# MAPLE RESEARCH

## PROGRAM OVERVIEW

| Potential Benefits | Sports and Performance | Extract/ By-products | Production/ Quality Control |
|---|---|---|---|
| Anti-inflammatory Properties | Performance and Endurance Benefits | Anti-inflammatory Properties | Quality Control Test |
| Antimicrobial/ antibiotic Properties | Source of Energy | Antimicrobial/ antibiotic Properties | Sap Production and Conservation Process |
| Antioxidant Properties | | Antioxidant Properties | |
| Glucose Management | | Cosmeceutical Properties | |
| Immune Properties | | | |

**Nutrition Facts**

| Serving size | 2 tbsp (30mL) |
|---|---|
| Amount per serving Calories | 110 |
| | % Daily Value* |
| **Total Fat** 0g | **0%** |
| Saturated Fat 0g | **0%** |
| *Trans* Fat 0g | |
| **Cholesterol** 0mg | **0%** |
| **Sodium** 0mg | **0%** |
| **Total Carbohydrate** 27g | **10%** |
| Dietary Fiber 0g | **0%** |
| Total Sugars 26g | |
| Includes 26g Added Sugars | **53%** |
| **Protein** 0g | |
| Vitamin D 0mcg | 0% |
| Calcium 31mg | 2% |
| Iron 0.2mg | 0% |
| Potassium 96mg | 2% |
| Thiamin 0.03mg | 2% |
| Riboflavin 0.2mg | 15% |
| Niacin 0.1mg | 0% |
| Magnesium 8mg | 0% |
| Zinc 0.2mg | 0% |
| Copper 0.1mg | 8% |
| Manganese 0.8mg | 35% |

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

## NUTRITION FACTS

- Pure maple syrup from Canada contains 11 vitamins and minerals – at approximately 110 calories per serving (2 tablespoons; 30 mL).
- Maple is an excellent source of manganese (35% DV).
- Maple is a good source of riboflavin (15% DV).
- Maple syrup contains calcium (2% DV), thiamin (2% DV), potassium (2% DV), and copper (8% DV).
- Scientists have identified more than 67 different plant compounds, or polyphenols, nine of which are unique to pure maple syrup. One of these polyphenols, named Quebecol, naturally forms when the sap is boiled to produce maple syrup.[i]

## PURPOSE

**Québec Maple Syrup Producers (QMSP)** is the world leader in maple ingredients production (syrup and sap) and maple research. QMSP is committed to advancing the understanding and knowledge of the potential benefits of maple ingredients and maple compounds for health promotion and/or disease risk prevention and mitigation among animals and humans.

**Québec Maple Syrup Producers** leads and directs the **International Maple Research and Innovation Network** which contributes to **QMSP's Maple Research Program**.

The following summaries highlight ongoing, published and/or unpublished research studies relating to Potential Benefits, Sports and Performance, Extract/By-products, and Production/ Quality Control.

Visit https://maplescience.org/ for more information about QMSP's research program.

[i] Li, L., & Seeram, N. P. (2011). Further investigation into maple syrup yields 3 new lignans, a new phenylpropanoid, and 26 other phytochemicals. *Journal of agricultural and food chemistry*, 59(14), 7708-7716.

# POTENTIAL BENEFITS

## Anti-inflammatory Properties

**Model:**
Characterization
**Product:**
Maple sap

Khalf M, Dabour N, Kheadr E, et al.
**Viability of probiotic bacteria in maple sap products under storage and gastrointestinal conditions**
*Bioresource Tech. 2010, 101: 7966–7972*

Abstract
Funding: Agriculture and Agri-Food Canada (AAFC)
This study was undertaken to develop new probiotic products based on liquid maple sap or its concentrate. Sap and concentrate, with or without inulin (2%) were inoculated with Bifidobacterium lactis Bb12 and Lactobacillus rhamnosus GG valio at initial counts of $10^7$-$10^8$ CFU/ml. Viability was assessed over four weeks of storage at 4°C and under in vitro simulated gastrointestinal conditions using dynamic gastrointestinal model known as TIM-1. Viability was maintained throughout the storage period at the same order of $10^7$ to $10^8$ CFU/ml. Inulin significantly enhanced the survivability during passage through the gastrointestinal tract simulator. The developed products could be an excellent alternative for delivering probiotics, especially for individuals suffering from lactose intolerance to dairy products.

**Model:**
In vivo
**Product:**
Maple syrup

Watanabe Y, Kamei A, Shinozaki F, et al.
**Ingested maple syrup evokes a possible liver-protecting effect-physiologic and genomic investigations with rats.**
*Biosci Biotechnol Biochem. 2011;75(12):2408-10. Epub 2011 Dec 7*

Abstract
This pilot study investigated the health-promoting effect of maple syrup that may be evoked in experimental animals. Rats fed a 20%-maple syrup diet for 11 days showed significantly lower values of various hepatic dysfunction markers than animals fed a 20%-sugar mix syrup diet (control). DNA microarray analysis revealed that the expression of genes for enzymes of ammonia formation were down-regulated in the liver of maple syrup group.
Funding: Council for the Development of Agriculture Québec (CDAQ), Agriculture and Agri-Food Canada (AAFC)

**Model:**
In vivo
**Product:**
Maple water, maple syrup, concentrate maple water

Hammami R, Ben Abdallah N, Barbeau J, et al.
**Symbiotic maple saps minimize disruption of the mice intestinal microbiota after oral antibiotic administration**
*Int J Food Sci Nutr. 2015;66(6):665-71.*

Abstract
This study investigated the in vivo impact of new symbiotic products based on liquid maple sap or its concentrate. The combination of inulin and probiotics in maple sap and maple concentrate appeared to minimize the antibiotic-induced breakdown of mice microbiota with a marked effect on bifidobacterium and bacteroides levels, thus permitting a more rapid re-establishment of baseline microbiota levels.

**Model:**
In vitro
**Product:**
Maple syrup

Aaron C, Beaudry G, Parker JA, et al.
**Maple Syrup Decreases TDP-43 Proteotoxicity in a Caenorhabditis elegans Model of Amyotrophic Lateral Sclerosis (ALS)**
*J Agric Food Chem. 2016 May 4;64(17):3338-44.*

Abstract
This study investigated the neuroprotective activity of maple syrup in a C. elegans model. Researchers found maple syrup to be protective against proteotoxicity, a hallmark characteristic of ALS (Lou Gehrig's disease). Results suggest the potential of maple syrup against various neurodegenerative diseases.
Funding: CHUM Foundation, ALS Society of Canada

**Model:**
Characterization, prebiotic
**Product:**
Inulin, maple syrup

Sun J, Ma H, Seeram NP, et al.
**Detection of Inulin, a Prebiotic Polysaccharide, in Maple Syrup**
*J Agric Food Chem. 2016 Sep 28;64(38):7142-7.*

Abstract
This study investigated isolated polymeric components from maple syrup. Researchers found one neutral polysaccharide characterized as inulin, which represented the first isolation of this prebiotic carbohydrate from a xylem sap. In addition, two acidic polysaccharides with structural similarity were identified as arabinogalactans derived from rhamnogalacturonan type I pectic polysaccharides. Further tests to determine the biological potential of these compounds remain to be done.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:**
In vivo
**Product:**
Maple syrup extract

Kamei A, Watanabe Y, Shinozaki F, et al.
**Quantitative deviating effects of maple syrup extract supplementation on the hepatic gene expression of mice fed a high-fat diet**
*Mol. Nutr. Food Res. 2017, 61, 2, 1600477: 1-15*

Abstract
This study investigated the effects of a polyphenol-rich maple syrup extract (MSXH) on the physiology of mice fed a high-fat diet (HFD). The mice were fed a low-fat diet (LFD), an HFD, or an HFD supplemented with 0.02% (002MSXH) or 0.05% MSXH (005MSXH) for 4 weeks. The study suggested that the effects of MSXH ingestion showed (i) dose-dependent pattern involved in energy metabolisms and (ii) reversely pattern involved in stress responses.
Funding: Ministry of Agriculture, Fisheries and Food (MAPAQ)

**Model:**
Characterization
**Product:**
Maple syrup

Karboune S, Li M.
**Enzymatic enrichment and biogeneration of fructooligosaccharides and levans from maple products through transfructosylation reaction**
*McGill University*

This project illustrated the feasibility of developing new maple-based products through a levansucrase-catalyzed transfructosylation reaction. Investigators demonstrated that sugars in maple products could be converted to higher value compounds, including fructooligosaccharides (FOS).
*This study is currently unpublished.*

**Model:** Characterization
**Product:** Maple sugar

Liu Y, Rose KN, DaSilva NA, et al.
**Isolation, Identification, and Biological Evaluation of Phenolic Compounds from a Traditional North American Confectionery, maple sugar**
*J. Agric. Food Chem. 2017, 65, 4289−4295*

Abstract
Maple sap, collected from the sugar maple (Acer saccharum) tree, is boiled to produce the popular plant-derived sweetener, maple syrup, which can then be further evaporated to yield a traditional North American confectionery, maple sugar. Although maple sap and maple syrup have been previously studied, the phytochemical constituents of maple sugar are unknown. Herein, 30 phenolic compounds, 1-30, primarily lignans, were isolated and identified (by HRESIMS and NMR) from maple sugar. The isolates included the phenylpropanoid-based lignan tetramers (erythro,erythro)-4”,4”’-dihydroxy-3,3’,3”,3”’,5,5’-hexamethoxy-7,9’;7’,9-diepoxy-4,8”;4’,8”’-bisoxy-8,8’-dineolignan-7”,7”’,9”,9”’-tetraol, 29, and (threo,erythro)-4”,4”’-dihydroxy-3,3’,3”,3”’,5,5’-hexamethoxy-7,9’;7’,9-diepoxy-4,8”;4’,8”’-bisoxy-8,8’-dineolignan-7”,7”’,9”,9”’-tetraol, 30, neither of which have been identified from maple sap or maple syrup before. Twenty of the isolates (selected on the basis of sample quantity available) were evaluated for their potential biological effects against lipopolysaccharide-induced inflammation in BV-2 microglia in vitro and juglone-induced oxidative stress in Caenorhabditis elegans in vivo. The current study increases scientific knowledge of possible bioactive compounds present in maple-derived foods including maple sugar.
Funding: Ministry of Agriculture, Fisheries and Food (MAPAQ)

**Model:** Clinical
**Product:** Maple syrup

Abe K, Kamei A, Toyoda T.
**Human intervention trial on maple syrup to evaluate its biological effects**
*The University of Tokyo, Kanagawa Institute of Industrial Science and Technology*

This study investigated how maple syrup ingestion influenced physiological functions in humans. Twenty human subjects consumed maple syrup extract or sucrose control for two weeks in a randomized cross over design. No significant differences were found between treatments in blood borne markers or in the gut microbiome. However, results suggested that maple syrup administration, compared to control, may have immunological benefits based on differences in mRNA expression.
*This study is currently unpublished.*
Funding: Health Japan Ministry

**Model:** Characterization
**Product:** Maple sugar

Brochu M, Lafrance CP, Landry E, et al.
**Isolation and characterization of major polysaccharides from maple sugar**
*TransBIOTech, PolyAnalytik*

This study investigated the isolation and characterization of major polysaccharides from maple sugar. Previous research suggested that sugars present in maple products may possess beneficial properties for the treatment of diabetes and other metabolic disorders, which could be related to the presence of oligosaccharides or polysaccharides. In this project polysaccharides in maple sugar were isolated, characterized and identified. In most fractions, fructose was the most abundant saccharide identified, suggesting the presence of fructan polysaccharides like inulin. Arabinogalactans and dextrans were identified as well.
*This study is currently unpublished.*
Funding: Agriculture and Agri-Food Canada (AAFC)

# Antioxidant Properties

**Model:**
In vitro
**Product:**
Maple syrup extract, maple syrup, maple sap

Legault J, Girard-Lalancette K, Grenon C, et al.
**Antioxidant Activity, Inhibition of Nitric Oxide Overproduction, and In Vitro Antiproliferative Effect of maple sap and Syrup from Acer saccharum**
*J Med Food 13 (2) 2010, 1–9*

Abstract
Antioxidant activity, inhibition of nitric oxide (NO) overproduction, and antiproliferative effect of ethyl acetate extracts of maple sap and syrup from 30 producers were evaluated in regard to the period of harvest in three different regions of Québec, Canada. Oxygen radical absorbance capacity (ORAC) values of maple sap and syrup extracts are, respectively, 12 +/- 6 and 15 +/- 5 micromol of Trolox equivalents (TE)/mg. The antioxidant activity was also confirmed by a cell-based assay. The period of harvest has no statistically significant incidence on the antioxidant activity of both extracts. The antioxidant activity of pure maple syrup was also determined using the ORAC assay. Results indicate that the ORAC value of pure maple syrup (8 +/- 2 micromol of TE/mL) is lower than the ORAC value of blueberry juice (24 +/- 1 micromol of TE/mL) but comparable to the ORAC values of strawberry (10.7 +/- 0.4 micromol of TE/mL) and orange (10.8 +/- 0.5 micromol of TE/mL) juices. Maple sap and syrup extracts showed to significantly inhibit lipopolysaccharide-induced NO overproduction in RAW264.7 murine macrophages. Maple syrup extract was significantly more active than maple sap extract, suggesting that the transformation of maple sap into syrup increases NO inhibition activity. The highest NO inhibition induced by the maple syrup extracts was observed at the end of the season. Moreover, darker maple syrup was found to be more active than clear maple syrup, suggesting that some colored oxidized compounds could be responsible in part for the activity. Finally, maple syrup extracts (50% inhibitory concentration = 42 +/- 6 microg/mL) and pure maple syrup possess a selective in vitro antiproliferative activity against cancer cells.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:**
Characterization, polyphenols
**Product:**
Maple syrup, 46 polyphenols

Li L, Seeram NP.
**Maple Syrup Phytochemicals Include Lignans, Coumarins, a Stilbene, and Other Previously Unreported Antioxidant Phenolic Compounds**
*J Agric Food Chem. 2010 Nov 24;58(22):11673-9.*

Abstract
This study investigated the phytochemical components that can be found in maple syrup. Over 40 compounds, 23 of which demonstrated phenolic activity, were isolated from a butanol extract of Canadian maple syrup using chromatographic methods. Among the isolates, 16 compounds were reported in maple syrup for the first time. This was one of the first studies to isolate and identify compounds with purported health benefits in maple syrup.
Funding: Council for the Development of Agriculture Québec (CDAQ), Agriculture and Agri-Food Canada (AAFC)

**Model:** Characterization, polyphenols
**Product:** Maple syrup

Li L, Seeram NP.
**Further Investigation into Maple Syrup Yields 3 New Lignans, a New Phenylpropanoid, and 26 Other Phytochemicals**
*J Agric Food Chem. 2011 Jul 27;59(14):7708-16.*

Abstract
This study was a continuation of prior work conducted by this research group to extract and identify value-added compounds in maple syrup. Researchers isolated and identified 30 additional compounds. Four were new compounds, and 20 compounds were identified in maple syrup for the first time. The new compounds include 3 lignans and 1 phenylpropanoid. The study advanced scientific knowledge of maple syrup constituents and suggested that diverse phytochemicals may impart potential health benefits to this natural sweetener.
Funding: Council for the Development of Agriculture Québec (CDAQ), Agriculture and Agri-Food Canada (AAFC)

**Model:** Characterization,
**Product:** Maple sap

Yuan T, Li L, Zhang Y, et a.
**Pasteurized and sterilized maple sap as functional beverages: Chemical composition and antioxidant activities**
*J Func Foods, 2013, 5: 1582-1590.*

Abstract
Maple sap has been consumed for centuries as a tonic by the indigenous peoples of eastern North America but is primarily utilized in this region to produce maple syrup. The natural watery form of maple sap makes its application as a functional beverage appealing but due to microbial growth, sterilization or pasteurization would be necessary before sap could be consumed. This study was designed to investigate the chemical composition (sugars, amino acids, organic acids, minerals, and phenolics) and antioxidant effects of maple sap after undergoing pasteurization and sterilization. After both processes, sugars, amino acids, organic acids, and minerals were preserved in the sap samples and they had similar phenolic contents (0.25–0.27 mg/100 g gallic acid equivalents) and antioxidant activities (IC50 ca. 550 µg/mL by DPPH assay). HPLC-DAD analyses revealed over 25 constituents in the sap samples of which 15 were identified using phenolic standards. In addition, one compound, 3′,5′-dimethoxy-4′-hydroxy-(2-hydroxy) acetophenone, not previously reported from maple syrup, was isolated and identified (by NMR) for the first time from maple sap. Therefore, the preservation of chemical constituents and antioxidant activity in maple sap after pasteurization and sterilization warrants its application as a functional beverage beyond its primary use for maple syrup production alone.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** Characterization,
**Product:** Maple sap

Lagace L, Leclerc S, Charron C, et al.
**Biochemical composition of maple sap and relationships among constituents**
*Journal of Food Composition and Analysis. 2015 Aug; 41:129-136.*

Abstract
This study aimed to establish a typical chemical composition of maple sap by analyzing a large number of maple sap samples over two seasons of production. Results confirm that key sap components change over time. Total soluble solids and sucrose concentration were higher near mid-season. Phenolic compounds of interest were present mainly at the beginning of the season and decreased as the season progressed. The concentrations of the main minerals (K, Ca and Mg) increased over the sap flow season and the presence of calcium and magnesium seemed highly correlated. Results can help in establishing mean values and ranges for many components of maple sap.

**Model:** Characterization,
**Product:** Maple sap

Yuan T, Zhang Y, Li L, et al.
**Preservation of Phenolics and Other Chemical Constituents in Maple Sap after Thermal Treatments**
*University of Rhode Island*

This study investigated the chemical composition of maple sap after thermal treatments (sterilization and pasteurization) to explore its functional beverage potential. After heat processing, sugars, amino acids, organic acids, minerals and at least 25 phenolic compounds were preserved in the sap samples. Researchers concluded the preservation of chemical constituents and antioxidant activity in maple sap after pasteurization and sterilization warrant its application in functional beverages beyond its primary use for maple syrup production alone.
*This study is currently unpublished.*
Funding: Agriculture and Agri-Food Canada (AAFC)

## Glucose Management

**Model:** In vivo
**Product:** Maple syrup

St-Pierre P, Pilon G, Dumais V, et al.
**Comparative analysis of maple syrup to other natural sweeteners and evaluation of their metabolic responses in healthy rats**
*Journal of Functional Foods. 2014; 11:460-471.*

Abstract
The objective of this study was to systematically compare the chemical composition of maple syrup with that of other natural sweeteners and assess their metabolic responses in healthy rats. Maple syrup produced significantly lower peak and global responses of serum glucose, insulin and gastric inhibitory polypeptide (GIP) as compared to brown rice syrup, corn syrup and dextrose. Both the composition of maple syrup and the metabolic responses to its ingestion in rats suggest that it represents a healthy natural alternative to various other sweetener options.

**Model:** In vivo
**Product:** Maple syrup extract

Abe K.
**Analysis of physiological functions of maple syrup by nutrigenomics**
*The University of Tokyo*

This study investigated the effects on bodily physiology when mice were placed on diets with polyphenol-rich extracts. In this study, researchers removed a large percentage of sucrose from maple syrup, prepared extracts (MSE, MSX-high and MSX-low) rich in polyphenols and fed them to diabetic mice for eight weeks. MSX decreased insulin resistance, hepatic cholesterol synthesis, and markers of liver dysfunction compared to a sugar control group.
*This study is currently unpublished.*

# SPORTS AND PERFORMANCE

## Performance and Endurance Benefits

**Model:**
Clinical
**Product:**
Maple syrup, maple sap/water

Tremblay J, Leduc-Savard N.
**Maple syrup as a substitute for commercial sports drinks: can it be a viable solution for recreational and elite athletes?**
*Université de Montréal*

This study compared the energetic effects maple syrup (MS), and maple water (MW) with commercial sports drinks (CSD) during a two hour exercise bout. Results indicated that both MS and MW solutions can be readily absorbed and used as a source of energy during prolonged exercise. MW led to a greater exogenous carbohydrate oxidation than MS, and to a similar energy yield as a common CSD during prolonged cycling. Findings suggest that maple products could be used as viable natural sweeteners in sports drinks and warrant further investigation for their potential in improving sports performance.
*This study is currently unpublished.*
Funding: Agriculture and Agri-Food Canada (AAFC)

## Source of Energy

**Model:**
Clinical
**Product:**
Maple syrup, maple sap/water

Lavoie L, Leduc-Savard N, Tremblay J.
**Ingestion of maple-based sports drinks, effect on perceived exertion, palability and time trial performance: an interventional study**
*Université de Montréal*

The aim of the current study is to assess the palatability of maple-based sports drinks ingested during prolonged exercise and investigate their effect on perceived exertion (RPE) and performance. Male recreationally and competitively active subjects (n = 76, mass = 73.7 ± 10.3 kg, VO2peak = 4.4 ± 0.5 L/min, MAP = 309 ± 42 W) ingested either one of four carbohydrate solutions (maple water, syrup, glucose or a commercial sports drink, all at 60 g/L) or sweetened water (stevia) at every 30 minutes during 120 min of steady-state exercise (SSE) on a cycle ergometer at 55% MAP, followed by a 20 km time trial (TT). Perceived exertion (RPE, Borg CR-10) was recorded at each 30 min throughout SSE and TT. A questionnaire meant to assess sensory characteristics (sweetness, acidity, thirst-quenching ability, and overall taste) and appreciation (sweet, acid and overall) was administered 30 minutes before (immediately after the first ingestion) and after SSE. Results from before and after exercise were averaged. Sweetness was reported to be higher for commercial sports drinks and maple water than glucose and, and maple syrup scored higher than maple water for the appreciation of the sweet taste. Furthermore, subjects that had ingested maple water, reported a significantly lower RPE throughout exercise than with commercial sports drinks and maple. There was no difference in TT performance in any of the conditions.
*This study is currently unpublished.*
Funding: Agriculture and Agri-Food Canada (AAFC)

# EXTRACT/BY-PRODUCTS

## Anti-inflammatory Properties

**Model:** In vitro
**Product:** Ethyl acetate extract of MS (MS-EtOAc), butanol extract of MS (MS-BuOH)

Apostolidis E, Li L, Lee C, et al.
**In Vitro Evaluation of Phenolic-Enriched maple syrup extracts for Inhibition of Carbohydrate Hydrolyzing Enzymes Relevant to Type 2 Diabetes management**
*J Func Food 2011, 3:100-106*

Abstract
This study investigated phenolic-enriched extracts of Canadian maple for their ability to inhibit carbohydrate hydrolyzing enzymes relevant to type 2 diabetes management. Results indicated that maple syrup extracts inhibited activity of alpha amylase and alpha glucosidase, enzymes involved in the breakdown and absorption of ingested carbohydrates. These findings suggest the potential for maple syrup extracts to mediate type 2 diabetes management, as well as management of other metabolic conditions that involve carbohydrate metabolism.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** Characterization, unique compound
**Product:** Quebecol

Li L, Seeram NP.
**Quebecol, a novel phenolic compound isolated from Canadian maple syrup**
*Journal of Functional Foods. 2011;3(2):125-128.*

Abstract
This study investigated and isolated a novel phenolic compound from maple syrup – Quebecol. The compound is likely produced during processing, as it does not appear to exist naturally in unprocessed syrup. Additional research is required to further characterize quebecol's biological potential as a novel nutraceutical ingredient.
Funding: Council for the Development of Agriculture Québec (CDAQ), Agriculture and Agri-Food Canada (AAFC)

**Model:** In vitro
**Product:** Red maple leaves extract, sugar maple leaves extract

Apostolidis E, Li L, Kang B, et al.
**Seasonal Influence on Phenolic-mediated Antihyperglycemic Properties of Canadian Sugar and Red Maple Leaves Using in vitro Assay Models**
*Food Sci. Biotechnol., 2012, 21(3): 753-760*

Abstract
Red and sugar maple leaves collected in the summer and fall from Canada, were evaluated for phenolic content, antioxidant, α-glucosidase, and α-amylase inhibitory activities variation. The phenolic contents of summer red maple leaves (RML-S) and summer sugar maple leaves (SML-S) were higher than red and sugar maple leaves collected in fall (RML-F and SML-F, respectively). HPLC analyses showed differences in phenolic compounds present in the SML samples compared to the RML samples. The extracts were assayed for yeast and rat α-glucosidase inhibitory activities. Both results showed that SML-S extracts had the highest inhibitory activity which could possibly be attributed to the unique phenolics present therein. Milder effects were observed in terms of α-amylase inhibitory activity, with RML-F having the highest inhibitory activity. These results suggest that maple tree leaf extracts may have potential for phenolic-mediated α-glucosidase inhibition, relevant to type 2 diabetes management, with SML-S extract having the highest bioactivity.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** In vitro
**Product:** Red maple bark extract

Seeram NP, Xu J, Li L, et al.
**Mining Red Maple (Acer rubrum) Trees for Novel Therapeutics to Manage Diabetes**
*Med Health R I. 2012 September; 95(9): 283–284.*

Abstract
Type 2 diabetes mellitus (T2DM) accounts for about 90% of all diagnosed cases of diabetes in adults with over 200 million people suffering from this disease worldwide. In the United States alone, in 2007, 10% of American adults had diabetes and the cost to manage diabetes was $174 billion and this figure is expected to skyrocket (Centers for Disease Control and Prevention, 2010). Plants and their derived products have been used for centuries by various cultures as traditional medicines for the management of diabetes. Plants contain secondary metabolites (known as phytochemicals; 'phyto' means plant), which are implicated in the prevention and treatment of several chronic human diseases, including diabetes. Among these natural products, polyphenols and phenolic glycosides, have attracted significant interests for their anti-diabetic properties.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** In vitro
**Product:** Red maple bark extract, (Maplexins F-I)

Yuan T, Wan C, Liu K, et al.
**New maplexins F-I and phenolic glycosides from red maple (Acer rubrum) bark**
*Tetrahedron, 2012, 68: 959-964*

Abstract
Four new gallotannins, maplexins FeI (1e4), two new phenolic glycosides, rubrumosides AeB (5,6), and eleven known compounds were isolated from red maple (Acer rubrum) bark. Their structures were elucidated based on spectroscopic analysis. The maplexins contained three galloylated derivatives at-tached to different positions of 1,5-anhydro-glucitol and were 10e20 fold more potent a-glucosidase inhibitors than the clinical drug, Acarbose (IC 50 ¼7e16 vs 161 mM), in vitro. These results support previous data suggesting that gallotannins are the main contributors to the a-glucosidase inhibitory activities of maple plant part extracts and that three substituents on the 1,5-anhydro-glucitol moiety are important for activity.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** Characterization
**Product:** Quebecol

Cardinal S, Voyer N.
**Total synthesis of quebecol**
*Tetrahedron Letters, 2013, 54: 5178–5180*

Abstract
We report here the total synthesis of quebecol, a new polyphenolic compound with potential applications recently isolated from maple syrup and produced during the condensation of the tree acer saccharum's sap. The synthetic approach we developed involves, as key steps, the formation of a dibromoalkene from an α-ketoester precursor followed by a double Suzuki–Miyaura reaction to unite the three aromatic rings of the target compound on a tetrasubstituted olefin precursor. Our methodology is an efficient pathway to the target compound and leads the way for future analogs.

**Model:** In vitro
**Product:** Quebecol, analogs

Pericherla K, Shirazi AN, Rao VK, et al.
**Synthesis and antiproliferative activities of quebecol and its analogs**
*Bioorganic & Medicinal Chemistry Letters, 2013, 23: 5329–5331*

Abstract
Simple and efficient synthesis of quebecol and a number of its analogs was accomplished in five steps. The synthesized compounds were evaluated for antiproliferative activities against human cervix adenocarcinoma (HeLa), human ovarian carcinoma (SK-OV-3), human colon carcinoma (HT-29), and human breast adenocarcinoma (MCF-7) cancer cell lines. Among all the compounds, 7c, 7d, 7f, and 8f exhibited antiproliferative activities against four tested cell lines with inhibition over 80% at 75 μM after 72 h, whereas, compound 7b and 7g were more selective towards MCF-7 cell line. The IC50 values for compounds 7c, 7d, and 7f were 85.1 μM, 78.7 μM, and 80.6 μM against MCF-7 cell line, respectively, showing slightly higher antiproliferative activtiy than the synthesized and isolated quebecol with an IC50 value of 104.2 μM against MCF-7.

**Model:** In vivo
**Product:** Maple syrup extract

Nahar PP, Driscoll MV, Li L, et al.
**Phenolic mediated anti-inflammatory properties of a maple syrup extract in RAW 264.7 murine macrophages**
*J Func Food, 2014; 6: 126-136*

Abstract
The in vitro anti-inflammatory effects of a phenolic-enriched Canadian maple syrup ethyl acetate extract (MS-EtOAc) and 15 purified phenolic constituents were evaluated in a LPS-stimulated RAW 264.7 murine macrophage cell model. MS-EtOAc decreased nitric oxide (NO) and prostaglandin-E2 (PGE2) production at 10–100 μg/mL concentrations. The observed NO inhibition was a direct result of reduced nitric oxide synthase (iNOS) protein and gene expression through suppression of NF-κB transcriptional activation. In addition, MS-EtOAc upregulated cyclooxygenase-2 (COX-2) mRNA and protein expression. Among the 15 pure isolates, (E)-3,3′-dimethoxy-4,4′-dihydroxystilbene was most effective in decreasing both NO and PGE2 levels. However, 4-acetylcatechol, tyrosol, and protocatechuic acid only reduced PGE2 levels. Thus, the potential anti-inflammatory activity of MS-EtOAc can be attributed to its unique combination of compounds and not as a result of a single purified phenolic constituent alone. Future research on the purified phenolic compounds will be useful in understanding the overall in vitro anti-inflammatory effects of maple syrup.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** In vivo
**Product:** Maple syrup extract

Zhang Y, Yuan T, Li L, et al.
**Chemical Compositional, Biological, and Safety Studies of a Novel maple syrup Derived extract for Nutraceutical Applications**
*J. Agric. Food Chem. 2014, 62, 6687−6698*

Abstract
Maple syrup has nutraceutical potential given the macronutrients (carbohydrates, primarily sucrose), micronutrients (minerals and vitamins), and phytochemicals (primarily phenolics) found in this natural sweetener. We conducted compositional (ash, fiber, carbohydrates, minerals, amino acids, organic acids, vitamins, phytochemicals), in vitro biological, and in vivo safety (animal toxicity) studies on maple syrup extracts (MSX-1 and MSX-2) derived from two declassified maple syrup samples. Along with macronutrient and micronutrient quantification, thirty-three phytochemicals were identified (by HPLC-DAD), and nine phytochemicals, including two new compounds, were isolated and identified (by NMR) from MSX. At doses of up to 1000 mg/kg/day, MSX was well tolerated with no signs of overt toxicity in rats. MSX showed antioxidant (2,2-diphenyl-1-picrylhydrazyl (DPPH) assay) and anti-inflammatory (in RAW 264.7 macrophages) effects and inhibited glucose consumption (by HepG2 cells) in vitro. Thus, MSX should be further investigated for potential nutraceutical applications given its similarity in chemical composition to pure maple syrup.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** In vivo
**Product:** Maple syrup extract

Kamei A, Watanabe Y, Shinozaki F, et al.
**Administration of a maple syrup extract to mitigate their hepatic inflammation induced by a high-fat diet: a transcriptome analysis**
*Biosci. Biotechnol. Bîochem., 2015, 79 (11): 1893-1897*

Abstract
Effects of the administration of maple syrup extract (MSX) on hepatic gene expression were investigated in mice fed a high-fat diet. Gene annotation enrichment analysis based on gene ontology revealed some changes in the expression of genes related to lipid metabolism and the immune response in MSX-fed mice. Detailed analysis of these data indicated that MSX ingestion mitigates hepatic inflammation.
Funding: Ministry of Agriculture, Fisheries and Food (MAPAQ)

**Model:** In vitro
**Product:** Quebecol

Cardinal S, Azelmat J, Grenier D, et al.
**Anti-inflammatory properties of quebecol and its derivatives**
*Bioorg Med Chem Lett. 2016 Jan 15;26(2):440-444.*

Abstract
This study looked at the anti-inflammatory properties of quebecol and its derivatives. Quebecol is a polyphenolic compound generated during processing of maple syrup. Bioassays demonstrated that quebecol displayed anti-inflammatory properties, suppressing levels of LPS-induced secretion of two pro-inflammatory cytokines, IL-6 and TNF-a in vitro.
Funding: NSERC of Canada, FRQNT of Quebec, Laval University, PROTEO

**Model:** In vitro
**Product:** Maple syrup extract

Hawco CL, Wang Y, Taylor M, et al.
**A Maple Syrup Extract Prevents β-Amyloid Aggregation**
*Can J Neurol Sci. 2016 Jan;43(1):198-201.*

Abstract
This study investigated the role of maple syrup, a natural product-based anti-protein misfolding agent, on the putative treatment of Alzheimer's disease (AD). Results indicated that maple syrup extract may decrease oligomerization and aggregation of both β-amyloid (Aβ) and tau peptides in vitro, the two pathological hallmarks of AD.
Funding: Others

**Model:** In vitro, in vivo
**Product:** Maple syrup extract

Ma H, DaSilva NA, Liu W, et al.
**Effects of a Standardized Phenolic-Enriched maple syrup extract on β-Amyloid Aggregation, Neuroinflammation in Microglial and Neuronal Cells, and β-Amyloid Induced Neurotoxicity in Caenorhabditis elegans**
*Neurochem Res 2016; 41:2836–2847*

Abstract
This study investigated the neuroprotective effects of a chemically standardized phenolic-enriched maple syrup extract (MSX). Using a combination of biophysical, in vitro, and in vivo studies, MSX was shown to reduce Aβ1–42 fibrillation and decrease oxidative and inflammatory stresses in murine BV-2 microglial cells and human SHSY-5Y neuronal cells. Furthermore, MSX imparted protective effects on Aβ1–42 aggregation induced neurotoxicity and paralysis in C. elegans. This data supports the potential neuroprotective effects of MSX warranting further studies on this natural product.

**Model:** In vitro
**Product:** Maple leaves extract

Alshammari S, Khurshid Y, Ma H, et al.
**Characterization of biologically active proteins from red maple (Acer rubrum) leaves**
*University of Rhode Island, Chapman University*

This study investigated the activity guided purification of proteins from red maple leaves collected in spring and fall seasons. Preliminary data revealed that different active protein fractions were identified in leaves in spring and fall. These proteins purport to impact inflammation and other pathologies; further studies are in progress to fully characterize the primary structure of these proteins, as well as their biological potential in red maple.
*This study is currently unpublished.*

**Model:** In vivo
**Product:** Maple syrup extract

Rose KN, Barlock BJ, DaSilva NA, et al.
**Dietary intake of a phenolic-enriched extract of maple syrup reduces neuroinflammation in the 3xTgAD mouse model of Alzheimer's disease**
*University of Rhode Island*

This study investigated whether dietary intake of a maple syrup derived extract (MSX) would mitigate neuroinflammatory markers in an in vivo murine model of Alzheimer's disease. The results demonstrated that the dietary intake of MSX reduces neuroinflammation in the 3xTgAD mouse model, suggesting antioxidant/anti-inflammatory benefits and warranting future investigation of this natural product.
*This study is currently unpublished.*
Funding: USDA Grant

**Model:** In vitro, in vivo
**Product:** Maple syrup extract

Slitt A, Ma H, DaSilva NA, et al.
**Evaluation of a food grade phenolic-enriched maple syrup extract against diet-induced Hepatic-steatosis and inflammation**
*University of Rhode Island*

This study investigated if maple syrup-derived extract (MSX) supplementation would protect against markers of diet-induced obesity and inflammation in murine and human cell models, following 18 weeks of a cholesterol-enriched diet with and without MSX. Results showed that MSX does exert anti-inflammatory activity and anti-lipogenic effects in vitro in mice; researchers suggested that MSX may exert similar anti-inflammatory effects in human-derived immune cells as observed in mouse models.
*This study is currently unpublished.*
Funding: USDA Grant

## Antimicrobial/Antibiotic Properties

**Model:** In vitro
**Product:** Maple syrup extract

Maisuria VB, Hosseinidoust Z, Tufenkji N.
**Polyphenolic Extract from Maple Syrup Potentiates Antibiotic Susceptibility and Reduces Biofilm Formation of Pathogenic Bacteria**
*Applied and Environmental Microbiology. 2015;81(11):3782-3792.*

Abstract
This study investigated the antimicrobial activity of a phenolic-rich maple syrup extract (PRMSE) on various bacterial strains. PRMSE exhibited strong synergistic interaction with selected antibiotics against Gram-negative clinical strains of Escherichia coli, Proteus mirabilis, and Pseudomonas aeruginosa. The study provided proof-of-concept data for investigating the molecular mechanism of the reported increase in bacterial antibiotic activity in the presence of PRMSE.
Funding: Natural Sciences and Engineering Research Council of Canada (NSERC), Canada Research Chairs Program (CRC)

**Model:** In vitro, in vivo
**Product:** Maple syrup extract

Tufenkji N, Maisuria VB, Nguyen D, et al.
**Maple syrup-derived polyphenolics potentiate antibiotics in vivo**
*McGill University, INRSInstitut Armand-Frappier*

Antibiotic resistance is a rapidly growing threat to global public health. This study looked at the potential of a polyphenolic rich extract from maple syrup (PRMSE) to potentiate the effects of common antibiotics in vivo, which could lessen the need for antibiotic usage. Results indicated that PRMSE and ciprofloxacin combination therapy displayed synergy against P. aeruginosa in and murine infection models at clinically relevant doses, suggesting that PRMSE may have potential as an antibiotic adjuvant for the treatment of different types of bacterial infections.
*This study is currently unpublished.*

## Antioxidant Properties

**Model:** In vitro
**Product:** Maple bark extract

Yuan T, Wan C, Gonzalez-Sarrias A, et al.
**Phenolic Glycosides from Sugar Maple (Acer saccharum) Bark**
*J. Nat. Prod. 2011, 74, 2472–2476*

Abstract
Four new phenolic glycosides, saccharumosides A-D (1-4), along with eight known phenolic glycosides, were isolated from the bark of sugar maple (Acer saccharum). The structures of 1-4 were elucidated on the basis of spectroscopic data analysis. All compounds isolated were evaluated for cytotoxicity effects against human colon tumorigenic (HCT-116 and Caco-2) and nontumorigenic (CCD-18Co) cell lines.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** In vitro
**Product:** Maple sap extract, maple syrup extract, maple leaves extract, maple twigs extract, maple bark extract, maple sapwoods extract

Gonzalez-Sarrias A, Li L, Seeram NP.
**Effects of Maple (Acer) Plant Part extracts on Proliferation, Apoptosis and Cell Cycle Arrest of Human Tumorigenic and Non-tumorigenic Colon Cells**
*Phytother. Res. 2012, 26: 995–1002*

Abstract
Phenolic-enriched extracts of maple sap and syrup, obtained from the sugar and red maple species (Acer saccharum Marsh, A. rubrum L., respectively), are reported to show anticancer effects. Despite traditional medicinal uses of various other parts of these plants by Native Americans, they have not been investigated for anticancer activity. Here leaves, stems/twigs, barks and sapwoods of both maple species were evaluated for antiproliferative effects against human colon tumorigenic (HCT-116, HT-29, Caco-2) and non-tumorigenic (CCD-18Co) cells. Extracts were standardized to total phenolic and ginnalin-A (isolated in our laboratory) levels. Overall, the extracts inhibited the growth of the colon cancer more than normal cells (over two-fold), their activities increased with their ginnalin-A levels, with red > sugar maple extracts. The red maple leaf extract, which contained the highest ginnalin-A content, was the most active extract ($IC_{50}$ = 35 and 16 µg/mL for extract and ginnalin-A, respectively). The extracts were not cytotoxic nor did they induce apoptosis of the colon cancer cells. However, cell cycle analyses revealed that the antiproliferative effects of the extracts were mediated through cell cycle arrest in the S-phase. The results from the current study suggest that these maple plant part extracts may have potential anticolon cancer effects.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:**
In vitro
**Product:**
Red maple stems extract, red maple bark extract, (Maplexins A-I) from red maple stems and bark

Gonzalez-Sarrias A, Yuan T, Seeram NP.
**Cytotoxicity and structure activity relationship studies of maplexins A–I, gallotannins from red maple (Acer rubrum)**
*Food and Chemical Toxicology, 2012, 50: 1369–1376*

Abstract
Maplexins A-I are a series of structurally related gallotannins recently isolated from the red maple (Acer rubrum) species. They differ in number and location of galloyl derivatives attached to 1,5-anhydro-glucitol. Here, maplexins A-I were evaluated for anticancer effects against human tumorigenic (colon, HCT-116; breast, MCF-7) and non-tumorigenic (colon, CCD-18Co) cell lines. The maplexins which contained two (maplexins C-D) or three (maplexins E-I) galloyl derivatives each, inhibited cancer cell growth while those with only one galloyl group (maplexins A-B) did not. Moreover, maplexins C-D showed greater antiproliferative effects than maplexins E-I (IC(50)=59.8-67.9 and 95.5-108.5 μM vs. 73.7-165.2 and 115.5-182.5 μM against HCT-116 and MCF-7 cells, respectively). Notably, the cancer cells were up to 2.5-fold more sensitive to the maplexins than the normal cells. In further mechanistic studies, maplexins C-D (at 75 μM concentrations) induced apoptosis and arrested cell cycle (in the S-phase) of the cancer cells. These results suggest that the number of galloyl groups attached to the 1,5-anhydro-glucitol moiety in these gallotannins are important for antiproliferative activity. Also, this is the first in vitro anticancer study of maplexins.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:**
In vitro
**Product:**
Maple syrup extracts

Gonzalez-Sarrias A, Li L, Seeram NP.
**Anticancer effects of maple syrup phenolics and extracts on proliferation, apoptosis, and cell cycle arrest of human colon cells**
*J Func Food 2012, 4:185-196*

Abstract
The antiproliferative effects of Canadian maple syrup (grades C and D) extracts and fifty-one purified phenolic constituents were evaluated against human tumourigenic (HT-29, HCT-116, and CaCo-2) and non-tumourigenic (CCD-18Co) colon cells. Overall, maple syrup ethyl acetate (MS-EtOAc), butanol (MS-BuOH), and methanol (MS-MeOH) extracts were more active against the tumourigenic versus non-tumourigenic colon cells. At equivalent phenolic levels, the antiproliferative activities of grade D > C maple syrup, and MS-BuOH > MS-MeOH > MS-EtOAc. Among the isolates, gallic acid, catechaldehyde, syringaldehyde, and catechol were most active and their higher levels in grade D MS-BuOH extract could account for the highest observed anticancer effects of that extract. Moreover, the maple syrup extracts did not induce apoptosis of the colon cancer cells but induced cell cycle arrest which was also associated with a decrease in cyclins A and D1 levels. These results suggest that phenolics may impart potential biological effects to maple syrup.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** In vitro
**Product:** Red maple bark extract, (Maplexins F-I)

Wan C, Yuan T, Li L, et al.
**New maplexins F-I and phenolic glycosides from red maple (Acer rubrum) bark**
*Bioorganic & Medicinal Chemistry Letters, 2012, 22: 597–600*

Abstract
Four new gallotannins, maplexins FeI (1e4), two new phenolic glycosides, rubrumosides AeB (5,6), and eleven known compounds were isolated from red maple (Acer rubrum) bark. Their structures were elucidated based on spectroscopic analysis. The maplexins contained three galloylated derivatives at-tached to different positions of 1,5-anhydro-glucitol and were 10e20 fold more potent a-glucosidase inhibitors than the clinical drug, Acarbose (IC 50 ¼7e16 vs 161 mM), in vitro. These results support previous data suggesting that gallotannins are the main contributors to the a-glucosidase inhibitory activities of maple plant part extracts and that three substituents on the 1,5-anhydro-glucitol moiety are important for activity.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** Characterization
**Product:** Stems of red maple extract

Wan C, Yuan T, Xie M, et al.
**Acer rubrum phenolics include A-type procyanidins and a chalcone**
*Bioch. Systematics and Ecology, 2012, 44: 1–3*

Abstract
The genus Acer (Aceraceae), commonly known as maple, contains approximately 200 species distributed in Asia, North America, and Europe (van Gelderen et al., 1994). Of these, thirteen species are indigenous to North America including the red maple (Acer rubrum L.) species which was used by the Native Americans for a variety of medicinal purposes (Ball, 2007; Arnason et al., 1981; Royer et al., 2011). The stems of red maple were collected in August 2009 by the Federation of Maple Syrup Producers of Quebec (Canada), shipped to our laboratory, and identified by Mr. J. Peter Morgan, (Senior Gardener, College of Pharmacy, University of Rhode Island). A voucher specimen (JPMCS2) has been deposited in the Heber Youngken Medicinal Garden and Greenhouse (College of Pharmacy, University of Rhode Island). 2. Previous work Phenolics are the predominant metabolites reported from the A. rubrum species. Previous studies have reported B-type linkage procyanidins (Narayanan and Seshadri, 1969), galloyl derivatives, ellagic acid, flavonols and flavanols (Abou-Zaid and Nozzolillo, 1999; Abou-Zaid et al., 2001, 2009), 2,3-dihydro-3,5-dihydroxy-6-methoxy-4H-pyran-4-one (Boyer et al., 2002) and glucomannan (Mian and Timell, 1960) from A. rubrum wood and leaves. In addition, our laboratory has recently reported nine new gallotannins and two new phenolic glycosides from A. rubrum bark and stems (Wan et al., 2011; Yuan et al., 2011).
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** In vitro
**Product:** Maple syrup extract

Liu W, Wei Z, Ma H, et al.
**Anti-glycation and anti-oxidative effects of a phenolic-enriched maple syrup extract and its protective effects on normal human colon cells**
*Food Funct. 2017 Feb 22;8(2):757-766.*

Abstract
This study investigated the antiglycation and anti-oxidation effects of maple syrup derived extract (MSX) on stressed human colonic cells in vitro. MSX (500μg mL−1) reduced the formation of advanced glycation endproducts (AGEs) by 40% in the bovine serum albumin (BSA)–fructose assay and by 30% in the BSA–methylglyoxal (MGO) assay. This study provided further proof-of-concept for the role of MSX as a possible dietary agent against diseases mediated by oxidative stress and inflammation.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** In vitro
**Product:** Red maple stems extracts, (Gallotannins: Ginnalins A–C)

Gonzalez-Sarrias A, Ma H, Edmonds ME, et al.
**Maple polyphenols, ginnalins A–C, induce S- and G2/M-cell cycle arrest in colon and breast cancer cells mediated by decreasing cyclins A and D1 levels**
*Food Chemistry, 2013, 136: 636–642*

Abstract
Polyphenols are bioactive compounds found in plant foods. Ginnalins A-C are polyphenols present in the sap and other parts of the sugar and red maple species which are used to produce maple syrup. Here we evaluated the antiproliferative effects of ginnalins A-C on colon (HCT-116) and breast (MCF-7) tumourigenic and non-tumourigenic colon (CCD-18Co) cells and investigated whether these effects were mediated through cell cycle arrest and/or apoptosis. Ginnalins A-C were twofold more effective against the tumourigenic than non-tumourigenic cells. Among the polyphenols, ginnalin A (84%, HCT-116; 49%, MCF-7) was more effective than ginnalins B and C (50%, HCT-116; 30%, MCF-7) at 50 μM concentrations. Ginnalin A did not induce apoptosis of the cancer cells but arrested cell cycle (in the S- and G(2)/M-phases) and decreased cyclins A and D1 protein levels. These results suggest that maple polyphenols may have potential cancer chemopreventive effects mediated through cell cycle arrest.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** In vitro
**Product:** Red maple bark extract, sugar maple bark extract

Bhatta S, Ratti C, Poubelle PE, et al.
**Nutrients, Antioxidant Capacity and Safety of Hot Water extract from Sugar Maple (Acer saccharum M.) and Red Maple (Acer rubrum L.) Bark**
*Plant Foods for Human Nutrition (2018) 73:25–33*

Abstract
Sugar maple (Acer saccharum M.) and red maple (Acer rubrum L.) barks were treated with hot water to extract nutrients in order to explore, for the first time, its potential as safe dietary antioxidants. The organic and inorganic nutrients of these extracts, as well as their safety on human PLB-985 cells differentiated into neutrophils-like cells, were determined. Proximate analysis showed that both bark extracts were low in moisture and fat. Sugar maple bark extract (SM-BX) showed crude protein and ash content higher than those found in red maple bark extract (RM-BX). In addition, SM-BX had total sugars higher than those evaluated in RM-BX, while complex sugars (oligo- and/or poly-saccharides) were similarly abundant in both bark extracts. Furthermore, SM-BX demonstrated a wide array of vital minerals (K, Ca, Mg, P, Na, Fe and Cu) in quantity larger than that evaluated in RM-BX, whereas RM-BX have Zn and Mn levels higher than those found in SM-BX. Phytochemical analyses showed that RM-BX exhibited total phenolic and flavonoid contents higher than those measured in SM-BX. Consequently, RM-BX presented an antioxidant activity higher than that of SM-BX: 2.85-fold ABTS radical cation scavenging capacity and 1.9-fold oxygen radical absorbance capacity. Finally, RM-BX and SM-BX were greatly safe since, at concentration up to 100 μg/ml, they did not modify the viability of neutrophils as determined by flow-cytometry assay using Annexin V-FITC/Propidum Iodide as markers. In conclusion, our in vitro studies indicate that both red and sugar maple bark extracts have a real potential as food additives.
Funding: Natural Sciences and Engineering Research Council of Canada (NSERC)

# PRODUCTION/QUALITY CONTROL

## Quality Control Test

**Model:** Characterization
**Product:** Maple syrup, maple sugar, maple sap

Liu Y, Ma H, Seeram NP.
**Development and UFLC-MS/MS Characterization of a Product-Specific Standard for Phenolic Quantification of Maple-Derived Foods**
*J. Agric. Food Chem. 2016, 64, 3311–3317*

Abstract
The phenolic contents of plant foods are commonly quantified by the Folin–Ciocalteu assay based on gallic acid equivalents (GAEs). However, this may lead to inaccuracies because gallic acid is not always representative of the structural heterogeneity of plant phenolics. Therefore, product-specific standards have been developed for the phenolic quantification of several foods. Currently, maple-derived foods (syrup, sugar, sap/water, and extracts) are quantified for phenolic contents based on GAEs. Because lignans are the predominant phenolics present in maple, herein, a maple phenolic lignan-enriched standard (MaPLES) was purified (by chromatography) and characterized (by UFLC-MS/MS with lignans previously isolated from maple syrup). Using MaPLES and secoisolariciresinol (a commercially available lignan), the phenolic contents of the maple-derived foods increased 3-fold compared to GAEs. Therefore, lignan-based standards are more appropriate for phenolic quantification of maple-derived foods versus GAEs. Also, MaPLES can be utilized for the authentication and detection of fake label claims on maple products.
Funding: Agriculture and Agri-Food Canada (AAFC)

**Model:** Characterization
**Product:** Maple syrup

Mellado-Mojica E, López MG, Seeram NP.
**Comparative analysis of maple syrups and natural sweeteners: Carbohydrates composition and classification (differentiation) by HPAEC-PAD and FTIR spectroscopy-chemometrics**
*J Food Comp. & Analysis, 2016, 52: 1-8*

Abstract
Maple syrup is a natural sweetener obtained from the sap of maple trees (Acer saccharum), highly rich in bioactive molecules placing it among the most desirable and natural sweeteners for human consumption (agave, sugarcane, corn and honey). Carbohydrate profiles (amounts and composition) as well as FTIR-PCA classification of maple syrup were performed and compared to other natural sweeteners. TLC and HPAEC-PAD revealed that maple syrup exhibits unique carbohydrate profiles dominated by high sucrose content (511–688 mg/g) followed by glucose and fructose traces. Alternately and highly relevant, it was possible to identify three oligosaccharides, not previously reported in maple syrup, with potential to be used as authenticity markers. The FTIR spectra displayed the most characteristic differences in the carbohydrate region (1185–950 cm−1), particularly, maple syrup exhibited strong absorption bands at 997 and 1054 cm−1 wavelengths in agreement with their high sucrose content. Principal component analysis of the FTIR carbohydrates region allowed maple syrup to be distinguished from other natural sweeteners based on botanical source. The above information would be helpful for the authentication, characterization, and subsequent detection of intentional adulteration of this natural sweetener.

**Model:** Characterization
**Product:** Maple sap

Nguyen GQ, Martin N, Jain M, et al.
**A systems biology approach to explore the impact of maple tree dormancy release on sap variation and maple syrup quality**
*Scientific Reports, 2018, 8:14658 : 1-13*

Abstract
Maple sap is a complex nutrient matrix collected during spring to produce maple syrup. The characteristics of sap change over the production period and its composition directly impacts syrup quality. This variability could in part be attributed to changes in tree metabolism following dormancy release, but little is known about these changes in deciduous trees. Therefore, understanding the variation in sap composition associated with dormancy release could help pinpoint the causes of some defects in maple syrup. In particular, a defect known as "buddy", is an increasing concern for the industry. This off-flavor appears around the time of bud break, hence its name. To investigate sap variation related to bud break and the buddy defect, we monitored sap variation with respect to a dormancy release index (Sbb) and syrup quality. First, we looked at variation in amino acid content during this period. We observed a shift in amino acid relative proportions associated with dormancy release and found that most of them increase rapidly near the point of bud break, correlating with changes in syrup quality. Second, we identified biological processes that respond to variation in maple sap by performing a competition assay using the barcoded Saccharomyces cerevisiae prototroph deletion collection. This untargeted approach revealed that the organic sulfur content may be responsible for the development of the buddy off-flavor, and that dormancy release is necessary for the appearance of the defect, but other factors such as microbial activity may also be contributing.

**Model:** Characterization
**Product:** Maple syrup

Mellado-Mojica E, Seeram NP, López MG.
**Maple syrup vs different natural sweeteners: sensory evaluation, physicochemical properties, carbohydrate profiles, and botanical classification by mid infrared spectroscopy-chemometrics**
*Cinvestav-Unidad Irapuato, University of Rhode Island*

This study investigated the sensory and physicochemical properties, carbohydrate profile, and MIR-PCA classification of several maple syrups and compared findings to different natural sweeteners (agave, corn sugar, cane syrups, and honey bee). Results revealed that maple syrups have a unique carbohydrate profile when compared to other natural sweeteners, showing high sucrose content (511-687 mg/g of fresh weight), and smaller amounts of fructose (0.55-10.03 mg/g), and glucose (0.93-11.0 mg/g). Agave demonstrated the greatest sweetness of the compounds tested; corn syrup the least sweetness. Maple syrup had a sweetness profile similar to sucrose.
*This study is currently unpublished.*

# CONFERENCE PAPERS/ POSTER SESSIONS

Dupuy O, Leduc-Savard N, Lavoie L, et al.
**Impact of maple syrup and sap ingestion on cognitive flexibility during high-intensity intermittent exercise**
*MOVE Laboratory; University of Poitiers, France*
**Model:** Clinical
**Product:** Maple syrup, maple sap/water
**Subcategory/Effect:** Performance and Endurance Benefits
*European College of Sport Science, (4th – 7th July 2018) / Dublin*
Funding: Agriculture and Agri-Food Canada (AAFC)

Lavoie L, Leduc-Savard N, Tremblay J.
**Ingestion of maple based sports drinks on ratings of perceived exertion, palatability and time-trial performance**
*University of Montreal, Quebec*
**Model:** Clinical
**Product:** Maple sap/water
**Subcategory/Effect:** Source of Energy
*European College of Sport Science, (4th – 7th July 2018) / Dublin*
Funding: Agriculture and Agri-Food Canada (AAFC)

Lavoie L, Leduc-Savard N, Tremblay J.
**Ingestion of maple sap during high-intensity intermittent exercise: comparison with Gatorade© and stevia on glycemia and exercise RPE**
*University of Montreal, Quebec*
**Model:** Clinical
**Product:** Maple sap/water
**Subcategory/Effect:** Source of Energy
*European College of Sport Science, (4th – 7th July 2018) / Dublin*
Funding: Agriculture and Agri-Food Canada (AAFC)

Tremblay J, Lavoie L, Leduc-Savard N.
**Fuel selection during prolonged exercise with maple syrup or sap ingestion: comparison with glucose and Gatorade**
*University of Montreal, Quebec*
**Model:** Clinical
**Product:** Maple syrup, maple sap/water
**Subcategory/Effect:** Performance and Endurance Benefits
*European College of Sport Science, (4th – 7th July 2018) / Dublin*
Funding: Agriculture and Agri-Food Canada (AAFC)

Park HY, Johnson SL, Ma H, et al.
**Potential neuroprotective effects of phenolicenriched maple syrup (MSX) extract**
*University of Rhode Island*
**Model:** In vivo
**Product:** Maple syrup extract
**Subcategory/Effect:** Anti-inflammatory Properties
*To be Presented at 2nd Global Symposium on Chemical and Biological Effects of maple syrup Products ACS Annual Meeting, 2019*
Funding: USDA grant

Valle M, St-Pierre P, Pilon G, et al.
**Maple syrup and other natural sweeteners alleviate insulin resistance and hepatic steatosis as compared to sucrose in diet-induced obese rats: potential mechanisms of action**
*University of Laval, Quebec*
**Model:** In vivo
**Product:** Maple syrup
**Subcategory/Effect:** Glucose Management
*To be Presented at 2nd Global Symposium on Chemical and Biological Effects of maple syrup Products ACS Annual Meeting, 2019*
Funding: Agriculture and Agri-Food Canada (AAFC)

Xu J, Ma H, Liu T, et al.
**Phenolic-enriched red maple leaf extract (Maplifa) prevents HFD-induced obesity, insulin resistance and inflammation via modulation of gut microbiota in mice**
University of Rhode Island
**Model:** In vivo
**Product:** Red maple leaves extract (MaplifaTM)
**Subcategory/Effect:** Anti-inflammatory Properties
*To be Presented at 2nd Global Symposium on Chemical and Biological Effects of maple syrup Products ACS Annual Meeting, 2019*
Funding: USDA grant