FARM FIELD RUNOFF: NITRATE AND PHOSPHATE OCCURRENCE IN MAPLE SYRUP

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ABSTRACT

The purpose of this project is to find out how maple tree (Acer) nitrate and phosphate intake from soil runoff would affect maple syrup, which is crucial for both environmental and health considerations as excessive runoff can lead to water quality problems and health issues when consumed. Homemade maple syrup inspired this research. The hypothesis is nitrate and phosphate levels will be greater in maple tree syrup closer to potential farm field runoff.

Forty mL of distilled water for every 5 mL of syrup were mixed for testing. Each mixture was tested for Nitrates and Phosphates using the CHEMets testing tools. The levels of nitrates and phosphates were measured with the CHEMets reaction tube example.

The data did not support the hypothesis. Nitrates were not found in 2023 maple syrup samples regardless of proximity to farm field run off, phosphates all tested less than 1 PPM except homemade which tested at 4 PPM. The main cause and change were believed to be synthetic cone-shaped filters or filter presses used by professional maple syrup producers resulting in little to no sugar sand, while homemade maple syrup is not filtered, resulting in sugar sand residues. To further test this supposition, 2024 sap samples (preboiling or filtering) indicated zero phosphates, but 6 PPM for both sites tested. This additional test validates filtering as the removal mechanism of phosphates.

As mentioned above, excessive consumption of nitrates and phosphates can contribute to health issues. This study indicates the importance of maple syrup filtering, whether produced commercially or by hobbyists.

PURPOSE

The purpose of this project was to find out if maple tree nitrate and phosphate intake from farm field run off intake affects maple syrup. Nitrates and phosphates are essential plant nutrients, but excess amounts can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. Eutrophication is an excessive richness of nutrients in a lake or other body of water, frequently due to runoff from the land, which causes a dense growth of plant life and death of animal life from lack of oxygen.

People all over the world have suffered from poor water quality for many years, even for decades. Consuming nitrates in too high of a concentration can affect blood carrying oxygen and cause methemoglobinemia. Methemoglobinemia is a condition with life-threatening potential in which diminution of the oxygen-carrying capacity of circulating hemoglobin occurs due to the conversion of some or all of the four iron species from the reduced ferrous (Fe^{2+}) state to the oxidized ferric (Fe^{3+}) state. For people with unsafe drinking water, the side effects of consuming too many nitrates include increased heart rates, nausea, and abdominal cramps. If someone with poor health has elevated consumption of nitrates and phosphates, poor health can increase if they do not have the right medical treatments. Drinking water with nitrate levels over 10 ppm is unsafe. Because maple syrup nutrition supplies inflammation-reducing polyphenol antioxidants, it can be considered part of a healthy diet that helps prevent certain diseases like arthritis, inflammatory bowel disease, or heart disease.

According to scientific studies of northern hardwood forests, sugar maples have a unique characteristic where they do not readily take up nitrates. This is supported by the fact that maple trees could grow often in lower nitrate soils. However, this may also increase the risk of nitrate leaching in maple stands. Nitrates are carried by soil water flow and can lead to leaching loss if there is enough movement of water out of the root zone. Nitrate leaching always occurs during the drainage season when precipitation and irrigation are higher than evaporation. The drainage season is ideally the springtime and summertime.

While Sugar Maple (Acer saccharum) trees grow well as a yard tree, they do not do as well in restricted urban sites. It requires a large area with noncompacted, fertile, moderately moist, well-drained, slightly acidic soils with a pH of 5.5 to 6.8 and adequate levels of organic matter, such as by a creek. The trees used in our homemade maple syrup are primarily Silver Maple (Acer saccharum) and one Red Maple (Acer rubrum), which might have an overall factor in the sugar content (Sugar Maples having the highest sugar concentration in sap). Any of the maples can be tapped, including the Box Elder (Acer negundo). In more northern areas, Birch trees (Betula sp.) are tapped for sap to make into syrup.

Each maple tree species has slightly different nutritional requirements. Nitrogen is the most needed nutrient specifically for maple trees. Phosphorus, potassium, calcium, and magnesium are also needed for maple trees to survive. Whether the nutrients translate to maple syrup or if they are removed in the filtering process is debatable and a goal of this research, with reference to nitrogen and phosphorus.

Several scientific studies suggest that higher intakes of phosphorus are associated with an increased risk of cardiovascular disease. As the amount of phosphorus consumed rises, so does the need for calcium. The delicate balance between calcium and phosphorus is necessary for

proper bone density and prevention of osteoporosis. Phosphorus then builds up in the blood and can affect bone health and worsen kidney disease, and it might increase the risk of death. Consuming less phosphorus and eating more foods containing calcium might help prevent the side effects of high phosphorus levels in people with severe chronic kidney disease.

Extra phosphorus causes body changes that pull calcium out of your bones, making them weak. High phosphorus levels also lead to dangerous calcium deposits in blood vessels, lungs, eyes, and heart. Over time this can lead to increased risk of heart attack, stroke or death. Clinical description. Ingestion of elemental white or yellow phosphorus typically causes severe vomiting and diarrhea, which are both described as “smoking,” “luminescent,” and having a garlic-like odor. Other signs and symptoms of severe poisoning might include dysrhythmias, coma, hypotension, and death.

RESEARCH QUESTIONS

Do maple tree syrup have elevated levels of nitrates and phosphates?

Do amounts of nitrates and phosphates in maple syrup have any correlation to proximity or topography of the sugar bush to farm fields runoff?

Sap is collected when it freezes at night and thaws during the day. Sap needs to expand and contract in order to flow through a maple tree making the sap available to collect by tapping the tree. If this is so, the rain would turn to snow and runoff would freeze. Finding nitrate and phosphate content in maple syrup is important because these two substances affect the health of the trees and the health of the consumers of maple syrup based off my literature review. My literature review refers to nutrient intake by the tree and the consumer affect shown in *Nutrition and Health Benefits of Pure Maple Syrup*.

HYPOTHESIS

The research hypothesis is nitrates and phosphates from the runoff will have an impact on the maple syrup with the sugar bush being closer to farm field runoff. A sugar bush is a stand or even a plantation of maple trees.

CONTROL

Distilled Water

VARIABLE

Tree Sap Locations:

My Backyard syrup (Unfiltered) and sap (Unfiltered)

Aggie Sojkaspear's (Seldom Seen Farms) syrup (Filtered)

Roger Gortner's syrup (Filtered, light and dark)

Jeff Borah's (Frary Woods) syrup (Filtered) and sap (Unfiltered)

MATERIALS

- CHEMets Nitrate test
    - Syringe
    - Reaction Tube
    - Cadmium Foil Packet
    - Sample Cup
    - CHEMets Ampoule
    - Pipette
    - Measuring Cup
- CHEMets Phosphate test
    - Sample Cup
    - Activator Solution
    - CHEMets Ampoule
    - Low Range Comparator
    - Pipette
    - Measuring Cup
- Camera
- Homemade maple syrup and sap
- Aggie Sojkaspear's maple syrup
- Roger Gortner's maple syrup (light and dark)
- Jeff Borah's (Frary Woods) maple syrup and sap
- Distilled water

METHODS

The following methods reflect GLOBE Program protocols for nitrates and phosphates. Currently I could not find any similar research using maple tree sap as a method to measure maple tree reaction to intake of farm field runoff.

Nitrate CHEMets Kit

Test Procedure

1. Using the syringe provided, obtain the following volume of the sample to be tested and dispense it into the empty reaction tube (green screw cap tube). K-6909D: 1.5 mL K6909A: 0.3 mL (used K-6909D: 1.5mL)
2. Dilute the contents of the reaction tube to the 15mL mark with distilled water
3. Empty the contents of one Cadmium Foil Pack into the reaction tube. Cap the reaction and shake it vigorously for exactly 3 minutes. Allow the sample to sit undisturbed for 2 minutes.
4. Pour 10mL of the treated sample into the 25mL sample cup. Do not transfer cadmium particles to the sample cup.
5. Place the CHEMet ampoule, tip first, into the sample cup. Snap the tip. The ampoule will fill leaving a bubble for mixing.
6. To mix the ampoule, invert several times, allowing the bubble to travel from end to end.
7. Dry the ampoule and wait 10 minutes for color development.
8. Obtain a test result by placing the ampoule between the color standards until the best color match is found.

Phosphate CHEMets Kit

Test Procedure

1. Fill the sample cup to the 25 mL mark with the sample to be tested.
2. Add 2 drops of A-8500 Activator Solution. Cap the sample cup and shake to mix the contents well.
3. Place the CHEMet ampoule, tip first, into the sample cup. Snap the tip. The ampoule will fill leaving a bubble for mixing.
4. To mix the ampoule, invert several times, allowing the bubble to travel from end to end.
5. Dry the ampoule and wait 2 minutes for color development.
6. Obtain a test result using the appropriate comparator.

Low Range Comparator: Place the ampoule, flat end first, into the comparator. Hold the comparator up toward a light source and view from the bottom. Rotate the comparator until the best color match is found.

High-Range Comparator: Place the ampoule between the color standards until the best color match is found.

Process to make maple syrup

1. Drill ($5/16^{th}$ inch drill bit) the tree trunk around three feet up, insert sprue, attach hose, and allow the sap to flow out into a bucket
2. The collected sap liquid is boiled until it reaches 104°C and has a brix of 54
3. As water evaporates, a thicker consistency develops
4. Filter through a cloth to prevent contamination before bottling

Nutritional Value for Maple Syrup

% of Recommended Daily Value (DV) Per ¼ cup (60 ml)

	Maple Syrup (80 g)	
	% DV	Mg
Riboflavin	37	0.59
Thiamin	1	0.01
Manganese	95	1.89
Zinc	6	0.58
Magnesium	7	16.5
Calcium	5	58.0
Iron	1	0.09
Selenium	1	0.4 µg
Potassium	5	167
Calories	216	

USDA Nutrient Database and Canadian Nutrient File

RESULTS

Distilled Water:

Nitrate: 0

Phosphate: 0

Notes:

Nitrate: Nothing happened.

Phosphate: Nothing happened.

Ours:

Nitrate: 0

Phosphate: 4

Metadata:
Nitrate: Nothing happened.

Phosphate: The color changed quickly.

Aggie's (Seldom Seen Farms) Maple Syrup:

Nitrate: 0

Phosphate: 0

Metadata:
Nitrate: Nothing happened.

Phosphate: Nothing happened.

Light Maple Syrup:

Nitrate: 0

Phosphate: 0.6

Metadata:
Nitrate: Nothing happened.

Phosphate: Changed slightly in coloration. Had a greenish tint but was associated with the fact that the sap was slightly yellow.

Dark Maple Syrup:

Nitrate: 0

Phosphate: 1

Metadata:
Nitrate: Nothing happened.

Phosphate: Changed slowly. Had to wait until after the 2 minutes was up until the color was fully developed.

Jeff Borah's Frary Woods Syrup

Nitrate: 0

Phosphate: 0

Metadata:
Nitrate: Nothing happened

Phosphate: Nothing happened

Post Experiment

Jeff Borah's Frary Woods Unfiltered Sap

Nitrate: 0

Phosphate: 6

Metadata:
Nitrate: nothing happened

Phosphate: abrupt change in color

Homemade Unfiltered Sap

Nitrate: 0

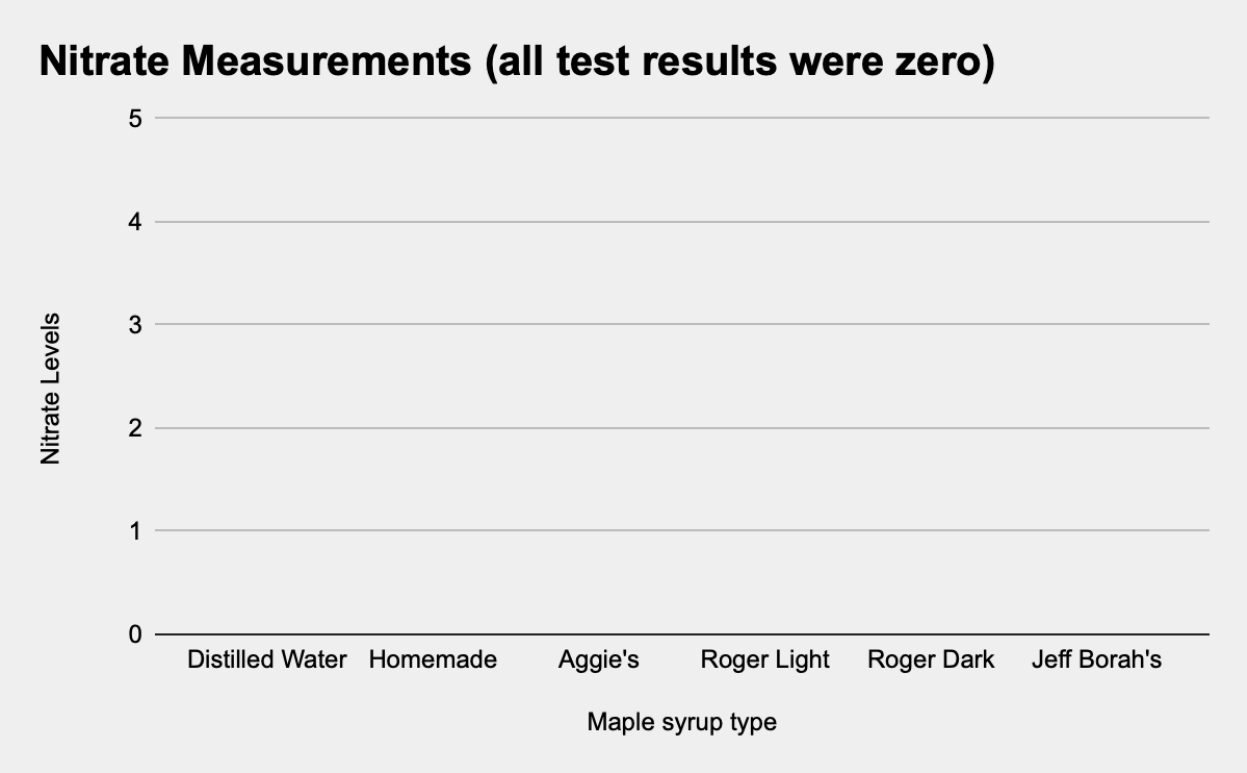
Phosphate: 6

Metadata:
Nitrate: nothing happened

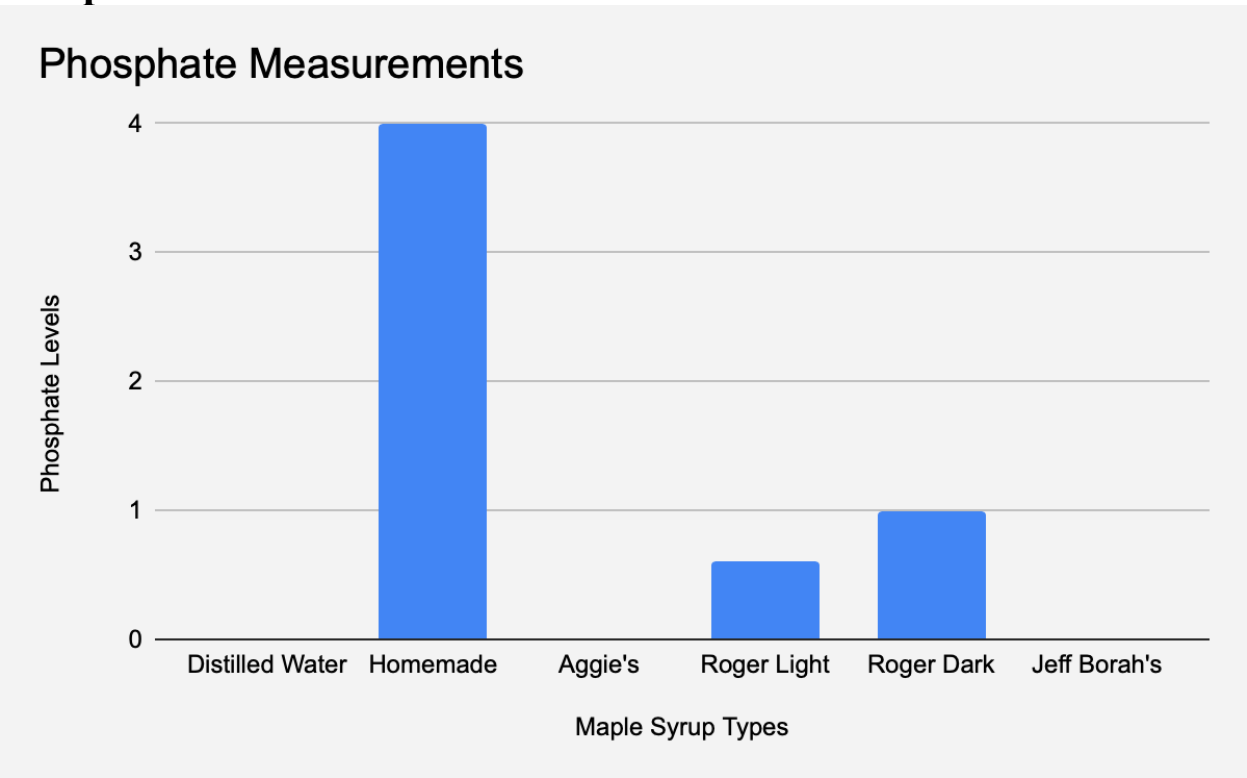
Phosphate: abrupt change in color

GRAPHS

Graph 1



Graph 2


Phosphate Measurements
Phosphate Levels
4
3
2
1
0
Distilled Water
Homemade
Aggie's
Roger Light
Roger Dark
Jeff Borah's
Maple Syrup Types

STUDY SITES

Roger Gortner

There are four different farm fields all sloping away from the sugar bush. There is also a creek running through the farm fields and through the sugar bush, which can help contribute to the farm field run off.

Aggie's (Seldom Seen Farm)

The sugar bush does not have any farm fields nearby, but there are several small gardens that could contribute to run off.

Frantz Property

In the backyard, there is a silver maple. There is also a school bus garage. Exhaust and smoke fumes are very close to the tree. The front yard has a red maple and is right by a road. Farm fields slope away from the maple trees.

Jeff Borah (Frary Woods)

There are a lot of farm fields surrounding Frary Woods. However, Frary Woods is on high ground and farm field runoff flows away from Frary Woods.

RESULT ANALYSIS

The distilled water sample served as the control shows no presence of nitrate or phosphate. Homemade maple syrup (Ours) showed the presence of phosphate at a relatively high concentration of four PPM, indicating a potential source of phosphate contamination or naturally occurring levels in the syrup. The other samples of maple syrup (Homemade, Light, Dark) showed varying phosphate levels, with some samples exhibiting negligible amounts while others had detectable concentrations. The variation in phosphate levels among the maple syrup samples may be attributed to differences in production methods, tree varieties, or environmental factors affecting sap composition, including the distance of the sugar bush from farm fields. Further analysis could explore the specific factors influencing phosphate levels in maple syrup and investigate potential implications for syrup quality and consumer health. Additionally, considering the absence of nitrate in all samples, future research could focus on other potential contaminants or nutritional components present in maple syrup.

CONCLUSION

The data does not support the hypothesis. All maple syrup samples record zero amounts of nitrates, except for our own, regardless of farm field runoff or not. One difference observed during this research was the filtering between homemade syrup and professionally made maple syrup had statistically different nitrate content. The professionals filter the syrup so thoroughly there is no sugar sand left in the maple syrup. Sugar sand is a mixture of calcium malate and sugar which crystalizes during the boiling of sap. We do not filter the sap during our boiling process, leaving sugar sand sediment at the bottom of our boiling pot. Professionally, sap is filtered multiple times, either through gravity filtering or vacuum filtering, to achieve the crystal-clear maple syrup seen on store shelves. This might have been a substantial factor to think about. Several questions came to mind. If we filtered our maple syrup, would our nitrate test results also be zero like everyone else? If not, could there be some other environmental thing making our maple syrup different than commercially made maple syrup?

Another thing to consider is the change in phosphate from 0.4 to 1 PPM from the light to dark maple syrup. They are both made by Roger Gortner, but light maple syrup is made at the beginning of the season and dark maple syrup is made at the end of the year. Does the time of the year also have something to do with phosphate measurements? Based on my conversation with Roger Gortner, his sugar bush is uphill from the farms and the direction of runoff, so runoff would not have played a huge part in his syrup. With only one dark maple syrup sample, there really isn't enough data to make a concrete conclusion.

All the maple syrup tested came from 2023 sap. Because of an unusually warm week in January, 2024, there was a weather window which sap could be taken from maple trees. I took

advantage of the weather pattern and tapped the silver maple tree in my backyard. Mr. Jeff Borah also tapped maple trees in his sugar bush.

Finally, a breakthrough in this research! Both samples still had no nitrates, but both had phosphate levels of six PPM. Both samples were raw sap, no boiling, no filtering, no bottling. Even though these were very small sample size, the results strongly point to filtering as the means with which phosphates were removed from maple syrup. Even though the data does not support the hypothesis, the data certainly sheds light on this aspect of maple syrup production.

NEXT STEPS

First, I would like to obtain more sap samples to test for nitrates and phosphates, in order to make a more solid confirmation of my present data. I have already contacted Mr. Gortner and Ms. Sojkaspear to obtain sap samples this year. I am also planning to visit maple syrup producers in northeast Ohio during Ohio Maple Madness Tour to obtain samples of 2024 sap and syrup.

Second, I am going to share my results with DR. Smith and Dr. Katie at the Ohio State University's maple syrup program at their Mansfield. They have been very supportive of this research and are curious about my results.

Third, I would like to present my research at the Ohio Maple Days Maple Syrup Conference at Ashland University. Perhaps there will be more gaps in maple syrup knowledge I might be able to fill.

Fourth, after all this work, I think it is time now to have a seat and enjoy a tall stack of pancakes smothered in pure, fresh, homemade maple syrup!

ACKNOWLEDGEMENTS

First, I would like to dedicate this research to Papaw, Mr. Lowell Frantz, my grandfather, who passed away during my research. He was unconditionally supportive of me not only of this project, but me as his granddaughter.

I would like to thank my father for taking me to the Maple Day Maple Syrup Conference at Ashland University. I would like to thank both my parents and brother, Stevie, for supporting me throughout my whole project. I would like to thank Aaron Wilson who suggested some people to contact. I would like to thank Aggie Sojkaspear, who won first place three years in a row for many different types of maple syrup. She was one of my donors of maple syrup. I would also like to thank Roger Gortner for donating two different batches of maple syrup, one light and one dark. I would like to thank Tony Kirkland. When my family went on vacation to Florida, we went on an airboat tour ride through the Everglades. Tony explained how the Cypress Trees (Callitris endlicheri) need tons of salt water to absorb the phosphates and nitrates to survive. I would like to thank Jeff Borah, a close family friend, for taking me on a tour of his property to see how he runs his sugar bush.

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