or absent [10].

Nature of the Sap Run

Sap flow is relatively unique to North America [9]. The process begins in the summer, when the maple tree produces sugars through photosynthesis [9]. These sugars are stored in the roots of the tree to promote growth. Vessels underneath the bark of the tree contain gases and allow for sap to move throughout the tree and deliver nutrients [9]. During spring, temperatures hit below freezing during the night and compress these gases - freezing the sap and expanding in the tree. As the vessels thaw in the morning, the gases decompress and bring water up from the roots, carrying the sugar with them. This pump-like action allows for the sap to flow freely from the tree. The sap runs for 4-6 weeks per year, and is dependent on temperature. Recovered volumes of sap can vary from under a quart, to several gallons [11].

CURRENT PROCESSING METHODS

MAPLE SYRUP PRODUCTION

Evaporation is used to reduce the amount of water in the sap. Originally, this was done in pots over an open fire, leading to evaporator systems that were heated by fires. Now, wood fired evaporator systems are typically used, with reverse osmosis being utilized before the evaporators to reduce the energy requirement of these units [9]. Reverse osmosis removes water by forcing it through a membrane at high pressures, separating it from the sap. This removal of water concentrates the sap from 2-4 weight % to 15-30 weight % [9] [14]. Reverse osmosis is used to reduce the potential costs of heating the evaporator system [9].

When it leaves the reverse osmosis system, the sap moves to an evaporator [9]. For a process that is more than 50 taps, a continuous evaporator is suggested [11]. The evaporator system consists of an arch, grates, pans and a stack with grates only necessary for the wood burning systems [6]. These evaporators act as large pans, though most consist of a flue and syrup pan [12]. The flue is designed in order to increase the surface area of the pan [12]. The pans are then separated so that the flow around the separations is slow [12].

Evaporators can be heated in various ways, such as by wood, oil and gas [10]. The sap is evaporated until the sugar concentration meets a minimum 66% or 66 Brix [9]. In order to meet this standard, the sap must be boiled to a temperature of 104°C [13]. A barrier to installing and using evaporators in Ontario is that they are regulated by the Technical Standards and Safety Act when oil is used as fuel [15]. This means they require field approval, where they would need to follow: Technical Standards and Safety Act, 2000, Fuel Oil Regulation 213/01 and Ontario Installation Code for Oil-Burning Equipment, 2006 [15].

Next, filtration is required before final packaging and testing. At small scales, the syrup is passed through wool or Orlon - a synthetic material similar to wool - and then canned while still hot [11] [16]. Filter press systems or various filters are utilized in continuous systems with card filters or banks of filters in order to remove substances such as calcium deposits or sugar sand (niter) which are undissolved nutrients [9]. This product is then tested for quality standards.

Health Benefits of Maple Syrup

While maple syrup may not be considered a 'typical' nutritious staple, it has been proven to have several health benefits, surpassing other common sweeteners. First of all, while similar to other sweeteners in calories, these other sweeteners have little to offer in terms of nutritional content. Maple syrup, meanwhile, is considered to be an excellent source of manganese & riboflavin, a good source of zinc, and a less significant source of several other important vitamins/minerals as seen in Table 1 [17]. Zinc is associated with positive heart health, both zinc and manganese are associated with immune and male reproductive system health, and riboflavin is known to aid in metabolic processes. In addition to this, maple syrup typically has no preservatives or other additives [18].

- **SETTLES DIGESTION ISSUES**
- **HELPS MUSCLES RECOVER**
- **PACKED WITH ESSENTIAL NUTRIENTS**
- **ANTIOXIDANT POWERHOUSE**

Table 1 - Nutritional information of maple syrup compared with other common sweeteners [7]

Per 60 ml portion in %DV*	Maple syrup of Canada	Honey	Sugar	Brown sugar
Manganese	100	3	0	9
Riboflavin (B2)	37	2	1	0
Zinc	18	2	0	1
Magnesium	7	1	0	7
Calcium	5	0	0	5
Potassium	5	1	0	6
Calories	217	261	196	211
Sugars (g)	54	71	51	54

Legend:
- Excellent source of
- Good source of
- Source of

ANTIOXIDANTS

Another key nutritional benefit of maple syrup is its relatively high concentration of antioxidants. 23 phenolic compounds with antioxidant activity have been found in maple syrup, 16 of which have only been discovered in maple syrup within the past decade. As such, while the wealth of various antioxidants likely have many health benefits, further research is required to determine the full extent of the benefit of these antioxidants [19]. Initial research done on the antioxidative properties of maple syrup has shown that, while not reaching the antioxidative potential of blueberries, it is comparable to that of oranges and strawberries. Moreover, in-vitro tests have shown anti-inflammatory effects as well as anti-proliferative effects on cancer cells [20]. A comparison of the antioxidative potential of maple syrup against some common fruits and vegetables can be seen in

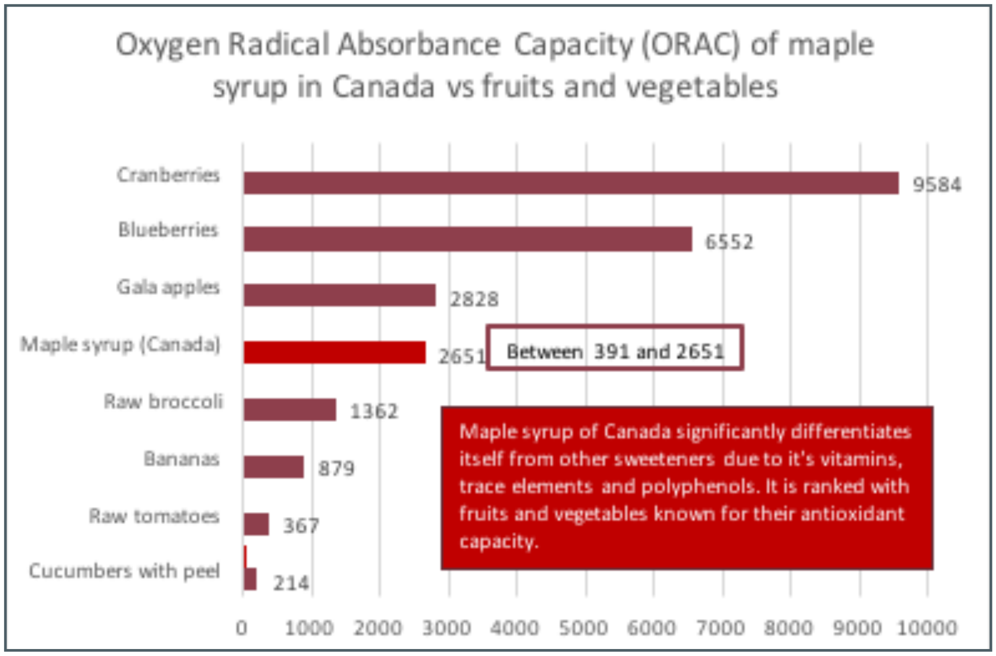

Figure 1 - Antioxidative potential comparison of maple syrup [9]

Maple syrup has also been found to contain abscisic acid, which has recently been found to stimulate insulin release and to increase sensitivity of fat cells to insulin, giving it the potential to combat metabolic syndrome and diabetes [21]. In another recent study, maple syrup was found to have excellent potential as a probiotic delivery system, a possible alternative for probiotics for those who are lactose intolerant [22].

Considering the number of discoveries made about the content of maple syrup in the last decade, it seems likely that there are further properties still to be discovered. The average molecular composition of maple syrup, as it is currently known, can be found below in Table 2.

Table 2 - Average molecular make-up of maple syrup [12]

Component	Quantity
Sucrose	68%
Glucose	0.43%
Fructose	0.30%
Water	31.70%
Malic acid	0.47%
Fumaric acid	0.004
Calcium	775 mg/L
Magnesium	167 mg/L
Potassium	2026 mg/L

Current Maple Research

Current research being performed by the **Ontario Maple Syrup Producers Association (OMSPA)***, and in* **Kemptville, Ontario** *and* **Vermont, USA** *may give rise to more expansion within the maple syrup industry and encourages a more holistic and comprehensive view on sugar making and sugar bush maintenance [30]. Specifically in Ontario, there is a greater emphasis on the community that sugar making provides and the cultural importance of maple syrup when it comes to research. The ability to tie these intangible qualities to tangible research is what makes these research centres so valuable to both the communities they are within and the heritage that they honour.*

OMSPA FACILITY FEASIBILITY STUDY

A MAPLE SYRUP BOTTLING FACILITY

Of the thirteen bottling facilities in North America, only one bottling facility is located in southwestern Ontario [32]. Increasing the available maple syrup bottling services in Ontario has the potential to significantly increase the efficiency of packaging maple syrup and could increase the availability of maple syrup produced in Ontario sugar bushes for local Ontario consumers. Increasing the availability of locally produced maple syrup may encourage more distributors to support Ontario-produced maple syrup.

With 1.8 million hectares of maple dominant stands, Ontario has a very low share of the maple syrup market, though it is home to nearly triple the maple trees available in Quebec [32]. A large majority of these maple trees in Ontario remain untapped. In addition to Ontario's supply of maple trees, northern Ontario is also inhabited by birch trees. Birch syrup is another organic product that retails for a high value. Producers of birch sap would further benefit from a syrup bottling facility in Ontario. Such a facility has the potential to significantly improve Ontario's economy by creating jobs and promoting consumption of local products. Furthermore, since both maple and birch trees only successfully grow in particular conditions, Ontario has a rare resource that could be extracted and sold for profit not only locally, but possibly globally. Though Quebec maple syrup producers currently dominate the global maple syrup market, increasing the ease of entering into the maple syrup production industry in Ontario could present Ontarian's with the opportunity to tap into their potential and thus gaining a

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Kemptville, Ontario, Canada Research

Research in Kemptville, Ontario is slowly on the rise as the Agroforestry Educational Centre reopens under new ownership by the Municipality of North Grenville. This centre was previously owned by the University of Guelph and has been out of service for the past three years. The reopening of the facility allows for the development of an Ontario based research campus, similar to those that exist in other syrup producing regions. The importance of providing this type of facility to the public is that it brings recognition to sugar bushes in Ontario and further strengthens the cultural ties that maple syrup has as a national emblem for Canada. The location of this facility offers a unique experience compared to other centres, as it is less common for Ontario sugar bushes to transport their sap to a centralized processing facility such as those in Quebec or Vermont, although that is what is occurring in Kemptville. This means that focus can be moved from syrup production to sap extraction and tree health – an area of maple syrup research that has little available information currently but will be paramount in preserving the future of sugar bushes all over North America.

Vermont, USA Research

The Proctor Maple Research Centre in Vermont, USA is a facility designed for research on the sugaring process, and the effects of different equipment and conditions on the production of maple syrup. The centre has their own sugar bush and a production facility, alongside a modern laboratory equipped for research purposes. The ability to provide comprehensive information and research on maple syrup production could drastically change the face of sugar making nationwide and could help standardize maple syrup production. The Proctor Maple Research Centre focuses more on the research itself and less on the community surrounding sugar making.

Towards Our Future

By applying and understanding these specified maple studies, and expanding research in the future, our national comprehension of maple products and their marketing potential will expand world-wide.

Maple Marketing Analysis

The global maple syrup market is predicted to grow, with Ontario currently only contributing to approximately 3% of the market [32]. Though producers of maple products in Quebec dominate the current market, Ontario has the potential to gain a larger portion of the market share and potentially replace the distribution of Quebec-produced maple products in Ontario. This analysis focuses on four primary maple products, within the industry, including maple water, maple syrup, sugar sand, and granulated maple sugar.

MAPLE (SAP) WATER

With elevated levels of potassium, calcium, magnesium, zinc, and other beneficial components, maple water is considered to have many health benefits [33] [9]. Associated with initiating positive heart health and maintaining a healthy immune system, the components of maple sap are particularly beneficial to sustain a healthy life style, especially compared to many beverages.

MAPLE SYRUP

Much like maple water, maple syrup has many health benefits as previously mentioned. Furthermore, maple syrup is a Canadian staple that is becoming popularized beyond North America. The uses for maple syrup are also expanding - in addition to being the centerpiece of a Canadian breakfast, maple syrup is often used as a healthy alternative for a sweetener in drinks, baking, and cooking.

SUGAR SAND (NITER)

Like the rest of the identified maple products, sugar sand contains many nutrients that are often discussed to have anti-aging benefits. Due to the high levels of malic acid, sugar sand can have anti-aging properties when used as a skin care product. It can be used as a scrub and distributed to spas, cosmetic companies, or potentially directly to consumers in small farmers market-type settings.

GRANULATED MAPLE SUGAR

Granulated maple sugar is often known as an organic alternative to other sweeteners. Granulated sugar is produced by the boiling of maple sap until nearly all the water has evaporated, leaving a sugar composed of approximately 90% sucrose and 10% glucose and fructose [34]. Maple sugar is unique compared to cane sugar and beet sugar, as a small hint of maple flavour still remains in the product.

CUSTOMER PROFILE

MAPLE (SAP) WATER

Maple water appeals to health-conscious consumers with analysis identifying that the target market for maple water in Canada primarily consists of young consumers. Data shows that in 2015 up to 31% and 32% of Generation Z and millennials respectively, were willing to pay premium costs for goods produced with sustainably sourced ingredients [35].

MAPLE SYRUP

There are several target markets to consider when analyzing maple syrup sales. First, maple syrup can be sold directly to consumers for primary use in cooking and baking, or on its own. This market segment consists of consumers that earn a moderate to high income due to the premium price that maple syrup is generally sold at. Psychographic segmentation further divides our target audience into health-conscious consumers that value locally sourced goods. Alternatively, maple syrup can be sold for use as an ingredient in other products such as soft drinks, cereals, and snacks [36].

GRANULATED MAPLE SUGAR

The target audience for maple sugar is similar to the target audience previously identified for maple syrup. Compared to other sugar options, maple sugar is sold at a premium price and will likely attract consumers that value locally sourced goods and the health benefits of maple products.

SUGAR SAND (NITER)

The target audience for sugar sand, a maple sugar by-product, is companies that produce skin care products and spas that offer exfoliating treatments. Rather than selling directly to a consumer, the target audience for sugar sand is the cosmetic industry.

Maple Marketing Analysis Cnt'd.

Porters Five Forces

A Porter's Five Forces Framework was applied to the four maple products being created in the proposed process. The competition of other businesses was analyzed by means of five forces that determine competitive intensity, product attractiveness and thus potential company profitability. These five forces include, the **Intensity of Competitive Rivals,** *the* **Threat of New Entrants,** *the* **Threat of Substitutes,** *the* **Bargaining Power of Suppliers,** *and the* **Bargaining Power of Buyers.** *A summary of these 5 forces can be found below in Figure 2.*

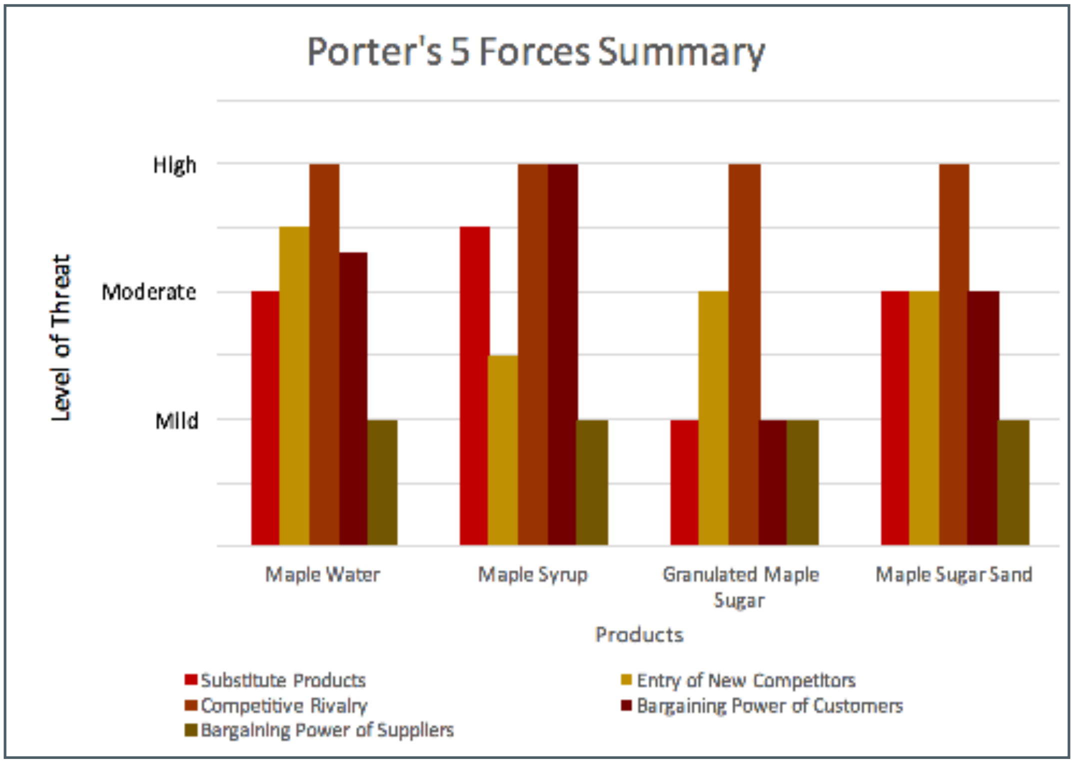
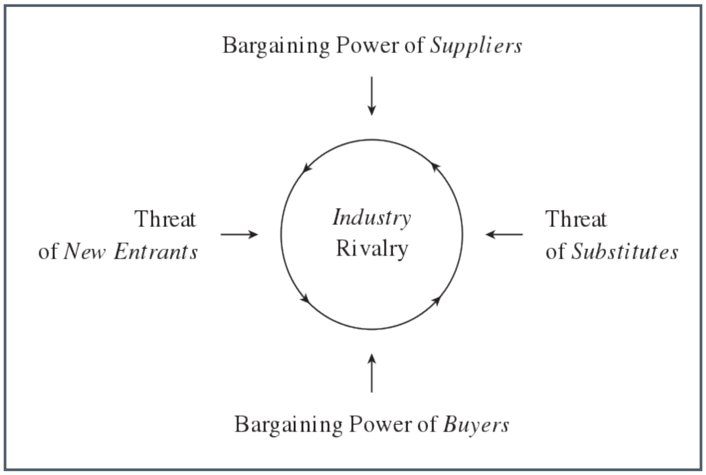


Figure 2 - Porter's 5 Forces Summary Chart



THREAT OF SUBSTITUTE PRODUCTS FROM COMPETITORS

The threat of substitute products is moderate in the maple water industry. **The popularity of health beverages is projected to increase, which creates demand in the market [51]. Further, consumers are increasingly prioritizing locally sourced goods [52]. As many facilities that produce maple products are similar, and likely incur similar costs, the location may be the final factor that determines a consumer's purchase. Since the cost for consumers to switch from one brand to another is low, the quality of the product and location of production are the primary factors that determine the consumers' decision to purchase alternative brands of maple water.**

THREAT OF THE ENTRY OF NEW COMPETITIORS

Existing maple water producers have an advantage over new competitors as these firms have already obtained large capital expenditures required to produce maple water. **Current maple syrup producers likely already have most of the equipment required to produce maple water, except for packing supplies and pasteurizing equipment. Since maple water is a new trend in the beverage market, there are only several well-established producers most of which have not yet established strong brand identities.**

01: Maple (Sap) Water

BARGAINING POWER OF SUPPLIERS

The bargaining power of suppliers is mild. **There are few suppliers required to produce maple water from the perspective of a sugar bush owner. The primary supplier to produce maple water is the packaging supplier, which would likely be either cardboard cartons, plastic bottles, or glass. With a multitude of packing supplier options, suppliers do not have much power in the maple water industry [58].**

BARGAINING POWER OF CUSTOMERS

Consumers in the food and beverage industry have a moderate to high bargaining power. **The demand for high-quality food products sold for a reasonable price put pressure on maple water producers. In the health-beverage market, sales have shown that many consumers are willing to pay a premium price for nutrient-rich beverages that taste sweet, especially if the product is organic [57]. Addressing maple water specifically, the bargaining power of customers is only moderate, since maple water options for consumers already exist. The widespread availability of similar products, such as coconut water, may give a competitive edge over maple water products.**

INTENSITY OF COMPETITIVE RIVALRY

The competition in the maple water industry is high. **Sap-based health drinks are recently trending in North America. As consumers shift their preferences from colas and soft drinks with high levels of refined and artificial sweeteners to healthy mineral-rich drinks, the opportunity to introduce a sap-based drink in Canada is promising. Products such as vitamin water and coconut water pose a threat to the concept of introducing sap drinks to the competitive non-alcoholic drink market. Large companies that dominate the non-alcoholic drink market, including Coca-Cola and Pepsi, have both invested in this new health-drink trend. Coca-Cola acquired vitamin water and Zico coconut water, while Pepsi obtained Vita Coco, the leading coconut water brand [53] [54]. This indirect competition in the health-drink market is well established and is projected to increase in popularity [51]. The large investments made by key players in the industry indicate that there is a promising market for health drinks. Maple sap drinks have also recently emerged as a health drink. Though not as popular as coconut water, maple water producers, such as SEVA, are finding success catering to a similar market of consumers. The top three leading manufacturers of maple water include Seva, Oviva, and Maple3, all of which produce their product in Quebec, Canada [55]. Several other comparable maple water producers prepare and distribute their product in the US, and are thriving, like their Canadian counterparts. Seva, the top Maple water producer, has already ventured into an international market [56]. While the success of current players in the health-beverage industry is a promising indication that maple water is popular among consumers, the competition in the market is high, particularly with companies based in Quebec.**

THREAT OF SUBSTITUTE PRODUCTS FROM COMPETITORS

The threat of substitute products is moderate to high in the maple syrup industry. **Agave nectar and honey are two similar products that could replace maple syrup as a viscous sweetener. These sweeteners are marketed for their health benefits, similar to maple syrup.**

THREAT OF THE ENTRY OF NEW COMPETITORS

Entry barriers are high for new competitors, therefore the threat of entry of new competitors is mild to moderate for maple syrup producers. **Successful sugar bushes require a healthy, lush forest of aged maple trees. A large source of maple sap is difficult to obtain without a sugarbush of maple trees. Furthermore, maple sap can only be collected in cool climates. Additionally, there are strict regulations for producing syrup in Canada, especially when producing organic maple syrup. Lantic, a Canadian company that currently has the largest share of the consumer market for refined sugar in Canada, has recently acquired L.B. Maple Treat Corporation, a Quebec company that produces maple syrup [59]. This acquisition may pose a threat to small-scale maple syrup producers that intend to enter the market individually. Alternatively, Lantic's interest in maple may also provide small maple sugar bushes with an opportunity to sell their product to large companies to be further distributed.**

02: Maple Syrup

BARGAINING POWER OF CUSTOMERS

The bargaining power of consumers in the maple syrup industry is high. **Consumers have a large variety of choice when it comes to maple syrup. Consumers make their purchasing decisions based on price, quality and the source of the product [62]. Consumers purchasing premium products are willing to pay an elevated price for high quality and locally sourced products, however, there are many maple syrup producers that offer a high-quality product. With high competition in the industry, consumers have high bargaining power.**

BARGAINING POWER OF SUPPLIERS

The bargaining power of suppliers is mild in the maple syrup industry. **Similar to the maple water industry, suppliers for the maple syrup industry include bottling equipment manufacturers and packaging suppliers. There is a large supply of packing suppliers in the industry and it is not very competitive for new suppliers to enter this industry.**

INTENSITY OF COMPETITIVE RIVALRY

Competition within the maple syrup industry is high. **Premium syrup producers can produce a varying quality of product, however, most consumers are naive to the quality of syrup when comparing pure maple syrup brands. Exporting 94% of all maple syrup produced in Canada, Quebec dominates the maple syrup market [60]. Since syrup producers in Quebec are the leaders in syrup sales, the competition for syrup producers in Ontario is high. Syrup producers in Quebec appeal to an international audience, while Ontario syrup producers predominately rely on local sales, specifically selling syrup directly from the production facility [61]. Sugar bushes in Quebec are well established in the industry and capitalize on the Canadian history of maple syrup. Maple syrup producers in Ontario have few avenues to differentiate from their competitors in Quebec, other than the quality of the syrup and the ability to appeal to Ontarians by promoting their locally-sourced products. Several studies have shown that consumers are more likely to purchase locally sourced foods, minimizing the threat of competitive rivalry within Ontario.**


VERMONT
Pure Maple Syrup

THREAT OF SUBSTITUTE PRODUCTS FROM COMPETITORS

Since the sugar and sweetener industry is so saturated with refined sugar and artificial sweeteners, there is little threat from new substitute competitors. As refined cane or beet sugar and artificial sweeteners are already available and competitively priced setting a high customer standard, any substitute product would have to be priced competitively in relation to existing products or have another attractive quality to entice consumers to purchase the new product [63]. Granulated maple sugar may be offered for a premium price, however being locally produced in Canada may attract consumers to purchase maple sugar as a sweetener rather than a cheaper refined sugar or artificial sweetener.

03: Granulated Maple Sugar

INTENSITY OF COMPETITIVE RIVALRY

The sweetener industry is highly competitive. With so many different forms of sweeteners, including refined cane and beet sugars, artificial sweeteners such as aspartame and sucralose, and natural sugars such stevia and maple sugar, there are multiple market segments in the sugar/sweetener industry. Consumers concerned with price may opt for refined sugars while health-conscious consumers may prefer natural sugars. Since many consumers that purchase artificial sweeteners do so for health reasons (ie. Diabetes), this report will exclude artificial sweeteners from analysis as these consumers are not included in the defined target audience.

Refined sugar cane is one of the most consumed sugars in Canada. While data from Statistics Canada illustrates a decline in sugar consumption over time, the industry is still quite profitable [64]. Approximately 85% of the refined sugar processed in Canada is sold to industrial customers, including food and beverage producers [64].

Maple sugar can be produced locally in Canada, particularly in Ontario and Quebec. Alternatively, beet sugar is primarily sourced from Alberta while cane sugar originates from southern, tropical regions. Cane sugar is generally imported from South and Central America, Australia, and the Caribbean, to Canada where it is refined to isolate the pure sugar [64].

THREAT OF THE ENTRY OF NEW COMPETITIORS

*The threat of new competitors in the maple sugar industry is moderate.*Since many Canadian maple sugar bushes prioritize producing syrup over maple sugar, the maple sugar market is small. Most maple syrup producers have the potential to enter the maple sugar market by only adding a few attachments to their current facility allowing for production of a large amount of maple sugar. Since maple syrup producers have overestimated the maple syrup demand in the past, resulting in a large amount of leftover syrup, expanding into the maple sugar market may be beneficial.

BARGAINING POWER OF CUSTOMERS

The bargaining power of customers is low for maple sugar as it is differentiated from other sugars. The large volume retailers that distribute sugars and sweeteners have the ability to bargain for lower prices. While maple sugar may be expensive, this premium cost is still marketable due to the product differentiation. Compared to many affordable refined sugars such as those made from beet or cane sugar, maple sugar is not produced on a large scale. Further, maple sugar is produced locally and ethically in Canada which is another factor that differentiates maple sugar from competing sweeteners.

BARGAINING POWER OF SUPPLIERS

The bargaining power of suppliers in the maple sugar industry is low from the perspective of maple sugarbush owners. Maple sugar producers generally only need to rely on equipment (fixed cost), packaging suppliers, and a small number of additives including safflower oil. Since Safflower oil is required at such a small scale in this process and because there are so many packaging suppliers, the bargaining power of suppliers is low.

04: Sugar Sand (Niter)

THREAT OF SUBSTITUTE PRODUCTS FROM COMPETITORS

The threat of substitute products is moderate in the beauty industry. As existing players in the industry invest more in creating new products, especially those made from raw natural materials, there is a high threat of substitute products being introduced. The increasing demand for organic beauty products puts pressure on the industry to find new products, such as maple sugar sand.

THREAT OF THE ENTRY OF NEW COMPETITIORS

The threat of new competitors in the maple sugar industry is moderate. While the cosmetic and skin care industry is profitable, there are several barriers of entry in this industry. In general, establishing a large-scale manufacturing setup requires a high amount of capital. Brands, such as Burt's Bees, Aveeno, The Body Shop, owned by Clorox, Johnson & Johnson, and L'Oreal, respectively, have already been established as key players in the natural beauty market [65]. With popular brands owned by large companies, it would be difficult for new competitors to enter the market without either an extensive branding strategy or support from a large, well-established company.

INTENSITY OF COMPETITIVE RIVALRY

The beauty industry in general is highly competitive, however, the competition in the natural beauty market is moderate. Skin care products are highly sought for in the industry, especially those that are natural and organic. As the natural and organic beauty market rapidly grows, more players in the industry will compete to obtain a share of the profits and meet consumer demand. The global market for organic personal care products is expected to be approximately 8-10% per year [66].

BARGAINING POWER OF CUSTOMERS

The cosmetic and beauty industry has a moderate bargaining power of customers. With a large variety of organic beauty products available to consumers, the buyer power in the cosmetic industry is high. The increasing competition within the cosmetic industry presents consumers with low switching costs, allowing consumers to easily switch brands [67]. In the context of maple sugar sand, with few manufacturers selling this product, consumers have scarcer opportunities to switch to another brand.

BARGAINING POWER OF CUSTOMERS

The bargaining power of suppliers in the natural beauty industry is low. There is a high number of suppliers and manufacturers in the cosmetic industry. With a high threat of substitute suppliers and little switching costs, suppliers have little power over manufacturers [67].

Potential For Other Maple Products

Aside from the commonly known products such as sap water, maple syrup and maple sugar, the versatile maple tree can produce much more. The ability to manipulate maple sap opens up opportunities for a huge variety of products, from maple vinegar to maple cream. Some products are by-products of the syrup making process, whilst others require designing an entirely new process of maple sap refinement.

MAPLE VINEGAR
A by-product of maple sap fermentation. A buttery and caramel tasting liquid that can add a sweet and tangy finish to any dish. It is easily produced through the addition of bacterial cultures, just as a regular malt or apple cider vinegar.

MAPLE FLAVOURINGS/EXTRACT
Produced by mixing maple sap or syrup with alcohol to extract oils from the raw materials. These oils carry intense, warming flavours that can add an essence of maple to many additional products.

MAPLE MEAD
Made with the use of syrup/sap, water and yeast. Oftentimes, the sap won't be taken straight to the syrup stage and instead will be left to ferment with some of its original water content, giving rise to a more complex variety of bacteria. The yeast ferment by feeding on the sugars within the mixture and producing small amounts of ethanol and carbon dioxide. The resulting product is rich and sweet, with a flavour similar to bourbon.

Experience and innovation are the two keys for us to move forward.

MAPLE CREAM/BUTTER
The product is a misnomer, is a sweet and creamy spread containing no butter or cream at all, and is named as such due to its consistency and versatility. It is produced through a similar process to maple candy, although the product only undergoes partial heating to produce a softer more malleable consistency.

MAPLE TAFFY
Taffy is a thickened syrup that is then cooled quickly to produce a soft and chewy candy. It is less hard than maple sugar or maple candy and is often made outside and laid on the snow to harden.

Additionally, by-products of the maple syrup production process can be applied in different ways. For example, the water removed from reverse osmosis is considered pure water, and is free of minerals. This enables it to be recycled and used as a cleaning agent to remove mineral deposits (niter) from the evaporating tanks and prevents the release of pure, mineral free water into municipal water supplies. It can also be sold to other manufacturers as pure water.

Process Analysis

Key Process Objectives and Reactions

Overall Chemical Reaction

An overall component balance was performed on the maple production process, which has been exhibited below in Figure 3. The maple sap is predominantly made of water with about 5% of its makeup being sugar (95-99% sucrose). Very small trace amounts of other substances, including organic acids, proteins, and minerals are also present. Since they are found in such small quantities, they are not labelled in the diagram.

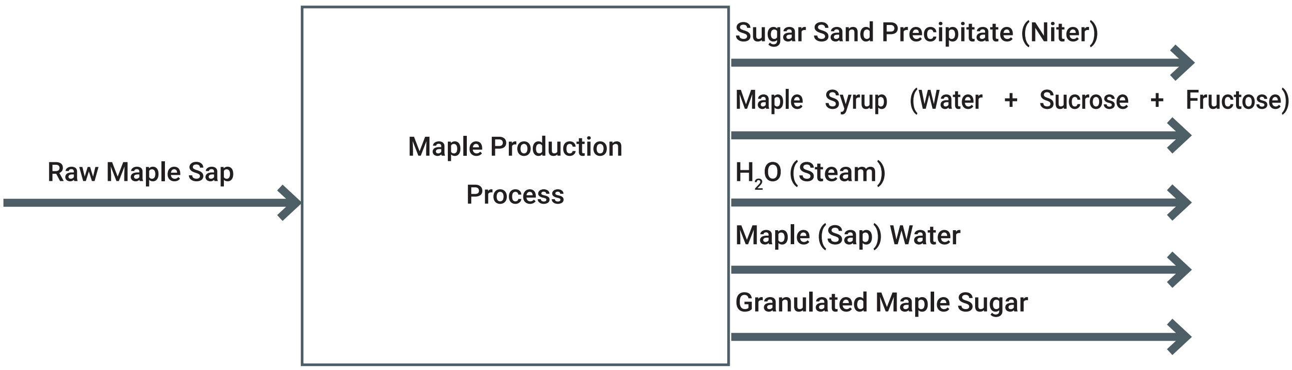


Figure 3 - Overall Maple Process Flow

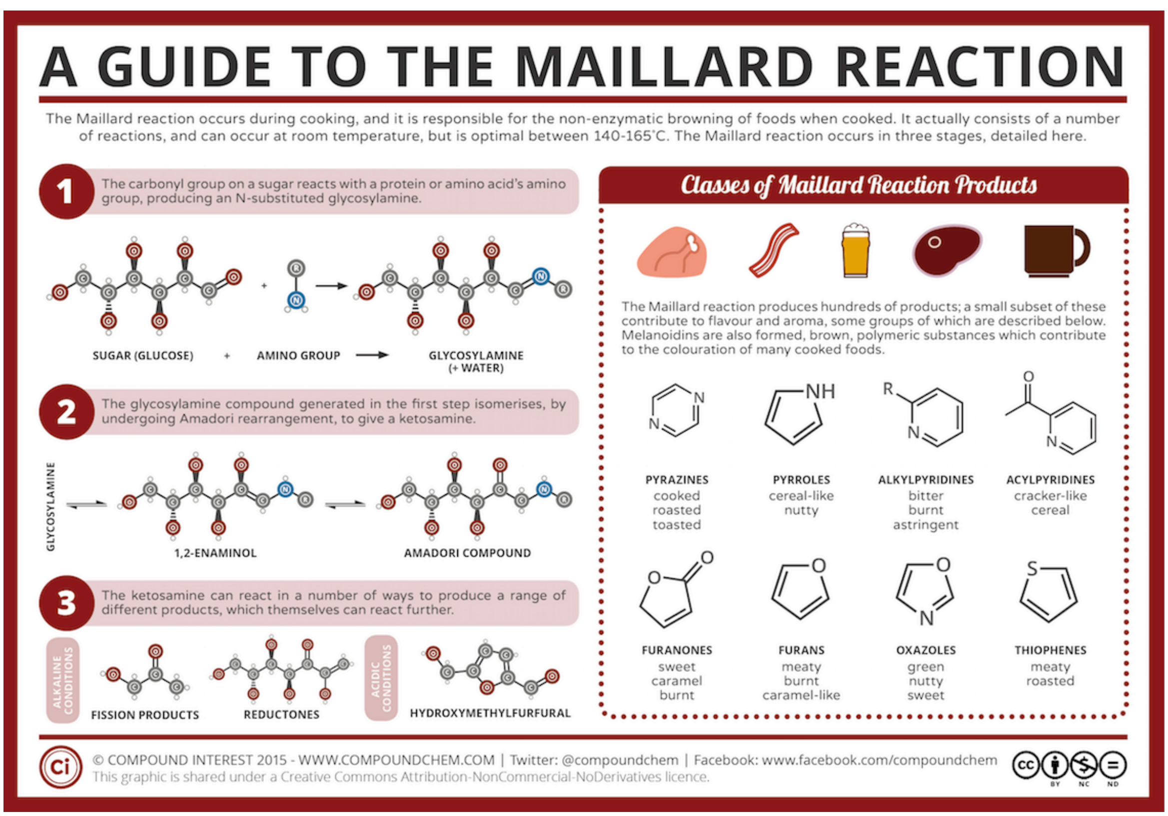


Figure 4 - A Guide to how the Maillard Reation Proceeds

Maple Syrup Reaction

When the sap runs through the tubing it picks up microbes (bacteria) on the way to the production facility. This causes the sucrose to invert into fructose and glucose. As the season progresses, more microbes and amino acids tend to be present in the sap.

As the sap is evaporated in the production process to get rid of the water content and produce syrup, the microbes are killed, and non-enzymatic browning reactions occur between the invert sugars and the amino acids which affect the colour and flavour. Since fructose and glucose are both more reactive than sucrose, the more inverted sugars present in the reactant (more initial microbes), the more the non-enzymatic browning reactions occur, and thus the syrup becomes darker and sweeter. The non-enzymatic reaction that occurs is crystallization, or a 'Maillard Reaction,' as seen in Figure 4.

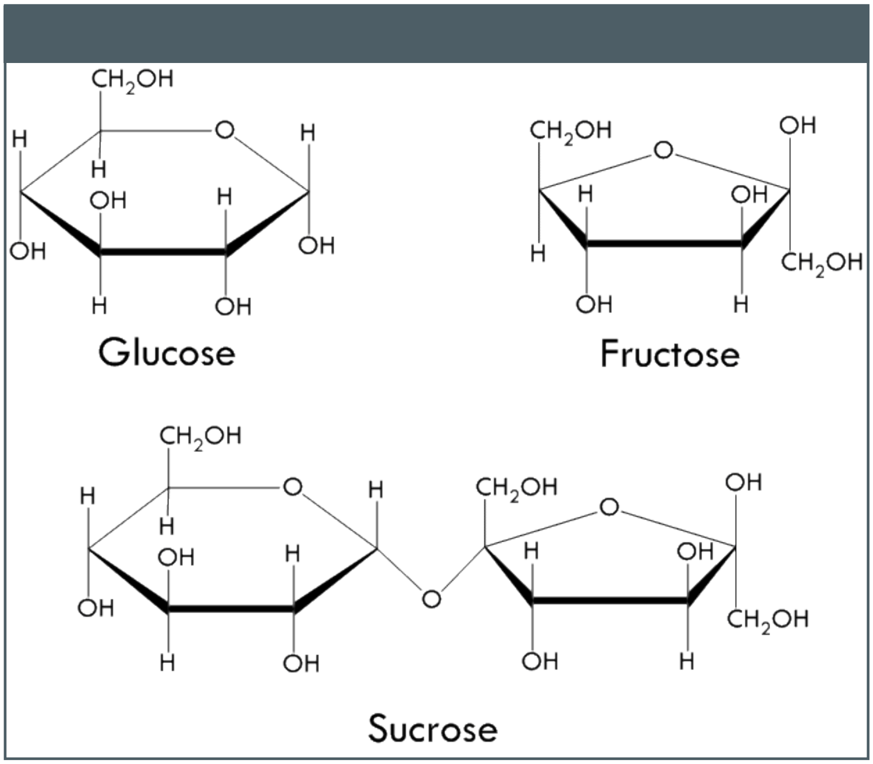


Figure 5 - Isomers of glucose

Alternative Product Processing

MAPLE (SAP) WATER

Once sap reaches the central processing facility, it needs to be pasteurized to be safe for raw consumption. Pasteurization is necessary in order to eliminate pathogens from the sap. To achieve this, the sap is fed through a continuous industrial pasteurizer, similar to those used in other beverage industries, such as fruit juice production. Once this is completed, the sap water is safe for human consumption. It must be stored in refrigerated tanks, and can either be transported in bulk amounts for off-site bottling, or bottled on-site.

GRANULATED MAPLE SUGAR

Maple syrup is taken from storage and is heated to approximately 128°C. Once removed from the heat, a fast and constant mixing motion is applied to the batch, causing the mixture to crystallize, vapourize, and transform into granulated sugar.

SUGAR SAND (NITER)

Since maple sap contains trace amounts of minerals and other substances, when the sap is boiled to remove water, these minerals become concentrated, forming a gritty sediment, known as sugar sand (niter).

RAW MATERIAL PURITY REQUIREMENTS

There are no known purity requirements from the unprocessed maple sap as long as proper protocol is taken to ensure that an excess of microbes is not present. (Either from poor tubing size, air leaks, or improper tapping techniques). Having too many microbes in the maple sap will cause an extremely dark syrup colour when boiled and produce a low-

UTILITIES AVAILABLE

The utilities used in this process mainly concern the inputs of energy used to ensure correct operation of equipment. Utility costs were calculated based off on-peak, worst case scenarios, yielding maximum costs. Utilities used include the wood pellets for evaporation, electricity used to power the reverse osmosis unit, pumps, pasteurizer, steam kettle, sugar machine, and other small operations.

Proposed Maple Production Process Flow Diagram

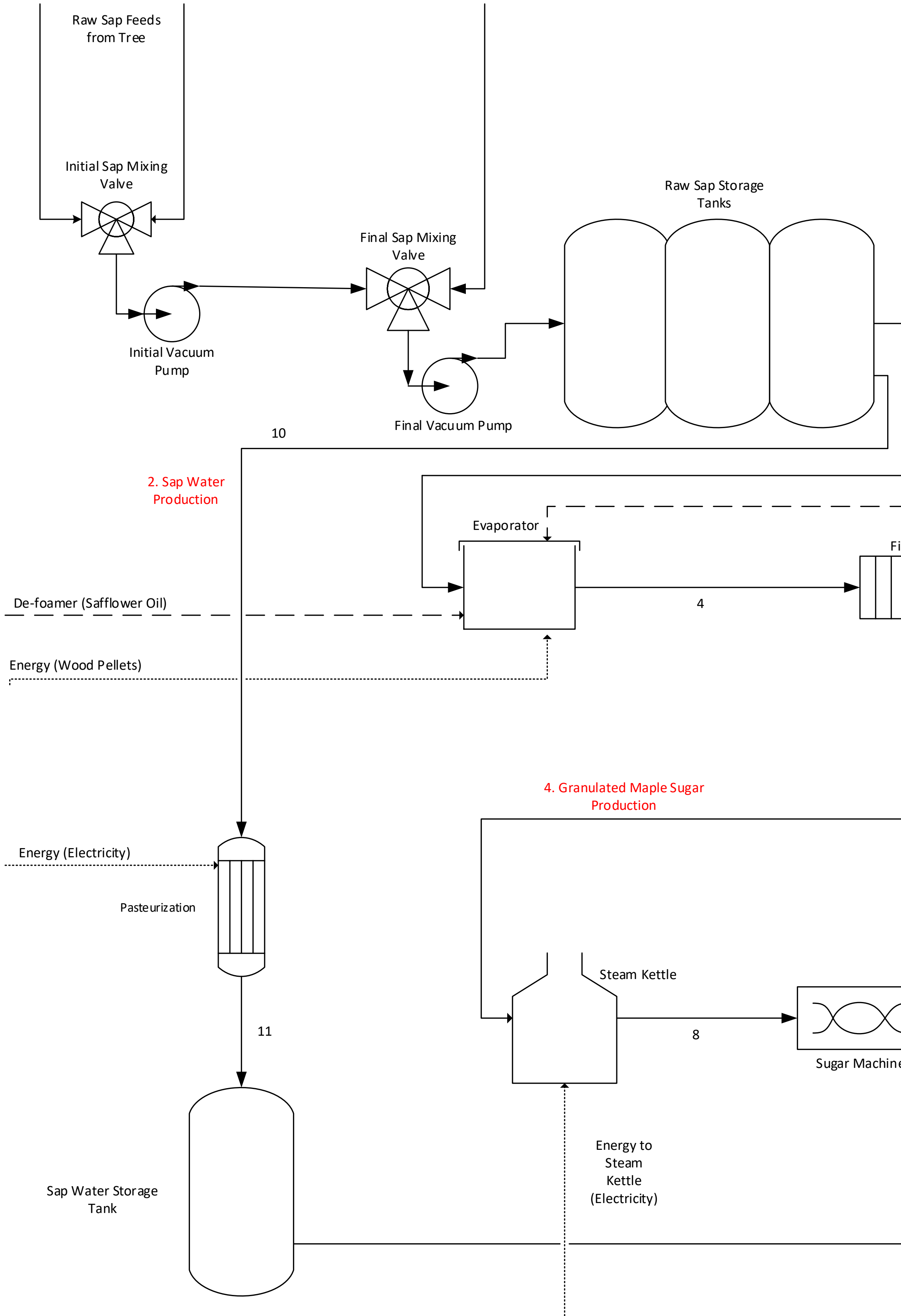
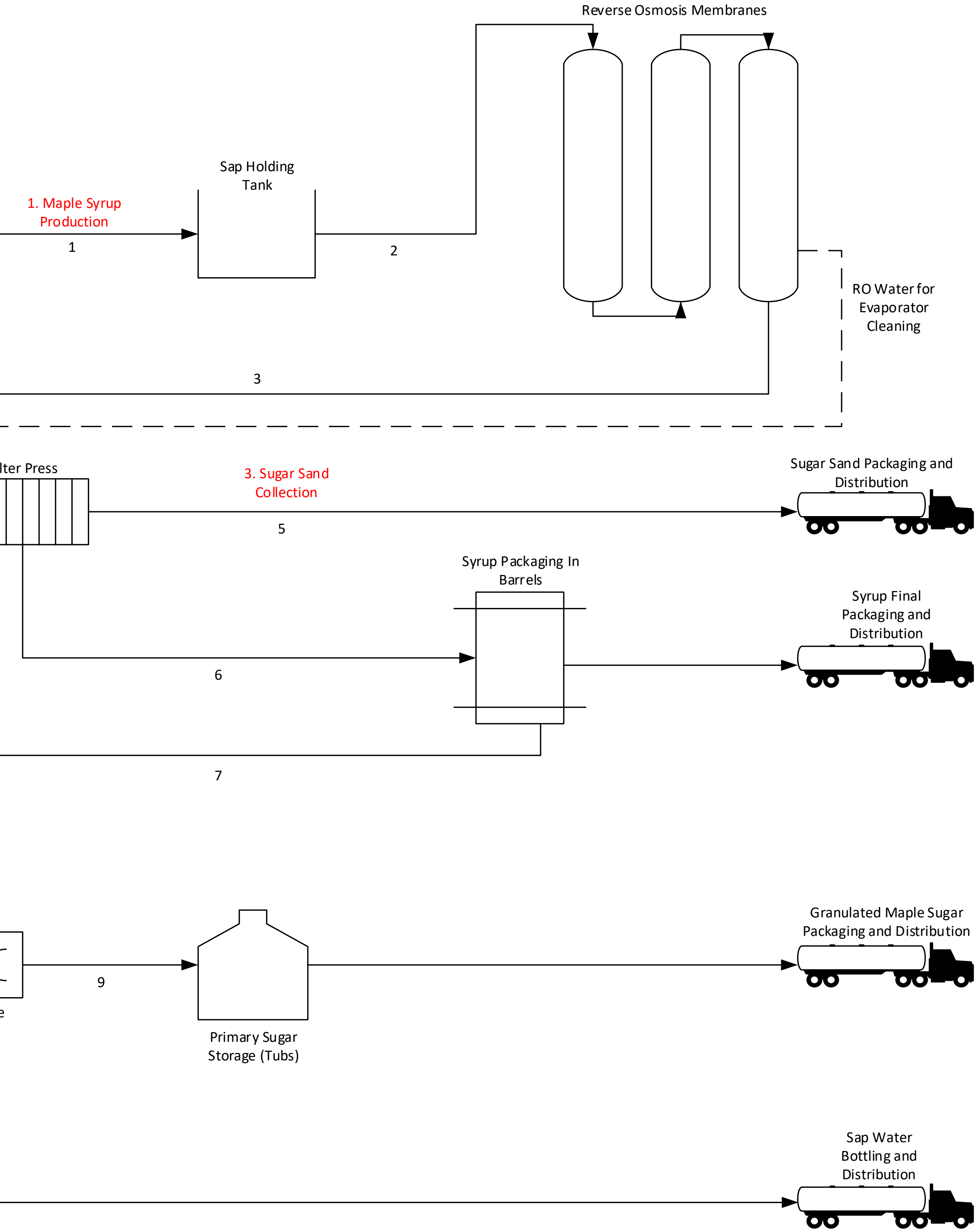


Figure 6 - Proposed Process Flow Diagram for the Production of a diverse range of Maple Products


Reverse Osmosis Membranes
Sap Holding Tank
1. Maple Syrup Production
1
2
RO Water for Evaporator Cleaning
3
lter Press
3. Sugar Sand Collection
Sugar Sand Packaging and Distribution
5
Syrup Packaging In Barrels
Syrup Final Packaging and Distribution
6
7
Granulated Maple Sugar Packaging and Distribution
9
Primary Sugar Storage (Tubs)
Sap Water Bottling and Distribution

How Does the Process Work?

PROCESS DESCRIPTION

The process that has been proposed and investigated as shown on the previous page in Figure 6, works according to the following methodology.

Beginning at the tree, a newly developed "relief valve tap" has been developed which will close if the pressure of the vacuum in the pump rises above the allowable maximum. This ensures the safety of the tree and allows for evacuation/cleaning of the tubes. Connected to each of these individual taps, a tubing system exists which links up to main lines. For greater distances, these tubes lead to vacuum houses which encompass the following operational units - a storage tank and vacuum pump - in order to lower the vacuum suction at the main sugar shack. The vacuum pumps work by facilitating the movement of sap back to the facility by means of pressure gradients. From these houses, the sap follows a primary tubing line to reach the main processing/refining facility.

Once at the main sugaring facility, the sap is collected in a storage tank. From the storage tank, the raw material moves on to one of two paths - through pasteurization for the creation of sap water, or through reverse osmosis for the production of maple syrup. The processed maple (sap) water will be sent to a storage vessel after pasteurization and sent for packaging and distribution. The material sent into the reverse osmosis vessel undergoes the following manipulation: water is removed and the reduced sap will be sent to an evaporator system. The evaporator works by boiling off the water in the reduced sap in the form of steam, and facilitating the caramelization/browning reactions. The pieces of equipment chosen are such that the required Brix content of the maple syrup, as specified by policy are met. This caramelized material is then filtered through a filter press where the sugar sand (niter) can be removed. Later in the season, when bacteria is more present in the raw sap, less niter is created (natural filter aid) and diatomaceous earth must be added to assist in this process. The sugar sand will be sold as a cosmetic product, with yield being high early in the season.

From this point, the syrup is placed into barrels where it can either be sent for further packaging, or for use as a reagent in the granulated maple sugar process. The syrup that is used to make sugar will be heated predominantly by means of a steam kettle, and then diverted into a sugar maker, inducing crystallization as it cools. This granulated product is filtered through a sieve and is sent for packaging, storage, and distribution.

Summary of Flow Rates & Brix Content in Each Process Line

Table 3 - Summary of Flow Rates and Brix Content

Line	Flow Rate (L/day)	Brix (% Sugar)
1	280000	2
2	280000	2
3	18600	30
4	7000	66
5	N/A	N/A
6	7000	66
7	80	66
8	80	66
9	52	100
10	120000	2
11	120000	2

Table 3 above summarizes the flow rates of the designated material (either sap, syrup, water, or sugar) in the proposed process. It also specifies what the sugar content, or Brix in the process line is. These flow rates allowed for the calculation of further energy requirements specified in this report, and process/equipment optimization. Exact specifications, including particular temperatures, pressures and handling capacities will be outlined for each unit in the process in the equipment section.

Plant Location

Climate and Environment of the Eastern Ontario Hardwood Forests

Potential Locations for Maple Processing Facility:

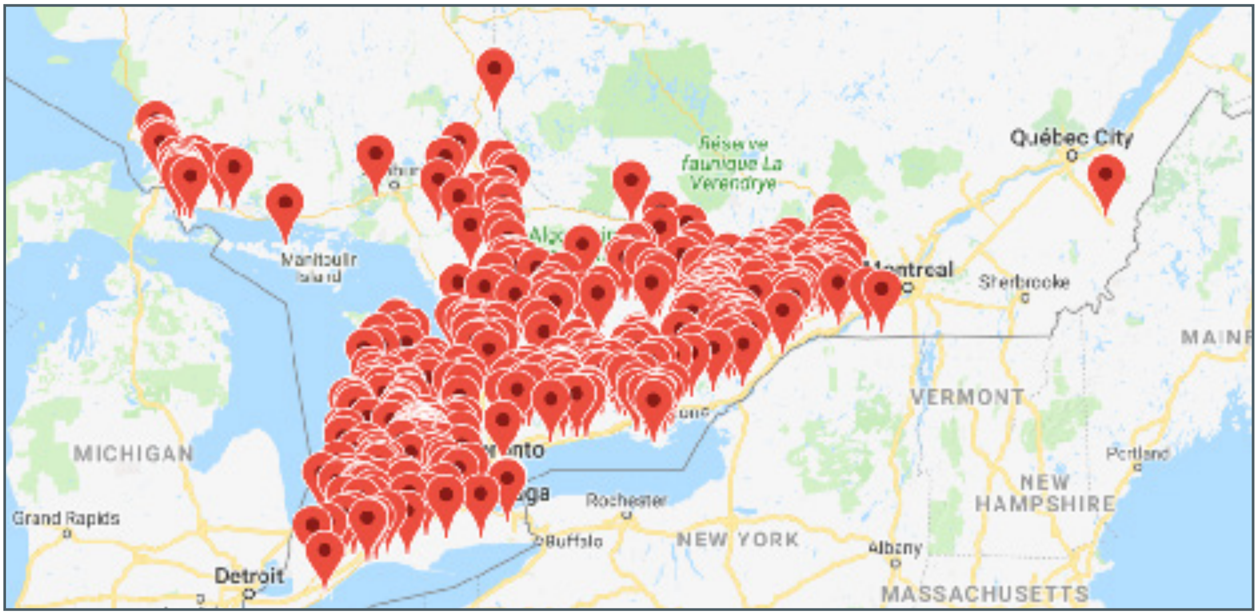


Figure 7 - Marked Locations of the Number of Sugar Bushes in Canada (From the Ontario Maple Syrup Producers Assoc.)

For the proposed design to be feasible, a large acreage that can support ~100,000 taps will be required to support the sap volume that this facility can process. Eastern Ontario is rich in hardwood forests, of which a percentage of the trees are maple trees capable of producing raw sap for processing.

Areas within Lanark County are already lush with maple trees, and there are several sugar bushes in operation. There is currently no system for large scale identification of maple trees – ie. there is no system for locating naturally grown sugar bushes, or areas fit to be converted into sugar bushes. A system that could track the growth of maple trees in this portion of Ontario would be invaluable since there are hundreds of maple trees that are currently untapped and have the potential for sap extraction.

The climate in Eastern Ontario has high precipitation and moderate temperatures year round. Sufficient sunlight and low cloud cover means that sunlight makes its way through the canopy of the hardwood forests and helps to sustain a diverse plant life on the forest floor.

Additionally, it is necessary that this plant is constructed in a location that is in close proximity to a sugar bush since sap transportation costs were not discussed in the design and will add an extremely high premium onto the product. Furthermore, the concentration of the raw sap/the microbe content in the raw sap worsens as time increases; a lower grade syrup would be produced from transported sap.

Equipment Specifications

Specifications for each piece of equipment outlined in the process flow diagram on pages 26 and 27 are described in detail. Sizes, handling capacities, materials of construction, and other important parameters are highlighted. All equipment was sourced from CDL Maple Sugaring Equipment, unless otherwise stated, and is based on an assumption that this process harvests sap from 100,000 Taps, thus obtaining a flow of 400,000 L per day of incoming sap, in a 1600 acre sugar bush. Costing for these units are listed in the financial analysis.

1. Pumps, Tubing, and Other Fittings

In any maple sap harvesting operation, the size and number of vacuum pumps, along with the length and layout of tubing, is highly dependent on the geography of the sugar bush. Both the physical dimensions and the topography of the bush can have an enormous impact. As such, when sizing and costing the sap transport system, assumptions were used to estimate an average for a sugar bush of this size, which will be reviewed and explained as they are put into use.

All sizing completed was done based on an assumed sugar bush size of **100,000 taps** on **1,600 acres of land.** Based off of data collected from syrup producers in the region, the following averages for tubing lengths were created: **0.2 km of 5/16' lateral line, 0.07 km of 1" mainline, 0.03 km of 1.25' mainline, and 0.01 km of 1.5" mainline per acre of land** [73]. Using this assumption, **320 km of 5/16' lateral line**, **112 km of 1" mainline**, **48 km of 1.25' mainline**, **and 16 km of 1.5" mainline**, would be required for the 1600 acre sugar bush [74].

The selected tubing is **polyethylene**, and has been approved for use with drinking water. Additionally, all tubing is translucent light blue in colour, which is ideal as it does not absorb as much heat as black tubing, keeping the temperature of the sap approximately 5 °C cooler than black tubing, which helps to prevent bacterial growth [74]. This tubing and its specifications were sourced from Leader Evaporator.

For the vacuum pumps used to draw the sap to the central processing facility, the experts at CDL Maple Sugaring Equipment provided a rough estimate for the number/size/rating of pumps [72]. They estimated that, for this number of taps on a sugar bush acreage as specified, **10 vacuum pumps** in discrete pumping stations would be necessary. These 10 pumps are **Airtech 250D vacuum pumps**, with a **power of 10 horse power** and a **power consumption of 27.5 amps at 208 volts** [72]. These pumps have a **maximum vacuum of 29.9" Hg**, and are equipped with a condensation tank to ensure pump performance. The pumps are also designed to be compact, silent, and low maintenance. [71]

VANE PUMPS L-SERIES (HIGH PERFORMANCE): L250DG110HP
AIRTECH PUMP L250D 10.0 HP 208-460V 3PH ASS.

Figure 8 - L250DG110HP AirTech Vacuum Pump for Raw Sap Transport

POLYETHYLENE TUBING

Figure 9 - Tubing for Raw Sap Transport

Table 4 - Length assumptions for 1600 acre sugar bush

Tubing Diameter	Length Assumption (km/acre)	Required Length (km)
5/16"	0.2	320
1"	0.07	112
1 1/4"	0.03	48
1 1/2"	0.01	16

Note: Specific equipment product codes for valves, fittings, connectors, and gauges are not provided, but are factored into the cost analysis.

2. Raw Sap Storage Tanks

STORAGE TANKS

Within this process, ten storage tanks will be utilized, eight of which will be for sap collection, and the remaining two for sap water storage. In order to accommodate for the large volume of sap that is coming in from the sugar bush (400 000 L/Day) it is necessary that the tanks be robust enough in size to handle the incoming volume of sap, as well as robust in terms of their material. The tanks that have been applied to this process are 1372 cubic feet and 27 feet long (internal).

Table 5 - Storage Tank Specs.

Storage Tank Specifications	
Quantity	10 (8 for raw sap, 2 for sap water)
Internal dimensions	7' height/width, 28' long
External dimensions	7.34' height/width, 28.72' long
Capacity	9065.2 US gal
Elevation	6"
Materials of construction	Painted steel frame, 304 stainless steel tank

Figure 10 - Example Stainless Steel Storage Tank (Not to same scale, but same design)

3. Reverse Osmosis

Figure 11 - 20+ RO unit from CDL [71].

REVERSE OSMOSIS

Reverse Osmosis is a membrane system which separates liquids through their osmotic pressure. It is used to reduce the amount of water present in the system before going to the evaporators in order to reduce the energy use of the overall process and reduce the cost to run the evaporator in particular. In this process, nearly pure water is removed from the sap, making a more concentrated intermediate product. The equipment selected is the CDL 20+ RO unit (30+ would be more energy efficient but is difficult to use for RO beginners). The equipment included in this system is as follows:

- 2 x 16" posts with 3 hp recirculation pump
- 8 x 8" posts with 1 hp recirculation pump
- 2 x 16" membranes
- 8 x 8" membranes
- Storage canisters for membranes
- 10 permeate flow meters
- 2 x 7.5 hp supply pump
- 4 x 10 hp high pressure pump
- 2 x 1.5 hp booster pump
- Continuous Brix Reader
- Rinsing opt. RO
- 2 x Concentrate flow meter

This device is stainless steel, to be in accordance with health and safety standards. The 16" and 8" posts/membranes allow for the separation of the components. Flow and Brix readings are taken throughout the unit for accuracy. 7.5, 10, and 1.5 horse power pumps allow for the system to surpass the osmotic pressure. Some advantages of RO and this device are: this system can accommodate up to 20 Brix reliably, is easy to clean, is an energy saving device, and is designed to allow high flow at high pressure (around 7600 gallons per hour for a reasonable work day). [71].

4. Evaporator

EVAPORATOR: 6720718 CDL MAPLE

The evaporator is one of the most important pieces of equipment in the syrup production process, as it is responsible for bringing the syrup to the final desired sugar content. A large pan evaporator is necessary for syrup volumes such as those used in this process, and the large surface area to volume ratio ensures appropriate caramelization of the product.

Information about the desired performance was provided to the experts at CDL, and with this they provided size and cost quotes. The option was provided for either wood pellets or oil as a fuel source. The capital costs for the oil-fueled evaporator are lower, however the operational costs are higher, such that after a production period of approximately 7 years, the wood pellet fueled evaporator will become more cost effective [72]. The resulting evaporator is a **7' x 18' wood pellet fueled CDL Master Evaporator**. This evaporator has been constructed with **304 stainless steel** and will bring the full day's load of syrup to the desired sugar content within typical working hours. Also included in the provided quote is the necessary equipment for efficient cleaning of the evaporator, a task that must be performed daily [71].

Figure 12 - 6720718 CDL Maple Master Evaporator Wood Model

IDEAL FOR:
Performance and efficiency in high Brix, including an unmatched boiling flexibility (from 2-35 Brix).

Recommended Wood Pellet Model:

1. Hood Preheater.
2. Flow Inverter in the Flue Pan.
3. No mechanisms near the syrup pans, thus no obstruction near front for the operation of the evaporator.
4. Drip Tray.
5. Multi-channel syrup pan (Can change pan in 5 minutes without stopping the fire)

5. Maple Syrup Collection: Filter Press & Holding Equipment

FILTER PRESS: 66217 CDL MAPLE

Maple syrup is passed through the filter press upon evaporation. The presence of a filter press is essential to ensure producers make a high-quality maple syrup, or maple sugar product. This filtration removes sugar sand (niter) from the syrup, which can be extracted and sold for profit. Two types of filters, gravity and pressure filters exist, however for the purposes of our proposed process, we recommend the use of a pressure filter, specifically, a plate filter press. Plate filter presses pump unfiltered syrup through a series of filters, often coated with filter aid, such as diatomaceous earth, under pressure. By providing a high-quality product, maple syrup producers can demand a higher price for their syrup.

Based from the assumed sap intake for this process, the use of a **20" filter press (product code 666217 from CDL Maple)** is the most appropriate for the large volume of maple syrup production [71]. This filter press has a maximum capacity of holding **9 hollow plates**, and has a high filtration capacity of up to **15 to 30 barrels of syrup** before needing to be cleaned [71]. The **plate thickness for this press is 3"** and offers easy assembly for the filter papers, which is beneficial for maple syrup producers that hope to collect and sell the sugar sand. Furthermore, an additional **Brix reader (product code 668421 from CDL)** will be installed to ensure consistency among all syrup produced prior to storage or use for the maple sugar process. This **Brix reader can read 0 to 80 Brix** and will provide automatic temperature compensation to ensure accurate Brix readings are recorded [71].

Figure 13 - 66217 CDL Maple Filter Press

PUMP: 730020 CDL MAPLE

The recommended filter press requires a **1" diaphragm pump (product code 730020).** Made of aluminum, this pump will be able to pump a sufficient volume of maple syrup through the filter press [71].

Figure 14 - 730020 CDL Maple Diaphragm Pump

TEMPORARY STORAGE: 676123 CDL MAPLE

A **4 x 4 x 4 storage tank**, comprised of a painted steel frame and a **304-stainless steel tank,** will be used to temporarily store maple syrup after the maple syrup has been filtered **(product code 676123 from CDL).** Outside dimensions measure at **50. 3/4 in large X 50. 7/8 in long X 45. 3/8 high,** and the capacity of this storage tank is **322,7 gallons (imp).** This storage tank can hold maple syrup prior to packaging and distribution, and can hold syrup that will eventually be made into granulated sugar. This temporary storage tank will be equipped with a stainless steel mixer **(product code 6792034 from CDL).**

6. Maple (Sap) Water Collection: Pasteurizer & Storage

THE PASTEURIZER

Since sap water is a natural product and does not come from a sterile environment, it is of huge importance to sterilize the product. Sap water contains approximately 2% sugar and therefore is heat sensitive. Prolonged heating will cause a caramelization of the sugars and a change in colour; sterilization by boiling is not an option. Heat pasteurization (similar to milk, fruit juices and other heat sensitive food products) ensures that no microbial growth occurs within the sap water so that it is safe for human consumption. The chosen pasteurizer for this process was sourced from Good Nature, and is an economical and reliable method of destroying bacteria and extending the shelf life of the maple (sap) water. The final product will be stored in stainless steel storage tanks similar to that of the raw sap previously described.

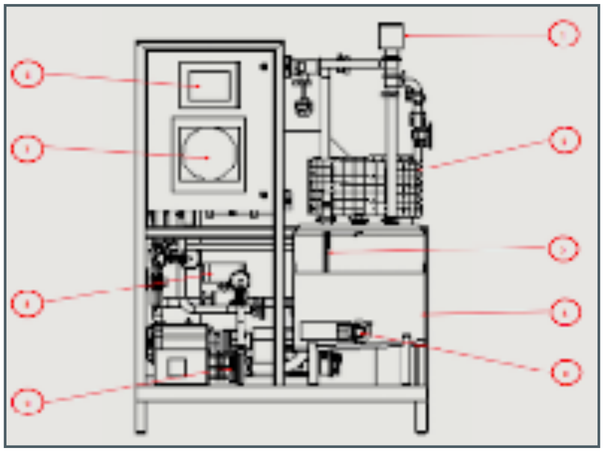


Figure 15 - Good Nature Pasteurizer Front View

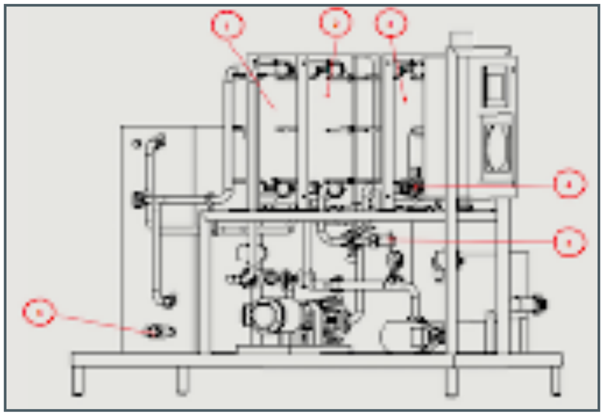


Figure 16 - Good Nature Pasteurizer Back View

Parts Included:
Divert Valve
Hold Manifold
Level Probes
Balance Tank
Product Inlet Valve
Operator Interface
Chart Recorder
Flow Meter
Booster Pump
Electric Boiler
Product Outlet
Dial Thermometer
Timing Pump
Sprayball Connection
Cooling/Glycol Supply
Filter/Regulator/Lubricator
Heating Section
Regeneration Section
Cooling Section
Cooling Water/Glycol Valve
Water Inlet

Table 6 - Pasteurizer Specifications

Pasteurizer Specifications	
Incoming liquid temperature	70°F
Pasteurization temperature	190°F
Holding time	15 seconds
Pump type	Positive displacement
Pump speed in	1800 RPM
Pump speed out	406 RPM
Machine weight	2200 lbs
Materials of Construction	
Frame	304 stainless steel
Tank	316 stainless steel

7. Granulated Maple Sugar Collection: Sugar Machine, Steam Kettle, & Storage

The two pieces of equipment required to convert maple syrup into granulated maple sugar include a steam kettle and a granulated sugar machine.

DOUBLE AUTOMATIC MAPLE SUGAR MACHINE: 668856A

For the volumes of sugar that are to be produced through this process, the larger of the two sugar machines sold by CDL will be appropriate, with specifications that are capable of handling up to 5 gallons of syrup per batch, producing 35 lb. The 8" double automatic maple sugar machine from CDL (668856A) was selected for this process. Aside from filling and emptying, the machine is fully automated, reducing the amount of labour necessary to produce the final product. This machine is constructed of stainless steel and is capable of mixing, grinding, and drying the sugar. The machine is moreover self-cleaning which further reduces labour requirements [2].

Figure 17 - 668856 A Double Automatic Maple Sugar Machine Machine

ADVANTAGES

- → Fully automated
- → Uniform granulation
- → Can function without supervision
- → Made of stainless steel
- → 3 in 1: mixer, grinder and dryer
- → Self-cleaning with hot water

STEAM KETTLE

The steam kettle has been constructed of stainless steel and runs on a 12 kW input. The kettle also includes an integrated thermostat and pressure gauge, as well as safety features to avoid over-pressuring. Due to volume increase from boiling, CDL recommends boiling in a vessel at least twice the volume of the syrup. Thus, a 10 gallon (40 quarts) steam kettle was sourced from Globe Equipment Company.

Specifications:
Table Top Kettle
40 Quart
Electric
2/3 Self-Contained Steam Jacket

Figure 18 - Proposed Steam Kettle

8. Interim Packaging of Maple Products

TEMPORARY STORAGE BEFORE DISTRIBUTION/PACKAGING

BARRELS STAINLESS STEEL: 668161

In between production and bottling, syrup will be stored in **45 gallon stainless steel barrels**, as sourced from **CDL (668161)**. These barrels are easily cleaned, and are safe for both long and short term storage of syrup. In order to determine the number of barrels that must be purchased, it was assumed that the entire day's production of syrup would be bottled that day. However, to account for washing and potential bottling delays, a 100% overdesign was implemented. The estimate is that 7,000 L, or 1,850 gallons, will be produced in a day; **82** of these barrels will need to be purchased.

POLYETHYLENE TUBS

Before packaging and distribution, both sugar sand and maple sugar will be stored in **55 gallon polyethylene tubs,** sourced from Uline. These tubs are food safe, and are rated to hold up to 450 lbs. of solids [1]. Maple sugar weighs approximately 7 lbs/gallon, while sugar sand weighs approximately 8 lbs/gallon, so the tubs should not be overburdened. An estimated 800 pounds of sugar sand will be produced over the course of the season, along with approximately 3,000 pounds of maple sugar. The assumption was made that enough tubs would be purchased to hold the entire seasons worth of both of these products, yielding **10** sourced tubs.

Figure 19 - 668161 Stainless Steel Barrels

Figure 20 - Polyethylene Tubs

Production Estimates

ASSUMPTIONS & ESTIMATES USED FOR SIZING & COSTING

The resultant production estimates were the numbers used in order to determine the capacities, volumes, and other necessary specifications to quantify the previously mentioned operational units. Furthermore, the methods used to make these assumptions are described. These production estimates will be used in the financial analysis to determine both CAPEX, OPEX, and other economic metrics.

MAPLE SYRUP

Using a basis of 100,000 taps as a source of sap, an extrapolation to syrup production was made using the standard assumption that each tap produces 4 litres of sap per day, and each litre of syrup taking 40 gallons of sap to produce [1]. It was then decided that 30% of the sap produced would be used to make sap water, while the remaining 70% would be processed into syrup and either sold in that form or further processed into granulated maple sugar. The daily syrup production is therefore 7,000 L/day with 80 L/day being further processed into maple sugar (as described below), leaving 6,920 L/day of syrup for sale. The sap harvesting season averages 21 days [2], yielding a syrup production of 145,320 L/season.

MAPLE (SAP) WATER

As mentioned above, 30% of the daily sap production will be used to produce sap water. Using the previously mentioned assumptions, 400,000 L of sap will be produced per day making 120,000 L of sap water per day (or 2,520,000 L/season) due to the small reduction in volume.

GRANULATED MAPLE SUGAR

The sourced sugar machine is capable of producing 35 lbs of granulated sugar from 5 gallons of syrup [4]. The batch time for this, including boiling in the steam kettle and cleaning, is 2-2.5 hours, so 4 batches may be completed in a 10-hour work day. Through these assumptions, it can be calculated that 140 lbs of sugar will be produced per day, or 2,940 lbs per season.

SUGAR SAND (NITER)

It is assumed that the utilized sugar bush will be in a fully developed forest; there will be many large trees that are capable of supporting 2 or 3 taps. As such, the sugar bush will average 2 taps per tree, yielding 50,000 trees in the sugar bush. Data suggests that 16-25 pounds of sugar sand (niter) can be retrieved from 1,000 trees over the course of a season. [3]. To be cautious, the low estimate of 16 lbs/1000 trees/season was used. As such, the estimate of sugar sand production was calculated as 800 lbs/season.

Financial Analysis + Economic Breakdown

An economic analysis of the proposed maple refining facility was conducted. Total costs, including capital expenses (CAPEX), and operating expenses (OPEX) were determined using calculations shown in the appendix.

Capital Expenses (CAPEX)

CAPEX estimates the total cost that companies incur to purchase major physical goods and services that will be used for the duration of the plant life. These capital expenditures are normally fixed assets, meaning their cost is non-recurring and only need to be covered once. The capital expenditures covered in this analysis include the plant and equipment purchases. Land, permits, building, electricity generation, and spares are not included in this estimate. Table 8 below outlines the total CAPEX costs. All prices are quoted in CAD dollars, yielding a final CAPEX of **$1,569,609.55.**

Table 8 - Total CAPEX Costs for Proposed Maple Product Refining Facility

Capital Cost	Quantity	Unit Price	Cost
Taps	100,000	$0.25 $/Unit	$25,000.00
Tubing (5/16" Lateral Line)	320,000 m	$0.46 $/m	$147,200.00
Tubing (1" Mainline)	112,000 m	$1.41 $/m	$157,920.00
Tubing (1.25" Mainline)	48,000 m	$2.46 $/m	$118,080.00
Tubing (1.5" Mainline)	16,000 m	$3.35 $/m	$53,600.00
Fittings/Attachments	5% of Tubing Cost		$23,840.00
Pumps	10	$16,000.00 $/Unit	$160,000.00
Storage Tanks	8	$11,580 $/Unit	$92,640.00
RO (incl. Brix Reader & 30+ Attachment)	1	$210,940 $/Unit	$210,940.00
Evaporator (incl. Washer)	1	$117,495 $/Unit	$117,495.00
Filter Press (incl. Pump)	1	$13,545 $/Unit	$13,545.00
Holding Tank (incl. Mixer & Brix Reader)	1	$10,315 $/Unit	$10,315.00
Steam Kettle	1	$9,135 $/Unit	$9,135.00
Sugar Machine	1	$12,635 $/Unit	$12,635.00
Pasteurizer	1	$190,000 $/Unit	$190,000.00
Sap Water Storage Tanks	2	$11,580 $/Unit	$23,160.00
Syrup Barrels	82	$275 $/Unit	$22,550.00
Granulated Sugar Tubs	8	$98 $/Unit	$784.00
Sugar Sand Tubs	2	$98 $/Unit	$196.00
SUM (incl. Installation)			**$1,389,035.00**
13 % HST			**$180,574.55**
TOTAL			**$1,569,609.55**

Operating Expenses (OPEX)

OPEX covers the costs that a company is required to pay to run the facility and daily process operations. Operating Expenditures include both direct and indirect manufacturing costs. The direct manufacturing costs for the maple facility include utilities, labour, and maintenance. As a negligible amount of defoamer and operating supply additives are used in the process, a factor for operating supplies was not added to the total OPEX cost. The indirect manufacturing costs include fixed manufacturing costs and general manufacturing costs relating to administrative applications.

Table 9 - Total OPEX Costs for Proposed Maple Product Refining Facility

Operation Cost	Daily Cost ($/Day)
Vacuum Pumps (10 Pumps)	$90.60
RO (20+)	$111.99
RO (30+)	$25.95
RO (8" Replacement Filters)	$288.89
RO (16" Replacement Filters)	$103.17
Evap (Heating)	$821.89
Evap (Electricity)	$17.92
Defoamer	Negligible
Filter Press Pump	$5.04
Filter Press (Diatomaceous Earth)	$47.64
Pasteurizer (Boiler)	$126.72
Pasteurizer (Pump)	$99.00
Steam Kettle	$6.34
Sugar Machine	$22.57
Syrup Final Packaging	$10,947.44
Sugar Sand Final Packaging	$9.45
Granulated Sugar Final Packaging	$34.80
Sap Water Final Packaging	$14,916.00
Marketing/Sales (Syrup)	$2,483.68
Marketing/Sales (Sugar)	$9.95
Marketing/Sales (Sugar Sand)	$14.65
Marketing/Sales (Sap Water)	$3,033.78
Labor (Incl. Maintenance)	$1,000.00
Administration	$250.00
Product Transportation	$1,841.22
Total	**$36,308.70**

The maintenance and repairs are reliant on the equipment sizes and installations. Costs of labour and materials are also associated with maintenance. Labour costs were determined on the assumption of a 4 person team working 10 hours a day at a pay of $25/hour, due to knowledge on equipment operation.

The administrative costs for the process are normally approximated to be between 15-25% of the operating labour. This cost was approximated using a factor of 25%.

Distribution and selling costs were based off a normal factor of about 2-20% of the product costs. [116] A factor of 20% was specifically applied to the distibution calculations for this process as a wide variety of product channels exist. Other packaging costs were determined as previously mentioned under production estimates, by multiplying each unit by packaging cost averages. Transportation costs for product outsource was also calculated based off of online transport averages as described in the appendix.

Utilities, and thus costs to run the equipment, were based off of their daily energy consumptions, multiplied by the cost of energy. Additionally, the replacement membranes in the reverse osmosis unit were priced, based

These operating expense factors were put into a chemical economic costing software to generate the daily cost values. As noted by Table 9, the total OPEX costs in CAD dollars on a per day basis is $36,308.70. Extraploated per annum, the total OPEX costs for a singular maple season of approximately 21 days is **$762,482.7.**

HYSYS Simulation & Optimization

Aspen HYSYS: Why?

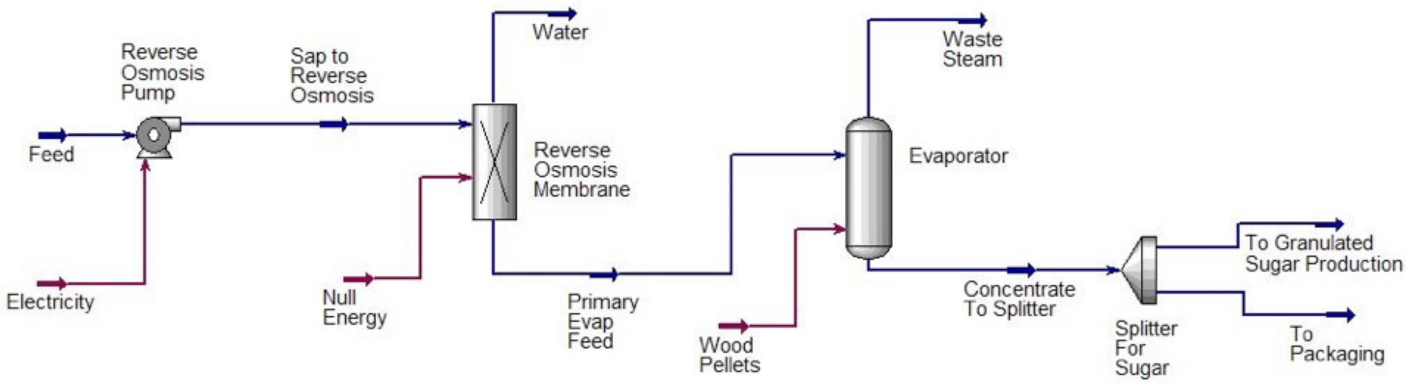


Figure 25 - Dominant Section of Maple Process Modelled using Aspen HYSYS for Costing Optimization of Energy

The simulation software, Aspen HYSYS, was utilized throughout this process. The reasoning behind the HYSYS model was to give an insight as to where energy was being used.

The technical model allowed process specifications to be confirmed, accepted, and justified from a mathematical standpoint. The system was modelled based off of ideal properties, since the maple refinery is a non-complex system involving sap (which is primarily water and a small concentration of sugar).

Energy used to run the equipment in this process was found to be predominantly used by the evaporators and the pump before the R.O. unit. The HYSYS model allowed for a thorough understanding of the process through its compositions in each line and operational unit, and by explaining other specifications such as necessary temperature, pressures, and phases for the system to work.

Since HYSYS is not well equipped with exact equipment representations for the reverse osmosis membrane and batch pan evaporators, the system was modeled using a component splitter and separation membrane. Slight variations in results might exist due to this simulation variation in equipment and other limitations shown by HYSYS.

In order to determine the correct balance between the use of reverse osmosis and evaporation, the daily energy costs to run both were calculated. Calculations were performed for the RO, bringing the sap from 2 Brix to 15 to 30 Brix, with the evaporator then bringing the syrup the rest of the way to the desired final value of 66 Brix. The necessary daily operational costs for each RO-Evaporation balance were then plotted, which can be seen in Figure 26.

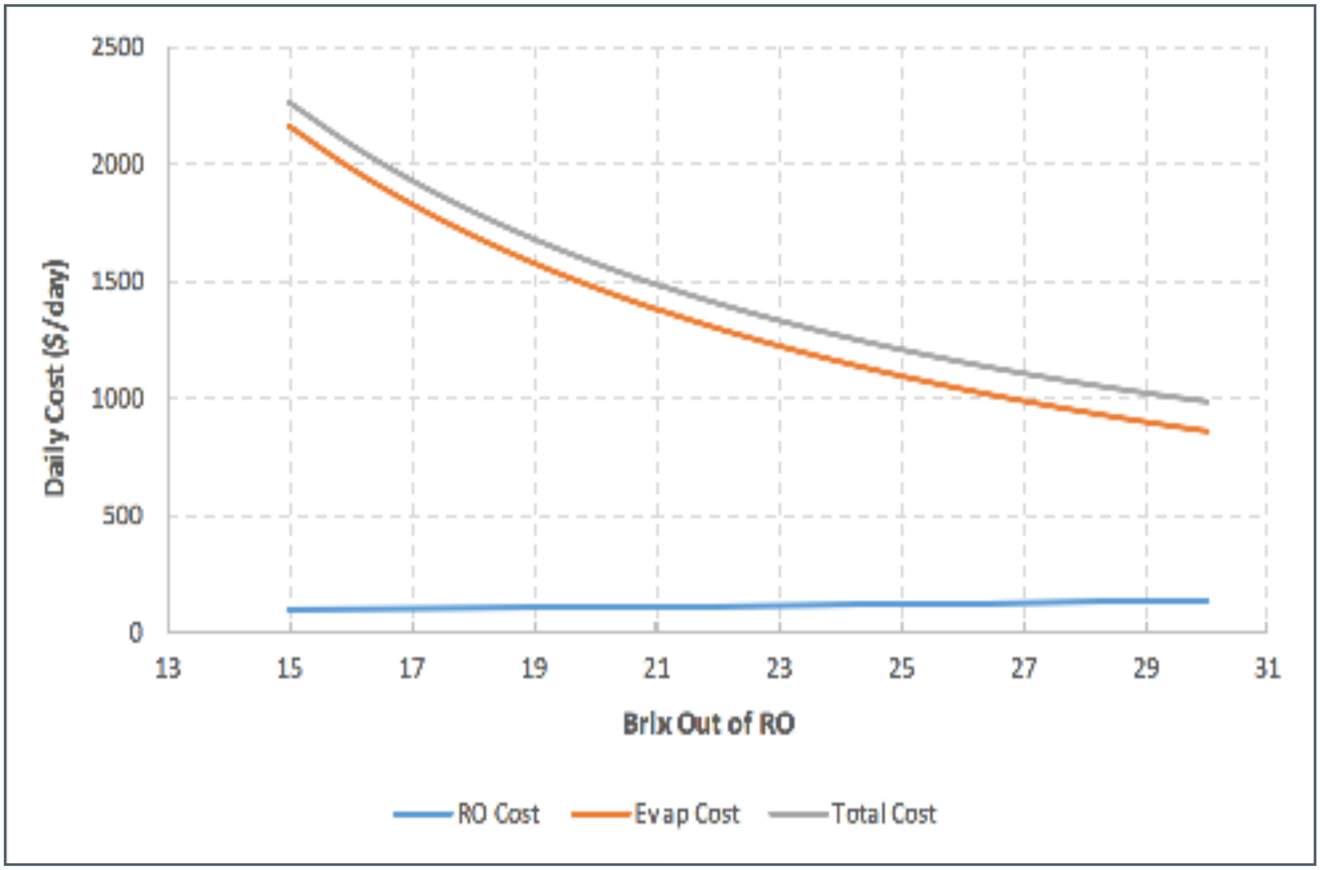


Figure 26 - Daily Operating Costs based off of Brix Out of Reverse Osmosis Membrane

As Figure 26 illustrates, the operational cost of the RO unit is significantly less than the operational cost of the evaporator. Thus, operational costs will continue to decrease as the RO is used more to remove water from the sap. This being said, there is an additional capital cost associated with purchasing an RO unit that is capable of bringing the syrup to 30 Brix, rather than one capable of only bringing it to 20 Brix. This additional cost, for the RO units sourced from CDL, is $69,995.00. The calculated energy savings between syrup brought to 20 Brix and syrup brought to 30 Brix through RO, for an operation of this size, is $587.79/day. Using the assumption of a 21 day season, this means that seasonal operational cost savings will be $12,343.59/season. These savings will exceed the additional capital cost for the RO over a time scale of 5.67 seasons!

Financial Metrics

Export

The maple products were priced based off of unit production costs, along with average market prices for comparable products. The selected pricing, along with the daily production amount and production costs, are summarized in Table 10. These values were then extrapolated, over an assumed 21 day season, in order to obtain seasonal revenue, production cost, and profit for each product, summarized in Table 11. Products were priced off of the assumption of bulk sale. (Whole-sale prices)

Table 10 - Summary of Product, Product Price, Amount of Daily Production, and Unit Production Cost

Product	Price per Unit	Daily Production	Unit Production Cost
Syrup	$13.00/L	6,920 L/day	$2.26/L
Sap Water	$2.50/L	120,000 L/day	$0.17/L
Sugar Sand	$10.00/lb	38 lb/day	$1.35/lb
Granulated Sugar	$10.00/lb	140 lb/day	$0.95/lb

Table 11 - Seasonal Revenue, Production Cost, and Profit for each Maple Product

Product	Seasonal Revenue	Seasonal Cost	Seasonal Profit
Syrup	$1,889,160.00	$328,002.22	$1,561,157.78
Sap Water	$6,300,000.00	$429,793.72	$5,870,206.28
Sugar Sand	$7,980.00	$1,077.30	$6,902.70
Granulated Sugar	$29,400.00	$2,800.42	$26,599.58

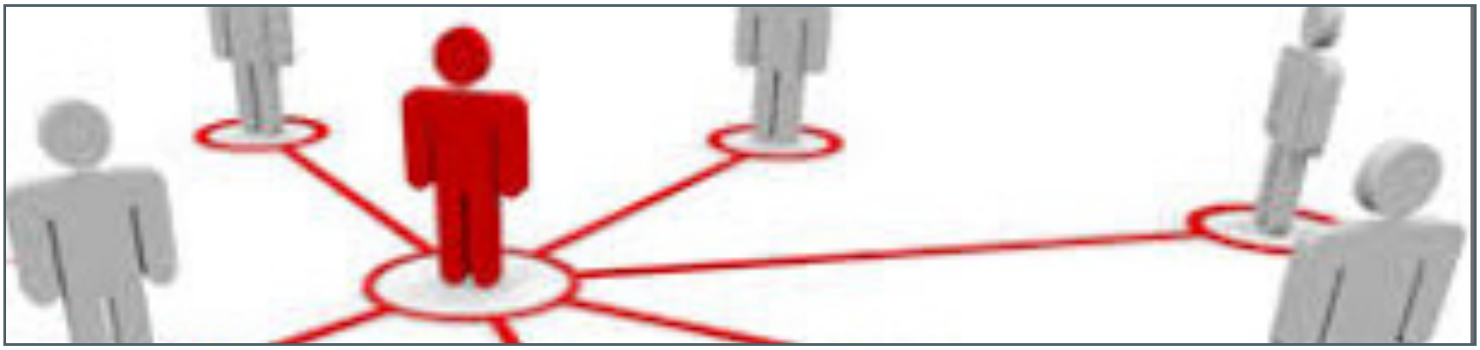
These profits are exceedingly high, showing yearly profits of $7.5 million against a capital cost expenditure of less than $1.6 million, representing a payback period of far less than a year. This was accounted for by several factors. First, this economic assessment assumes that the production facility will be constructed immediately at the desired size of 100,000 taps. This is not representative of a realistic maple production timeline, in which production usually starts with a small facility with progressive scale-ups in subsequent years. These calculations also assume that all of the product per year that is produced is able to be sold within that same year. This assumption may be unrealistic as, especially for a new producer without an established brand or industry connections, these production amounts are quite large. Additionally, the capital/operating costs did not include any costs for the purchase and/or lease of land for the sugar bush, nor were any costs for the physical structure of the processing facility accounted for. Finally, it is important to note that the sap production season is highly variable. While the average season length of 21 days was used for all calculations, the variability of the season length could have a large effect on seasonal

It is important to recognize that, though exact quantities were used where possible, assumptions had to be made to enable modelling at this level. The intention of these financials is simply to assess the overall feasibility of implementing a maple production facility at this scale. The short payback period and large seasonal profits do indicate that such a facility is feasible, but require completion of a detailed financial study for validation.

Distribution Channels

With a focus on maple products produced locally in Ontario, the feasibility of establishing a large distribution network may be limited. The success of acquiring a large distribution network may vary, depending on the product. For newly trending products, such as maple water and maple sugar, distribution through specialty retailers may help establish a brand. Maple syrup sales, however, may be successful if distributed through local grocers. Finally, the distribution of sugar sand is a difficult task to address. Since the maple sugaring process produces such little sugar sand, it is recommended that neighboring sugar bushes collaborate to supply sugar sand to interested investors. A similar strategy could potentially be used to distribute other maple products to increase yield and potentially open up more distribution network opportunities, depending on retailer demands.

Currently, most maple water and sugar products are primarily distributed by natural and specialty retailers, where most natural and organic products are found [33]. Some manufacturers, such as those that produce KiKi Maple Sweet Water, collaborate with third party distribution channels to increase their product reach [33]. Should maple products increase in popularity as predicted, they may be distributed across a number of various retailers, similar to how coconut water and natural sweeteners are now sold by many retailers in addition to just natural and specialty retailers. Some large retailers in Ontario that currently sell diverse maple products include Sobeys, Whole Foods Market, Metro, Longos, Vita Health Foods, Nature's Emporium, Bulk Barn, H Mart, and many more [107]. North America accounts for a large majority of maple product sales, however maple is becoming increasingly popular in Europe, Japan, and South Korea [33]. Exporting maple products from Canada causes a significant increase in price, so pursuing an international market is risky for maple producers as consumers in external countries have access to more affordable products that offer similar benefits as maple products, such as maple water and maple sugar.



Should producers of maple products in Ontario choose to pursue selling maple water, syrup, sugar or sugar sand, it is recommended that they do so by first distributing to specialty grocers that primarily sell organic and natural products. Once a brand has been well established, expanding to large grocer chains and potentially even to international distributors, as some companies are currently doing, may prove to be quite lucrative.

Maple Refinement Innovations

IMPLEMENTED/PROPOSED IMPROVEMENTS

When viewing the current maple process, it was seen that there were many potential areas for innovation, including the tree itself and other areas within the refining process. It was found that the main determining factor of the production of sap was the amount that the tree can produce, and the length of time suitable for harvesting sap.

There are currently no economically feasible processes that incorporate energy recycling. Some refining processes can reduce energy costs by re-using heat released from certain sections of the process, and redirecting it into other sections of the process. However, this technique is not particularly efficient for refining maple products.

Another potential area of improvement is the one-dimensionality of the process that is centered on producing only maple syrup. Expanding the variety of potential maple products that can be made in a continuous process will significantly improve sugar facilities worldwide and especially in Eastern Ontario.

Note: Other maple production innovations that have been critically examined which are not executed in this processing facility are mentioned later in this report as recommendations and potential areas of future growth.

These process improvements attempt to address the weaknesses and opportunities present in the current maple production process. These improvements were categorized into either biological improvements or process improvements. It is important to note that the suggested biological improvements will vary depending on the location, population, and age of the sugar bush.

1. Continuous Development of Diverse Maple Products

An improved process should incorporate a continuous design for producing sap water, maple syrup, granulated sugar and sugar sand (niter). By diverting the flow of sap and syrup at various points in the process and controlling the process specifications, it is possible to produce various deviations of maple with ease and predictability. While some maple products grow in popularity, having the ability to diversify the process and alter the production for certain products will be beneficial to sugar bush owners. For example, it may be more profitable for producers to allocate more sap towards the production of popularized maple-based products, such as maple water, and to cease the production other maple products. This process improvement allows maple product suppliers to base their production on the prevailing market.

The process outlined in the previously shown process flow diagram mimics the traditional style of many maple processing facilities, both in the selected equipment and production style. To maximize the financial potential of this facility and to take advantage of all that the maple tree has to offer, it was deemed necessary to produce more than just maple syrup. Traditionally, most sugar shacks produce maple candy (or sugar) as their alternate product since they can take the syrup right from its warm stage and produce either pressed or granulated sugar. This process is discontinuous since the infrastructure is not designed for this type of maple refinement. Additionally, this discontinuity can contribute to unpredictable quality of the alternate products and in turn loss of profits.

2. Biological Improvements

A) FUNGI IN SOIL

One potential biological improvement to the maple process includes adjusting the soil. Introducing fungi to soil has been reported to maintain and strengthen the health of the forest, which in turn may mildly increase sap yield [82]. The benefits of ***Mycorrhizae***, a fungus often found near tree roots, are well documented. Maple trees and mycorrhizal fungi are known to have a symbiotic relationship as this fungus improves nutrient and water uptake in trees, while trees provide carbohydrates to the fungus via photosynthesis [83]. Many forests are naturally populated by mycorrhizal species. The most popular type of mycorrhizae found near maple trees is ***Arbuscular mycorrhizae***. By providing maple trees with an elevated source of carbon, intervention that increases the presence of Arbuscular mycorrhizal fungi may positively impact the growth of the tree or sapling. The possible benefits of colonizing forest soil with this fungus is very dependent on the environmental conditions for that specific forest as many mycorrhizal populations grow naturally in forests and many forest floors may already provide a sufficient amount of carbon for maple tree uptake. Moreover, by colonizing a forest floor with beneficial fungi, such as Arbuscular mycorrhizae, potentially parasitic fungi which colonize in the same environment may be eliminated; this avoids competition for resources. Artificial inoculation with mycorrhizal fungi has however shown to have significantly beneficial effects in nurseries. Therefore it is possible that this fungus benefits younger trees and less established forests more so than older forests [83].



Figure 21 - Examplar Sapling Extraction

B) SAPLINGS & PLANTATIONS

Some recent plantations have experimented using maple saplings to collect sap and produce maple syrup. While there are many benefits to tapping saplings for sap, including the small amount of space required to produce an increased quantity of sap, a long term economic analysis will likely show that this method is not viable. As young saplings require both a significant amount of shade and retention of sap to promote growth, tapping saplings would ultimately result in premature fatalities in young saplings [84]. The benefit to introducing maple sapling plantations is that sugar bush owners can harvest more sap per acreage of their land. While saplings can produce a large amount of maple sap and present the opportunity to plant many saplings close together, this practice is not sustainable for a long-term basis and should only be considered during the early stages of a facility. Further studies would be necessary for this to be proven economically and biologically feasible on a long-term basis.

BITTER BUDDING FLAVOUR (A BIOCHEMICAL IMPROVEMENT)

As the end of sap harvesting season approaches, many maple syrup producers report that their syrup adopts a "buddy" flavour, also known as "metabolism", used to describe the bitter change in maple syrup flavour as the tree begins budding. This flavour can diminish the quality and thus the economic value of maple syrup. There are a few ways in which this buddy flavour could be removed. Researchers have found that the compound responsible for this flavour, 2,5 dimethylpyrazine (2,5-DMP), can be significantly reduced using heat [85]. With a boiling point of 311°F, either heating syrup up to 235-240°F, or by using a combination of heat and air injection techniques the presence of 2,5-DMP in the final product [85] will significantly decrease. Further, by using a vacuum throughout the course of heating, it is possible to decrease the presence of 2,5-DMP with lower temperatures (approximately 160-170°F) that would normally be required as a result of the pressure variation. It is important to avoid overheating when treating the syrup to maintain the quality of the final product. While this technique will darken the syrup, it can extend the maple sap harvesting season slightly. Specific details regarding the removal of 2,5-DMP via heating can be found in van den Berg, Perkins, Isselhardt, Godshall, and Lloyd's report [85].

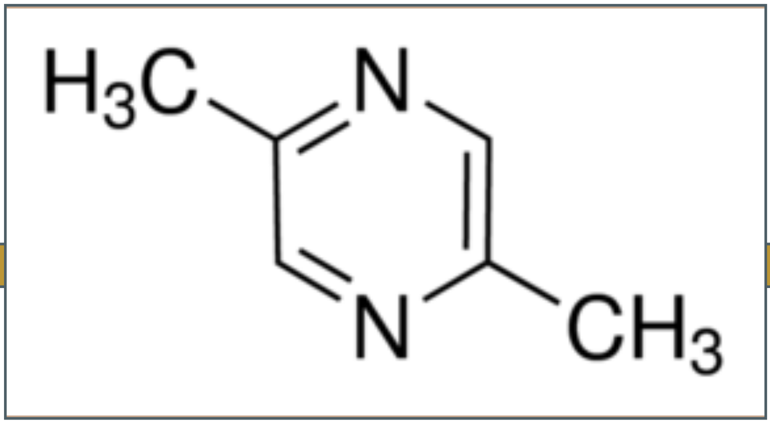


Figure 22 - 2,5-dimethylpyrazine

As an alternative, it is hypothesized that activated carbon may also be able to remove this flavour. As activated carbon is often used to soften and purify water, with similar structural properties to diatomaceous earth, it is possible that activated carbon may be a solution in improving syrup flavour. This would make it a good substitution in the filtering process. This speculation requires further research to determine if activated carbon is a feasible and economical solution to removing 2,5-DMP.

Figure 23 - Activated carbon

3. Process Improvements

INNOVATIVE RELIEF VALVE IN MAPLE TAP

A tap designed to act like a pressure relief valve may improve the quality of the sap produced. Once a specific vacuum pressure is reached, a valve in the proposed tap will close, protecting the flesh of the tree from embolisms and other health issues that may be associated with being subjected to high vacuum. The high pressure put forth by the vacuum pumps when the valve is closed will suck excess sap from the lines, cleaning the tube and reducing excess bacterial growth to preserve a lighter syrup product. Further, this tap design would prevent buildup, making mandatory seasonal tube cleaning easier. The preliminary sketch of this design is shown in Figure 24.

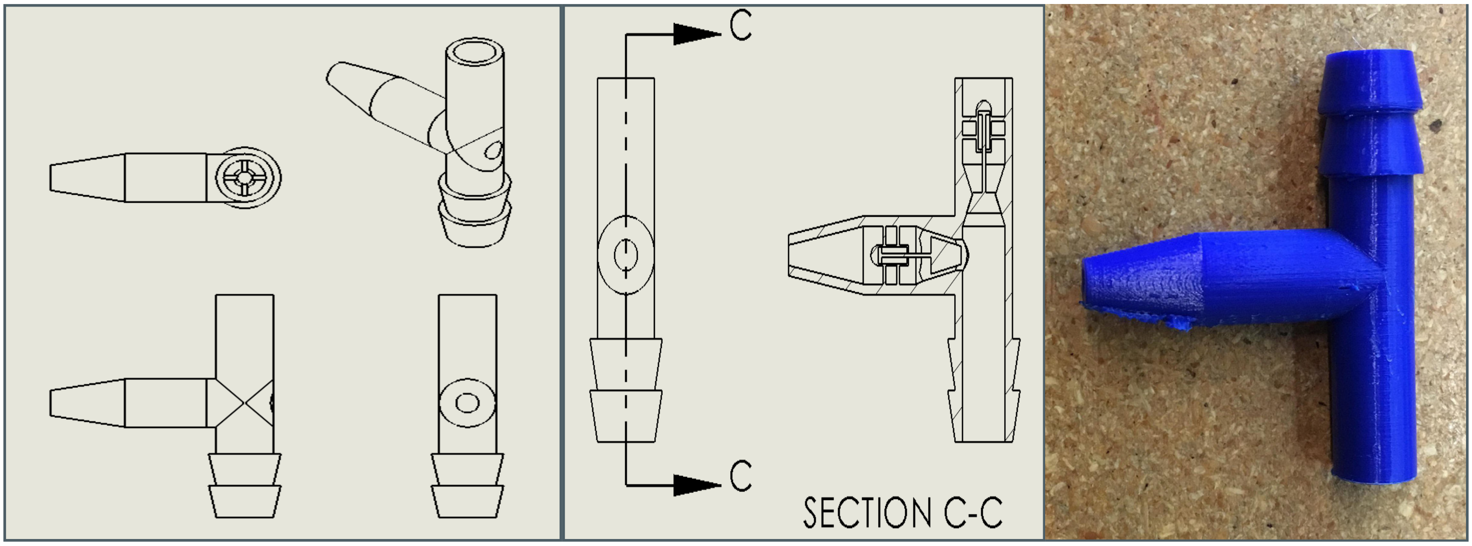


Figure 24 - Various views of the Maple Relief Valve Tap, designed and 3D printed using Solid Edge, and SparQ Studios

To further understand this, the proposed tap design was modeled in the CAD program SolidEdge. The tap was modeled with two valves, one on the sap inlet, and one on the air inlet. These are simple valves, the function of which is based purely around the resistance of the spring inserted into the valve. The concept of the function is that, a certain vacuum pressure, above the vacuum pressure normally used to extract sap, the resistance of the springs will be overcome, pulling shut the sap valve and cutting off sap flow, while pulling open the air valve and allowing air flow. Two key features are missing from the CAD model. Firstly, the two springs are not modeled, but would be present in a functional prototype. Secondly, there is no filter on the air inlet. In practice, a small filter would be placed on the air inlet, in order to prevent large particles from being sucked into the tubing at high vacuum. The CAD model, including a cross-section, can be seen above.

Safety & Process Hazards

Though, compared to many industrial processes, maple syrup production is considerably safe, there are possible hazards that may be encountered. The process runs at high temperatures, uses fuel, facilitates movement of hot liquids/gases, and has the potential for blockages. Other hazards in the process relate to malpractice on the labourer's part and/or equipment malfunction. Sugar boils at a much higher temperature than water, and thus can also cause serious burns if in contact with skin. It is of paramount importance that care is taken when handling hot syrup and/or hot sap.

MATERIALS & CHEMICALS INVOLVED

The materials/chemicals involved are as follows:

- Maple sap
- Water
- Maple syrup
- Safflower oil
- Granulated maple sugar
- Sap water
- Sugar sand (niter)

Table 7 - Table of potential hazards during the sugaring process

Hazard	Hazard Location	Hazard Prevention
Burn from hot syrup	Evaporator, piping from evaporator, exhaust steam	Wear PPE, do not touch product with bare skin
Exhaust steam leak	Evaporator	Ensure that fume hood is operating correctly, ensure steam has a proper removal pathway
Syrup boils over	Evaporator	Ensure that safflower oil is added at a sufficient rate to ensure that the syrup is de-foamed
Tubing from evaporator leaks	Piping to filter press	Maintain piping throughout season, check for leaks and/or blockages
Filter press clogged	Filter press	Ensure that if cakes form they are removed immediately to prevent overflow
Tripping on tubing	In and around the evaporator	Ensure that tubing/piping is neatly organized and secured to either the wall or the floor and covered
Backlog in outside tubing	Raw sap tank, tubing	Ensure that raw sap is being pumped out of the tank at a sufficient rate to prevent pushing raw sap back into the tap lines
Fire	Evaporator	Monitor the amount of fuel in the evaporator, do not overload, keep temperature consistent

Environmental/Consumer Criteria & Policy

CLASSIFICATION OF MAPLE PRODUCTS

Quebec

There is a strict inspection regiment for maple syrup quality in Quebec. The ACER center's inspection division (Research Center for Maple Development and Technological Transfer) is responsible for the authenticity, safety and cleanliness of Quebec's maple syrup [9]. This company performs all the testing of maple syrup [9]. They test for Brix, light transmission, clarity, authenticity/taste and lead [9]. Brix testing is done through the use of a reflectometer to ensure the product has the required sugar content [9]. Light transmission is tested using a spectrophotometer [9]. Clarity is simply tested visually [9]. Lead testing is done using an Andcare test kit with the syrup in hydrochloric acid [9]. Lastly, taste is tested by consuming some of the product [9]. There has been research performed at ACER to create a SpectrAcer, replacing the taste test with a more reliable method [9]. Any samples that do not conform to the authenticity tests are discarded [9]. Once a sample has been approved it obtains the SIROPRO certification and can be sold in barrels [9]. The Federation of Quebec Maple Syrup (FPAQ) governs the 7400 maple businesses in Quebec [88]. The FPAQ has been a large factor in the growth of the maple industry of Quebec through marketing tools such as quotas [14]. These marketing tools helped them standardize and strengthen the industry between 1990 and 2014 [14].

Ontario

In Ontario, Maple producers must pursue their own tests from accredited laboratories to ensure that they have met the necessary quality [16]. Tests are also done annually by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) in order to ensure food safety [87]. These tests are similar to those of ACER's.

STANDARDS & REGULATIONS

All forms of equipment should comply with the "Standards on Maple Equipment", intended for the production of maple syrup [46]. In this document the types of materials that should be used for each piece of equipment as well as their appropriate design and placement in the maple refining process is discussed [46]. This document has been utilized to ensure that the chosen equipment previously described meets policy.

MAPLE POLICY ANALYSIS

Regulating the manufacturing and distribution of maple products is very important in supporting industry advancement and competitiveness. It helps facilitate market access and entice Canadian investment while protecting the health and well-being of all users. There are numerous Canadian regulatory requirements that are mandatory to follow with respect to all maple products [95].

There are three dominant regulation acts that maple syrup products are subject to for labeling requirements. Predominantly, the Maple Products Regulations (MPR) describe the labeling requirements for maple products produced in federally registered areas, and for imported maple products. They underline the application, prohibition and health and safety of maple products, ensuring correct grade, purity, no contamination, edibility, and sanitary preparation. A full detailed document of the MPR can be seen on the Justice Laws Website from the Government of Canada [96].

The other two regulation acts refer to labeling requirements for maple products that are sold in Canada and for intraprovincial trade. These acts are the Food and Drugs Act (FDA), and the Consumer Packaging and Labelling Act (CPLA) [97].

Provincial Regulations are also enforced in certain provinces that sell maple products. In Canada, there are two regulations that govern the grading of maple syrup; the Canadian Federal Government grading system as outlined by the MPR, and the Quebec Provincial Government grading system. Ontario is also currently following the Ontario Maple Syrup Regulations underlined within the Food Safety and Quality Act [98]. The following categories describe the chief labeling requirements for maple products in Ontario.

Policy Analysis

Country Of Origin

All maple syrup and products that have a volume of less than 5 L/kg respectively are required to declare the country of origin on the label in English and French at a minimum type height of 1.6 mm, adjacent to the Identity and Principal Place of Business. If the maple product is a Canadian maple product packed in Canada, or an imported maple syrup that was blended, graded, packed, labeled, or turned into another maple product in Canada, the country of origin is an optional requirement. Quebec has separate indications of their provincial origin on maple products [99].

Grade Designation

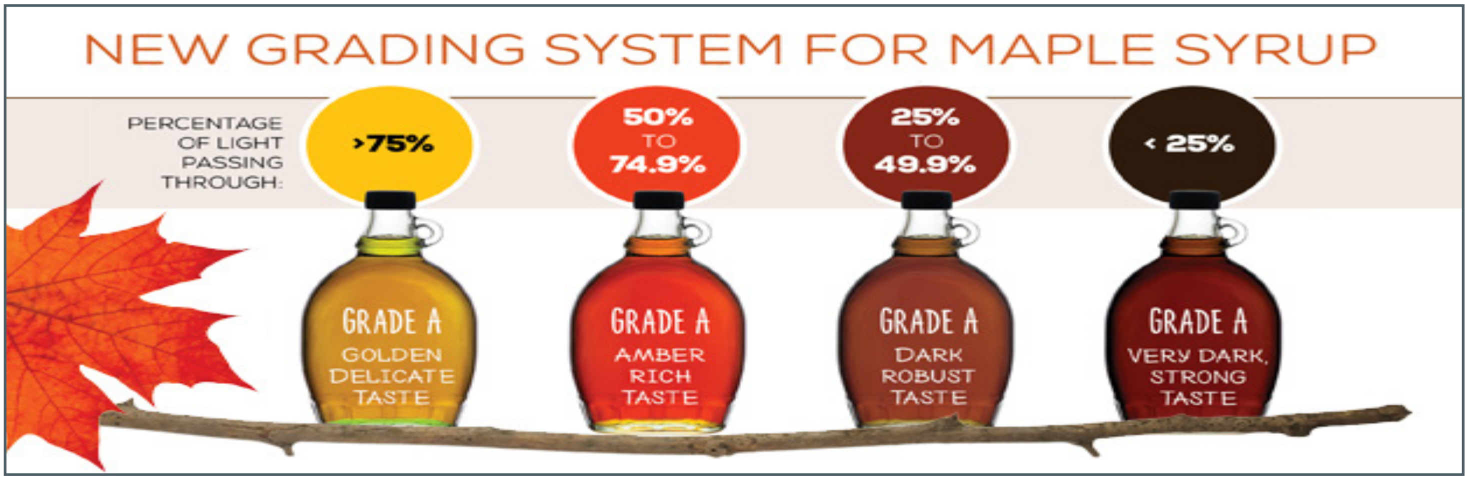
Canadian Maple Syrup undergoes two grade names; Canada Grade A, and Canada Processing Grade. Maple Syrup can be graded in a Canadian Food Industry Agency registered establishment under the MPR. Imported maple syrup uses the above grade names but removes 'Canada'. Syrup may only be graded if it is produced exclusively by maple sap concentration, is clean and fit for human consumption, has a minimum soluble solids content of 66% and a maximum soluble solids content of 68.9% [100].

Colour Classes

Maple Syrup can be classified into the following four colour classes:

1. **Golden, Delicate Taste (Not less than 75% Light Transmission)**
2. **Amber, Rich Taste (50% < Syrup < 75% Light Transmission)**
3. **Dark, Robust Taste (25% < Syrup < 50% Light Transmission)**
4. **Very Dark Strong Taste (Less than 25% Light Transmission)**

All of these are graded under 'Canada Grade A' unless they do not meet the requirements, in which case they are considered 'Canada Processing Grade,' which has no colour class. 'Canada Grade A' requirements include the syrup being free from fermentation, uniform in colour, free from sediments/cloudiness/turbidity, has a colour class, and has a maple flavour characteristic of its colour class that is free from any objectionable odour or taste. [101] The colour class must be printed on the label of the container [102].



Lot Number/Production Code, and Registration Number

Every container of maple syrup must be marked with a production code, and a registration number of the registered packing establishment [67] [68].

Export

All maple products that are exported are subject to requirements of that country. Furthermore, no maple syrup or product sold in Canada is subject to the addition of nutrients or amino acids in its manufacturing. This rule however may not apply if it is manufactured in Canada for export trade. The nutrient addition must be clearly indicated on the label if this is the case [105].

Maple Product Substitutes

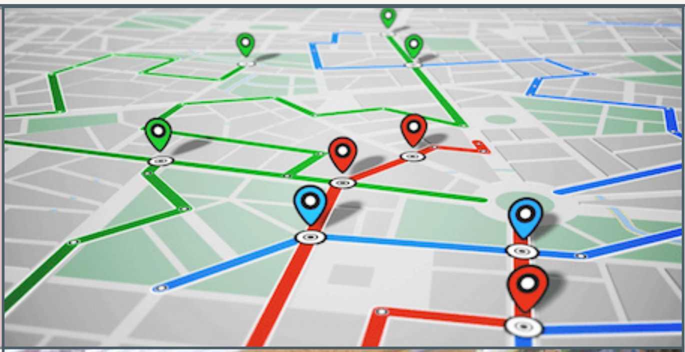
"No person shall market a product in import, export or interprovincial trade in such a manner that it is likely to be mistaken for a maple product for which a grade or standard is established under these Regulations". If the compositional standard for maple syrup is not met, a product cannot be marketed using this name [95].

Future Improvements and Areas of Interest for Research

Much of the research on the maple industry is passed on through generations. Like the maple trees, an extensive library of data, takes years to grow. While research regarding maple products, and maple forestry in general, has increased there are still many topics that have yet to be addressed. Identified below are several topics of interest that once investigated, may largely benefit the industry.

MAPPING OUT MAPLE

- Invest in a GPS system that locates maple trees could be particularly beneficial to potential sugar bush owners. A system such as this would map out the best forests to reconstruct into sugarbushes and allow for growth in sugar bushes in Ontario.
- A GPS system that pin points maple trees may enlighten researcher to understand the optimal environmental conditions for maple tree growth.

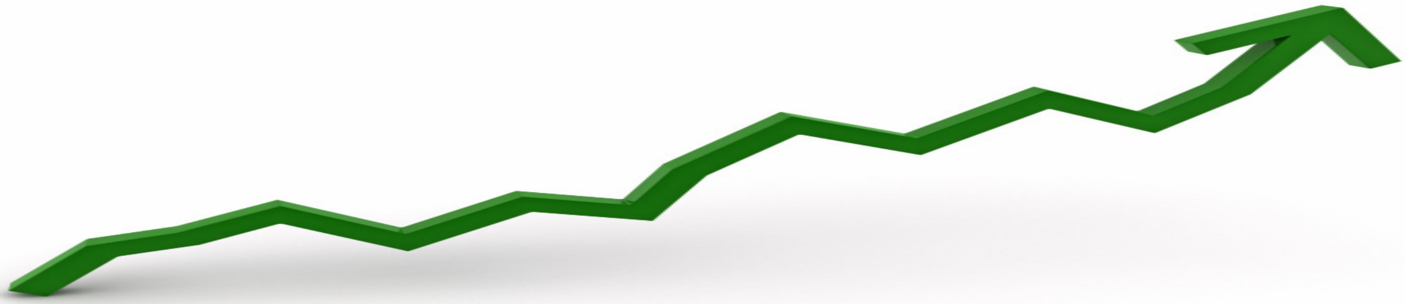


PUMPS

- Explore the feasibility of installing small pumps at each tap and the benefits of having additional pumping houses to facilitate in transporting sap
- By studying the utility and capital costs associated with implementing the use of small pumps and comparing them to the vacuum system currently being used, small pumps may prove to be advantageous. It is important to note that installing and maintaining so many pumps may outweigh the benefits, however, further investigation would be required to determine this.

REVERSE OSMOSIS

- Establish a balance between reverse osmosis and evaporation that both is energy efficient and produces a high-quality product.
- Reverse osmosis units are used in most evolved maple syrup producing facilities. To fully optimize the system based on energy consumption over the full process, reverse osmosis settings may be manipulated.
- Introducing a combination of reverse osmosis and nano-filtration to reduce the energy used on the evaporator, and thus create a more energy efficient process, however some maple syrup producers report that nano-filtration negatively affects the quality of their syrup [71]. Nano-filtration is a recently discovered membrane filtration process.
- Alterations in reverse osmosis techniques may affect the final grade of the syrup, as it will impact the amount of time maple sap spends in the evaporator.



FUEL & ENERGY

- Research a variety of cost efficient fuels for the evaporator as an alternative to wood pellets and oil to increase efficiency and decrease costs. Some possibilities to consider include the use of natural gas or propane to power the evaporators.
- Examine the feasibility of energy recycling in the process to potentially reduce energy costs. There is a sufficient amount of heat in the steam from the evaporator system that could possibly be recycled to slightly preheat the system and save some energy in the evaporator. With improved technology, implementing energy recycling may prove to be economically feasible.

DE-FOAMER

- Identify methods of de-foaming to replace the use of safflower oil and ensure that the final product does not include any additives.
- Mechanical methods of de-foaming may serve the function of safflower oil and replace the need for additives, however an efficient mechanical de-foaming technique has yet to be well-established for maple syrup production.

FILTRATION & FLAVOURS

- Investigate the use of activated charcoal as a filter aid and to function to remove bitter "buddy" flavours in syrup as previously mentioned in the "Process Innovations" section of this report

THE FINAL PRODUCT

- Determine the exact composition of the final maple syrup and discover if safflower oil remains in the final product
- Some experts speculate that the amount of safflower oil added is so insignificant that it likely boils off in the evaporator and is not present in the final product [71]. Tests would have to be done to verify this speculation to ensure that the final maple syrup product is pure.

MONETIZE BY-PRODUCTS

- Discover additional ways to further monetize the by-products for currency and market production.
- Examples may include the use of distilled water as a cleaning agent, or utilizing sugar sand for other uses. Some producers currently use these water-based by-products to clean equipment in the process.

PESTLE Analysis

A PESTLE analysis is an analysis of the political, economic, social, technological, legal and environmental factors related to a business or idea. By looking at the project from a birds-eye-view perspective, identifying problems or issues is more straightforward, and an all-encompassing analysis can be performed.

POLITICAL FACTORS

• The facility is large and will likely require multiple permits for construction.
• Incorporates a large acreage that may span multiple municipalities.
• Will likely increase the economic opportunities of the surrounding municipalities.

ECONOMIC FACTORS

• Has the ability to stabilize the maple industry's economy as the facility becomes more established within the market.
• Can significantly reduce the expenses associated with maple syrup production as practices become more standardized across all scales of maple sap refining.

SOCIAL FACTORS

• The maple tree and its products are incredibly important to Indigenous communities across Canada, especially in Ontario and Quebec.
• It is important that the traditional methods are respected and still incorporated into the process – this design is by no means to replace or disregard the practices created and performed by the Indigenous peoples of Canada.

TECHNOLOGICAL FACTORS

• Continuous system for production of multiple maple products. These designs have the ability to diversify the maple industry and build a stronger market base for maple products other than syrup)
• Redesigned maple tap with valve. Designed to close the tap during periods of low volumetric sap flow to clear the lines of immobile sap. Could help reduce bacterial growth in the lines and contribute to lighter, higher quality syrup.

LEGAL FACTORS

• Syrup must meet the standards for Ontario maple syrup production. (Colour, sugar content)
• Policies surrounding food product regulation.
• Health and safety regulations.
• Must meet all claims that are made regarding the health benefits of the products.

ENVIRONMENTAL FACTORS

• Process directly affects the environment since sap is being extracted from trees. (Not enough research on how this could impact the future of the tree/the entire forest)
• Certain environments/terrains are not suitable for a sugar bush. (Either needs manipulation to plant a sugar bush or must relocate)
• The process uses significant energy from the raw sap storage onwards. (Pumps and evaporators require energy)
• Wood pellets made from sawdust are used for energy – increases the sustainability of the process.
• No dangerous chemicals added – diatomaceous earth can be reused.

Conclusions/Recommendations

Maple's 'Untapped' Potential

In order to gain an advantage in the competitive maple market, it is recommended that a process is implemented that is capable of making several different maple products. Through this strategy, the relative production rates of various maple products can be tailored to the current prevailing market. This will allow for sales to be maximized and the producer to make the most of the sap, the base resource being harvested.

The financial analysis performed showed that, for a facility maple production of 100,000 taps, it is likely that the facility will quickly become profitable. However, this is contingent on the assumption that all of the products produced are sold within the year. This may be difficult, especially for a new producer that does not have an established brand or industry connections. As such, it is instead recommended that producers start at a smaller scale and progressively scale up their production as they gain the capacity for greater sales and obtain a comprehensive distribution network.

There is a great deal of potential for further research to be performed with respect to the maple industry. This includes further research into biological improvements to the process, such as introducing beneficial fungi to Forrest soil, sapling sap-harvesting, lengthening the production season by removing the "buddy" flavour found in sap at the end of the harvesting season, and reducing operational costs through implementation of nano-filtration or heat integration. While all of these have been identified as research topics that could strengthen the maple industry, further research will need to be conducted to determine the feasibility of implementing these changes.

Based on the Porter's Five Forces Analysis, several maple products appear to be quite profitable if introduced into the market with caution. Products, such as maple water, have a high potential to be quite profitable with consumers increasingly valuing organic and natural products. While the high threat of entry of competitors in the maple water industry poses a risk, it also indicates that there is a lot of opportunity in the maple water market. The "health water" industry is booming with products such as coconut water, birch water, and aloe water. It is clear that maple water will fit into this niche category smoothly. This result formed a basis for production estimates and more sap was allocated towards sap water as opposed to other maple products.

The intentional monetization of sugar sand is a relatively new and innovative application to the basic principles of sugar making. Sugar sand is often discarded, as it has no function within the maple syrup industry. Research into sugar sand has shown high levels of malic acid which has been proven to have anti-aging properties, thus adding value to this byproduct which was previously thought to have little worth. Sugar sand now stands to have a high chance of entering the cosmetic industry successfully due to its marketable qualities attributed to natural skincare products. Since sugar sand is produced on such a small scale, some cosmetic manufacturers may be deterred from acquiring sugar sand from just one supplier, or from just one sugar bush. For this reason, it is important to note that the potential for the monetization for sugar sand is reliant on the collaboration of sugar makers throughout Ontario. It is more likely that selling sugar sand will be more successful if multiple sugar makers collectively combine their byproducts to then be sold to players in the beauty industry.

All of this comes together to show that Ontario has great potential in the maple industry that has yet to be accessed. Despite the current dominance of Quebec in the market, Ontario has the natural resources necessary to gain a larger share of the maple market, if properly utilized. The promising prospects of recently trending maple products, present Ontarians with the opportunity to tap into less-crowded markets and re-establish a brand as Canada's sweetest maple producers.

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Queen's UNIVERSITY


MINNIE PEARL

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Appendix

SAMPLE CALCULATIONS AND ASSUMPTIONS

ECONOMICS

CAPITAL COSTS

Capital costs were produced from quotes gathered from vendors unless specified below:

FITTINGS

Fittings were difficult to cost, as the amount and type of fittings depends heavily on the topography of the land and the layout of the tubing network. Since this was unknown in this case, a general assumption was used that the total cost of the fitting would be approximately equal to 5% of the total tubing cost.

VACUUM PUMPS

Vacuum pumps were also difficult to price accurately, as the required power and number of vacuum pumps is highly dependent upon the topography and geographical layout of the sugar bush. However, the experts at CDL were able to give a rough estimate of what pump, and what quantity would be required for a sugar bush of the assumed size of 100,000 taps on 1,600 acres. CDL stated that these 10 of these pumps would cost approximately $16,000 per unit [71].

OPERATIONAL COSTS

Operational cost were calculated as follows:

PUMP COSTS

The operational cost of all pumps was calculated using the equation below:

$$Daily\ Pump\ Cost = (Power\ Consumption)\ x\ (Hours\ Run\ Per\ Day)\ x\ (Electricity\ Rate)$$

In order to prepare a conservative estimate, a current on-peak electricity rate of 13.2 ¢/kWh was used for the calculation of all electric operation costs [97]. Power consumptions were calculated from the required voltage and amperage for each type of pump, found on the spec sheets.

HEATING POWER FOR EVAPORATOR COST

The daily cost of heat generation for the evaporator was calculated using the equation below.

$$Evap. Heating\ Cost = (\frac{Hours}{day})\ x\ \left(\frac{Tons\ of\ wood}{hour}\right)\ x\ (\frac{Cost\ of Pellets}{ton})$$

The wood consumption of the evaporator was provided by the spec sheet provided by the CDL quote [98]. The cost of wood pellets, meanwhile, was sourced through provider Gildale Farms [99].

REVERSE OSMOSIS MEMBRANE REPLACEMENT

The assumption was made that all RO membranes would need to be replaced once over a three year period. As operation costs were done on a per day basis, the total replacement membrane cost was spread over three 21 day seasons. The RO membrane costs were approximated by using another companies values for similar sizes.

$$\frac{Membrane\ Cost}{Season} = \frac{Initial\ Membrane\ Cost}{Replacement\ Period}$$

DEFOAMER

Defoamer was assumed to be a negligible cost, as very little needs to be added to the evaporator for effective defoaming, and the defoamer itself (safflower oil or similar), is an inexpensive product.

PACKAGING

The method of packaging differed between products. It was decided that syrup was to be sold in plastic jugs of various sizes, as sourced through CDL [100]. An average of the cost/volume was taken to be applied for a packaging cost estimate. The decision was made to sell sap water in 1 liter Tetrapaks, as is common for similar products on the market. Both sugar sand and sap sugar were to be packaged in food-safe packaging as sourced through Uline [101]. The packaging costs were all calculated through the general equation below:

$$Packaging\ Cost = \left(\frac{Packaging\ Cost}{Unit}\right) x \left(\frac{Unit\ Production}{Day}\right)$$

MARKETING/SALES

General guidelines for marketing/sales costs suggest somewhere in the range of 2 to 20% of manufacturing costs for that product [102]. To maintain a conservative estimate, the upper estimate of 20% of manufacturing costs was selected. The operational costs were then divided into the amount of those costs necessary to produce each individual product, and the 20% factor was then applied to this.

LABOUR & ADMINISTRATION

It was estimated that, in order to run a facility of this size, four workers experienced with the equipment would be necessary. A 10-hour work day was assumed, and since the workers must be experienced with the specific maple processing equipment wages were estimated at $25/hr.

General guidelines suggest that administrative costs can be approximated as 15-25% of labour costs [102]. As before, the most conservative estimate was used, so a factor of 25% was added to the labour costs.

$$Labour\ Costs = (Price\ of\ Labour)\ x\ (Hours\ Worked)$$

PRODUCT TRANSPORTATION

Since distribution was assumed to be specifically within Ontario during the initial production years, it was assumed that product would be transported to destination by standard 53' semi trailers. Based on the internal dimensions of a 53' semi trailer, and the approximate physical size of daily product produced once packaged, it was estimated that three trailers worth of product would be produced per day, with the majority of this load being sap water. Current average trucking rates stand at $2.14 USD/mile [103]. Since the assumed production facility is near the eastern border of Ontario, and the bulk of the product would likely end up being shipped to the Greater Toronto Area, it was decided that the distance from the GTA to the production facility in Eastern Ontario would be an acceptable estimate for average distance traveled by trucks. As such, daily transport costs were determined by multiplying the three trucks by this distance (traveled by each truck), then multiplied by the previously mentioned average trucking rate (converted to $CAD).

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