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Preliminary research on the effects of freezing on sugar concentrations of artificial sap

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Preliminary Research on the Effects of Freezing on Sugar Concentrations of Artificial Sap

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1. Introduction

Native Americans were one of the first people to harvest maple sap to make maple syrup or sugar. Three historically referenced methods that they used to accomplish this was by freezing, stone boiling, and direct fire. (Holman Egan, 1985) Native Americans would make an incision in the bark of a maple tree and then collect the sap in a birch container; the sap would then be boiled by either of the first two methods or frozen. When frozen, the ice that formed on top of the sap would be thrown out and the concentrated sap would be collected for boiling into the final product. (Holman Egan, 1985) In our own local maple syrup production at Saint John's when a layer of ice forms on sap it may occasionally be discarded, we wanted to determine what, if any, maple syrup loss results from this. In our experiment we tested the freezing method implemented by Native Americans.

2. Purpose

1. To determine the percent concentration of sugar in the discarded ice and the remaining unfrozen sap
2. To develop several equations relating the percent of original sap frozen to syrup produced and the sugar concentration compared to the sap remaining

4. Methods

Two freezing trials were performed to test sugar concentration of frozen artificial sap (sugar and water) and remaining unfrozen sap. Both samples started at a 2% sucrose solution were frozen until 70%-80% of the original sap had been frozen. After each freeze the unfrozen sap's volume and sugar concentration were measured and recorded using a Misco Digital Sugar Refractometer. The frozen sap was allowed to melt and the volume and sugar concentration were measured. Starting and ending freezing time was recorded as well. Initial and end volume of sap and volume of ice were also recorded to calculate the percentage of total sap frozen, percentage of original volume lost as ice, and cumulative amount of syrup lost.

The first trial involved 14 liters of artificial sap where as the second trial involved 50 gallons (189.3 Liters). The 14-liter sample was frozen using a chest freezer with a standardized temperature. The 14-liter sample was kept in the freezer for 5 hours and then ice was removed for testing. The next 5 samples varied from 4 hours to 12 hours. Ice was removed a total of 6 times. The 50-gallon sample was kept to freeze outside. The trial took place over 7 days and ice was removed 6 times. Ice was removed more frequently due to cold weather conditions reaching below 0 degrees Fahrenheit.

3. Equations

The rule of 86 was used to calculate the syrup produced and ultimately lost.

Rule of 86

86/% sugar concentration=gallons of sap required to produce one gallon of syrup

Table 1. Equations from all three trials and their corresponding correlation coefficient and average when possible.

-	Trial 1	Trial 2	Trial 3	Average
[Sugar] Unfrozen vs Total Time	y=0.0366x+2.088	y=.0749x+1.8	y=.0799x+1.7851	y=0.0638x+1.891
R^2	0.988	0.916	0.943	
Syrup Lost vs % Original Sap Frozen	y=0.6269x-0.224	y=1.1373x+1.097	y=0.6829x-5.667	y=0.8156x-1.449
R^2	0.98	0.852	0.933	
[Sugar] Unfrozen vs % Original Sap Frozen	$y=1.93e^{0.0097x}$	$y=1.979e^{0.0097x}$	$y=1.964e^{0.0099x}$	N/A
R^2	0.93	0.924	0.984	
Syrup Produced by Remainder vs % Sap Frozen	y=-0.0725x+11.587	y=-0.1163x+11.93	y=-0.0752x+11.634	y=-0.088x +11.717
R^2	0.98	0.864	0.934	

Winter 2014-2015 Trial

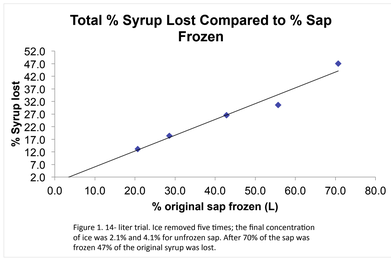

Figure 1. 14- liter trial. Ice removed five times; the final concentration of ice was 2.1% and 4.1% for unfrozen sap. After 70% of the sap was frozen 47% of the original syrup was lost.

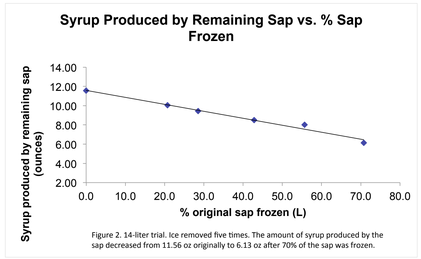

Figure 2. 14-liter trial. Ice removed five times. The amount of syrup produced by the sap decreased from 11.56 oz originally to 6.13 oz after 70% of the sap was frozen.

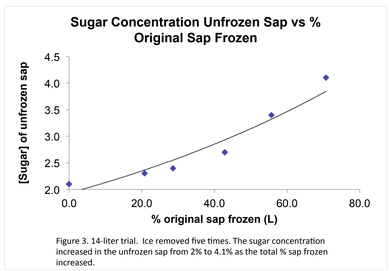

Figure 3. 14-liter trial. Ice removed five times. The sugar concentration increased in the unfrozen sap from 2% to 4.1% as the total % sap frozen increased.

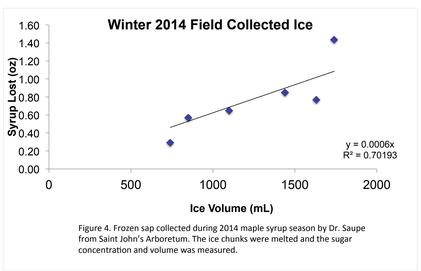

Figure 4. Frozen sap collected during 2014 maple syrup season by Dr. Saupe from Saint John's Arboretum. The ice chunks were melted and the sugar concentration and volume was measured.

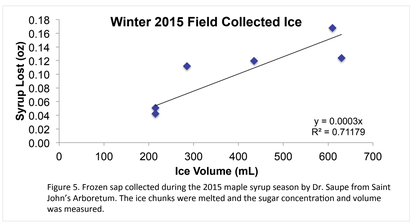

Figure 5. Frozen sap collected during the 2015 maple syrup season by Dr. Saupe from Saint John's Arboretum. The ice chunks were melted and the sugar concentration and volume was measured.

5. Conclusions

The sugar concentration of the sap and ice increased after each freeze. This indicates that syrup is being lost in ice every time the sap is frozen as the ice is discarded. The sugar concentration levels of even 1.5% are fairly significant as sap used to produce maple syrup is 2% sugar.

Our findings suggest that it may be more economical to save the frozen sap rather than discarding it. The frozen sugar sap could be recycled for the production of more syrup. This would prevent the waste of an extremely important resource, especially in smaller operations such as at Saint John's.

5. Results

The concentration of the sugar in the frozen sap reached 1.5%-2.0% in the 14-liter trial at which point up to 23% of the syrup may be lost on a small scale experiment such as this trial. The unfrozen sap had a sugar concentration of 4.3%-5.0%. The frozen sap in the 50-gallon trial reached 4.47% at which point up to 13.5% of syrup may be lost.

8. Future Work

Future testing should be performed testing the sugar concentration in the ice in response to varying starting levels of sugar concentration of the original sap.

Spring 2015 Trial

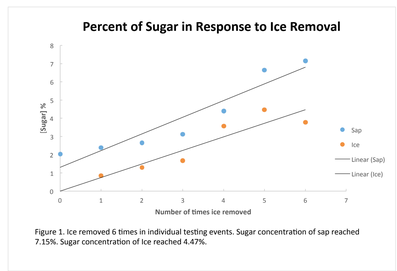

Figure 1. Ice removed 6 times in individual testing events. Sugar concentration of sap reached 7.15%. Sugar concentration of ice reached 4.47%.

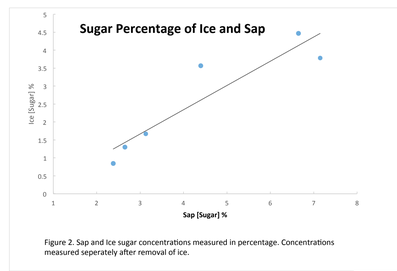

Figure 2. Sap and Ice sugar concentrations measured in percentage. Concentrations measured seperately after removal of ice.

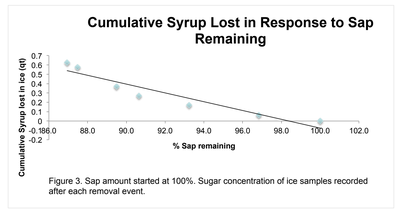

Figure 3. Sap amount started at 100%. Sugar concentration of ice samples recorded after each removal event.

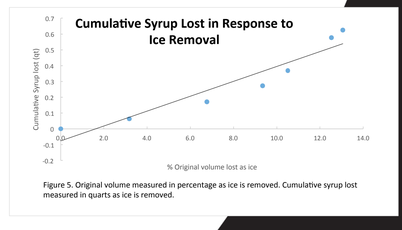

Figure 5. Original volume measured in percentage as ice is removed. Cumulative syrup lost measured in quarts as ice is removed.

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Sources

- Egan, Kathryn C., Holman, Margaret B. Summer 1985. Processing Maple Sap with Prehistoric Techniques. *Journal of Ethnobiology* 5(1): East Lansing, MI
- Henshaw, H.W. October 1890. Indian Origin of Maple Sugar. *American Anthropologist.* 3(4)