The dosage of invert sugar in maple syrup

Problems

When maple syrup is made with a maple sap of high microbiological quality, almost all of the sugars (which make up more than 98% of all the solids dissolved in it) is in the form of sucrose. The sucrose molecule is made up of a chain of 12 carbon atoms ($C_{12}H_{22}O_{11}$). Because of the microbial enzymes contained in the maple sap, the sucrose, a non reducing sugar, goes through an enzyme hydrolysis that splits the molecule into two reducing sugars, glucose and fructose. Those sugars contain six carbon atoms each and have, in their anhydrous form, an identical molecular mass of 180,16 g/mole (**Figure 1**). This phenomenon is called "inversion of the maple syrup". The mass of the glucose and the fructose expressed compared to the mass of the syrup becomes the "Percentage of invert sugar" or "invert %".

Sucrose	H_2O →	Glucose	+	Fructose
$C_{12}H_{22}O_{11}$	H_2O →	$C_6H_{12}O_6$	+	$C_6H_{12}O_6$

Figure 1
Illustration of the inversion process of a sucrose molecule

Since the physico-chemical attributes of invert sugars are different from those of sucrose, the inversion process causes some changes in the behaviour of maple syrup as the process runs its course. For example, a maple syrup that is more invert will be less likely to crystallize because invert sugar is more soluble than sucrose. So, for the production of maple taffy or maple caramel (products that should not have gone through the crystallization process even though they have a very heavy concentration of sugar), it is advantageous to use syrup that is highly invert. On the other hand, when it comes to products that you wish to see go through the complete crystallization process, it is better to choose a syrup with a rate of invert as low as possible.

In the past, the method called *Clinitest* (CPVQ, 1989) was used to determine the "invert %" in maple syrup. It is a test that gives a qualitative response based on the interpretation of the colour of a solution that is revealing in terms of how much invert sugar there is in the syrup. The kit needed to run this test (*Clinitest*) is still available in pharmacies, but it has to be ordered in. To obtain a more precise and especially a more quantitative measurement of the inversion rate, it is more advantageous to use a blood glucose monitor, also called "glycaemia monitor".

The blood glucose monitor is essentially made up of a monitor and of test strips. The enzymatic and electrochemical reactions that occur on the test strips when they come in contact with a diluted solution of maple syrup produce a very small electric current. This current is interpreted by the monitor who then displays the level of glucose (millimoles per litre or mmoles/litre).

This instrument is available in pharmacies. It was created to dose, among other things, the level of glucose in the blood of those with diabetes. The method described in this section was tested with an instrument of the Accu-Check brand (Boehringer Mannheim). If an instrument of another brand is used, it is recommended, beforehand, to compare the response given by your instrument to the one given by the Accu-Check monitor. To use the numbers in **table 1**, you have to convert the output on the new blood glucose monitor to an "Accu-Check output" as follows:

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% from Accu-Check = x
% from the new blood glucose monitor = y } x/y ratio

Equivalent output from Accu-Check = Output from the new blood glucose monitor multiplied by the x/y ratio

Example

Let's suppose that, for the same sample of syrup, the Accu-Check blood glucose monitor shows a result of 3 mmole/litre and that the new blood glucose monitor shows a result of 6 mmole/litre. The result of the Accu-Check monitor is divided by the result of the new monitor (3/6) to obtain the x/y ratio. In this case, all the results obtained with the new monitor must be multiplied by 0,5 to use **table 1** with data that would be equivalent to the data that you would obtain with the Accu-Check blood glucose monitor. It is important to note that the x/y ratio must be constant and that it would be prudent to validate the dosage with 3 to 5 samples from different syrups.

Normative References

Consensus.

Procedures

Equipment necessary to dose the level of invert sugar in maple syrup

- A blood glucose monitor (the method was verified with the Accu-Check blood glucose monitor from Boehringer Mannheim).
- Test strips.
- Calibration strip (Which generally comes with the test strips).
- A plastic syringe that can precisely measure a volume of 10 ml.
- A measuring cup or a calibrated cylinder with a capacity of 500 ml.
- A drop counter.

- Pure water (when in doubt, use distilled water or bottled water that is not heavily mineralized.

Models of blood glucose monitors other than Accu-Check.

- Since the method used to measure the "invert %" was developed with an Accu-Check blood glucose monitor, verify the accuracy of any model with another brand name. If an Accu-Check blood glucose monitor is still available, compare the outputs of the two monitors. If it is not available, draw up a new calibration curve that applies specifically to the blood glucose monitor that will be used.

- Obtain samples of syrup containing different quantities of invert sugar, going from 1 to 30 mmole/litre (for example: 0, 5, 15, 25 and 30 mmoles/litre). Those samples will serve as a baseline (indicator)

- Read all the baseline samples and take note of what appears on the monitor. Put down the results in **figure 2**.

- Draw the curve that shows the relation between concentration of the baselines (real concentration) and the output of the monitor.

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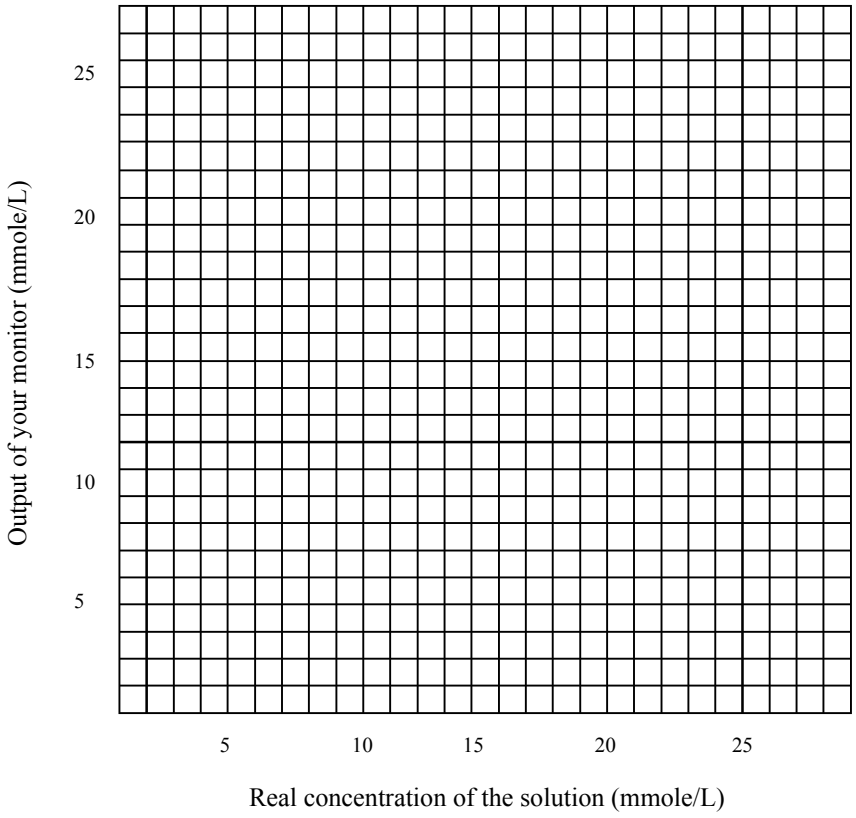

Table 2

Illustration of the relation between the output of your monitor and the real concentration of invert sugar

- Fill the column "Output of your blood glucose monitor" in **table 1** with the data illustrated in **figure 2**. For each concentrations of invert sugar in **table 1**, put down the equal value from the output of the monitor.

- Carry on with the steps involved in the procedure that was developed for the Accu-Check monitor.

Accu-Check blood glucose monitor

- With the syringe, take a 10 ml sample of a maple syrup that needs to be measured for the "invert %". Empty the content of the syringe in a calibrated container and rinse the syringe with pure water. Be sure to add the water used to rinse the syringe to the syrup.

- Use pure water to fill the rest of the container up to the desired volume (100 ml for a syrup you believe to be not very invert or not invert at all) (**table 1**).

- Make a perfect mix with the syrup solution that was just diluted

- Put the monitor (blood glucose monitor) on a smooth surface and turn it on by following the instructions of the manufacturer.

- Verify the calibration of the monitor by following the method described in the owner's manual of the model of blood glucose monitor chosen.

- Insert a test strip in the monitor. Handle it with care and be sure not to spoil the contacts.

- With a drop counter, place a drop of the solution on the reactive zone on the test strip.

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Table 1

Variation of the percentage of invert sugar in the syrup according to the output of the blood glucose monitor

Output of the Accu-Check Blood glucose monitor (L) (mmole/litre)	Output of your Blood glucose monitor (L) (mmole/litre)	Volume of syrup (V_{syrup}) = 10 ml Volume of water (ml)					
		40	**90**	**140**	**190**	**240**	**490**
		Volume of the solution (V_{sol}) (ml)					
		50	**100**	**150**	**200**	**250**	**500**
		Percentage of invert sugar in the syrup					
"Error"		<0,1%	<0,3%	<0,4%	<0,5%	<0,7%	<1,4%
"Low"							
1		0,1%	0,3%	0,4%	0,5%	0,7%	1,4%
2		0,3%	0,5%	0,8%	1,1%	1,4%	2,7%
3		0,4%	0,8%	1,2%	1,6%	2,0%	4,1%
4		0,5%	1,1%	1,6%	2,2%	2,7%	5,4%
5		0,7%	1,4%	2,0%	2,7%	3,4%	6,8%
6		0,8%	1,6%	2,4%	3,3%	4,1%	8,2%
7		1,0%	1,9%	2,9%	3,8%	4,8%	9,5%
8		1,1%	2,2%	3,3%	4,3%	5,4%	10,9%
9		1,2%	2,4%	3,7%	4,9%	6,1%	12,2%
10		1,4%	2,7%	4,1%	5,4%	6,8%	13,6%
11		1,5%	3,0%	4,5%	6,0%	7,5%	14,9%
12		1,6%	3,3%	4,9%	6,5%	8,2%	16,3%
13		1,8%	3,5%	5,3%	7,1%	8,8%	16,7%
14		1,9%	3,8%	5,7%	7,6%	9,5%	19,0%
15		2,0%	4,1%	6,1%	8,2%	10,2%	20,4%
16		2,2%	4,3%	6,5%	8,7%	10,9%	21,7%
17		2,3%	4,6%	6,9%	9,2%	11,5%	23,1%
18		2,4%	4,9%	7,3%	9,8%	12,2%	24,5%
19		2,6%	5,2%	7,7%	10,3%	12,9%	25,8%
20		2,7%	5,4%	8,2%	10,9%	13,6%	27,2%
21		2,9%	5,7%	8,6%	11,4%	14,3%	28,5%
22		3,0%	6,0%	9,0%	12,0%	14,9%	29,9%
23		3,1%	6,3%	9,4%	12,5%	15,6%	31,3%
24		3,3%	6,5%	9,8%	13,0%	16,3%	32,6%
25		3,4%	6,8%	10,2%	13,6%	17,0%	34,0%
26		3,5%	7,1%	10,6%	14,1%	17,7%	35,3%
27		3,7%	7,3%	11,0%	14,7%	18,3%	36,7%
28		3,8%	7,6%	11,4%	15,2%	19,0%	38.0%
29		3,9%	7,9%	11,8%	15,8%	19,7%	39.4%
30		4,1%	8,2%	12,2%	16,3%	20,4%	40.8%
"High"		>4,1%	>8,2%	>12,2%	>16,3%	>20,4%	>40.8%

- Note the output (in mmole/litre) and use **table 1** to determine the "invert %" of the syrup.

Explanation of the calculation:

$$\textit{Invert \%} = 2 \times \frac{\left(L \times \frac{\text{mole}}{1000\ \text{mmole}} \times \frac{\text{litre}}{1000\ \text{ml}} \times M \times V_{sol} \right)}{V_{syrup} \times PS_{syrup}} \times 100 \qquad \text{Equation 1}$$

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Where:

M = Molecular mass of the glucose and the fructose (180g/mole)

L = Output of the blood glucose monitor (mmoles of glucose/litre of solution)

V_{sol} = Volume of the solution (ml)

V_{syrup} = Volume of syrup used (10 ml is considered a constant value)

PS_{syrup} = Specific mass on the syrup at 66 ºBrix, meaning 1,3248 g/ml

By substituting the constant values, we obtain:
Invert % = 27,174 x 10-**4** x L x Vsol

It is important to note that the variant called “invert %” represents the percentage in mass of reducing sugars (invert sugars) or the total amount of glucose and fructose expressed compared to the total mass of the syrup.

Informative References

CPVQ. 1989. Érablière: produits dérivés du sirop d’érable. Conseil des productions végétales du Québec. Agdex 300/70. 40 p.

Cooking degrees over the boiling point of water for derivative products, based on the percentage (%) of invert sugar in maple syrup.

Name of product	Percentage of invert sugar	Cooking degrees	
		°C	°F
Maple taffy ➢ in a container	From 2 to 4% More than 4%	14,5 15	26 27
➢ On snow	More than 2%	13	24
Maple butter	Less than 1%	11,5	21 to 22
	From 1 to 4%	12	22 to 23
Soft maple sugar	Less than 1%	14,5	26
	From 1 to 4%	15	27
Maple sugar candies - First preparation	Less than 4%	15,5	28
- Second preparation		14,5	26
Hard maple sugar	Less than 1%	17 to 18	31 to 32
	From 1 to 4%	18 to 20	32 to 36
Granulated maple sugar	Less than 3%	22 to 24	40 to 44