Cornell Maple Bulletin 206 (2007)

Measuring and Adjusting Invert Sugar in Maple Sugar

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Adapted from C.O. Willits and C.H. Hill 1976. Maple Syrup Producers Manual. USDA Agriculture Handbook No. 134 and North American Maple Syrup Producers Manual, 2nd ed, 2006

General Background

Invert Sugar

For an explanation of what effects invert sugar can have on making confections see the bulletin titled "Chemistry of Maple Syrup".

Sucrose is common table sugar and is the only sugar in sap when it comes from the tree. Some of the sucrose in sap is converted to invert sugar as a result of microbial fermentation during handling and processing. Microbial metabolism is temperature dependent and occurs to a greater extent in sap that is collected late in the season when temperatures are warmer.

Sucrose is sugar with twelve carbon atoms. Invert sugars are six carbon sugars, glucose (dextrose) and fructose (levulose). They have the same number of carbon, oxygen and hydrogen atoms, but they differ slightly in how these atoms are assembled. The name "invert" refers to the way these sugars bend polarized light. They also are called "reducing sugars" referring to their chemical reactivity. The splitting of sucrose, commonly by the action of microorganisms, acids, or invertase, produces invert sugars. A certain amount of invert sugar is desirable in maple syrup that is to be made into a maple confection.

Need to Test

In general, all grades of maple syrup contain some invert sugar. The amount varies among different grades. Lighter syrup (Grade A Light Amber), particularly that made early in the production season, generally has the least invert sugar. Very dark syrup (Grade B or Extra Dark for Cooking), particularly that made late in the production season, has the most invert sugar. The color grade of syrup can be a very general guide in selecting syrup for making a specific confection, but testing has shown a wide variation in invert levels in the different grade classifications. This variability of invert sugars in syrup makes it necessary to test and adjust the invert sugar levels to match the specific characteristics desired for a given confection. Testing syrup and adjusting to a proper invert sugar level can eliminate batch failures and help the maple producer make confections of consistent quality. For many years the use of the Clinitest tablets was suggested as the way to measure invert sugars in syrup. Now, a simple test using the common glucose meter used to monitor blood sugar can be very helpful in selecting and blending syrups to make the most consistent products. Testing syrups before they are purchased for the purpose of making confections assures you are getting syrup that will make the confections you want.

Need to Dilute Syrup

Diluting Syrup to Measure Glucose

Maple syrup cannot be tested directly with a glucose meter. It is too thick and will not properly enter the test strips. Also the glucose concentrations from undiluted maple syrup usually would be higher than the range of most meters. To solve this problem you must dilute the maple syrup with water before testing. Since maple syrup and water are of very different weights it is best not to make the dilution by volume. The most accurate and easy method is to dilute by weight. This is best done with a scale. Scales with one tenth of a gram (0.1 g) accuracy and a range of 0 to 300 or 600 grams are now available at reasonable costs and are easily ordered on the internet. A one in ten dilution of syrup seems to work well for most

syrups, it is easy to calculate on a scale, and gives a reading on the glucose meter that is in the range for invert sugar concentrations required for most confections. Once you have a scale and are familiar with it's operating instructions, follow these simple directions:

- Place an empty cup on the scale
- Tare the scale to read 0 with the cup in place
- Drip 10 grams of syrup into the cup
- Pour 90 grams of warm water into the cup, adding the last amounts slowly in drops
- The scale total should now read 100 grams total
- Remove the cup from the scale and stir the water and syrup vigorously

Your maple syrup 1 in 10 dilution is now ready to be tested with a glucose meter.

We recommend 10 grams of syrup to 90 grams of water, rather than 1 to 9, because small measurement errors will make less of a difference.

Types of Meters

Types of Glucose Meters

There are a wide variety of glucose meters available in drug stores, the pharmacy section of department stores, or on the internet. Most glucose meters should be useful for measuring glucose in maple syrup, but meters that give numerical readings throughout their range (rather than Hi/Lo at the extremes) are best. These can range in price from nearly $100 to less than $10. There is also a wide range of prices for the test strips used in the various meters. Consider both the initial cost of the meter and the cost of test strips in determining which to buy. The more expensive meters offer recording and storage of information options that will be of no use to maple producers.

Most meters use test strips where the fluid is drawn into the strip by capillary action and an enzyme converts glucose to another chemical that triggers and electrical signal which relates to the amount of glucose present. These meters specifically measure glucose and not other invert sugars. The chemicals in the test strips deteriorate with time. Don't use test strips past their expiration date. The chemical reactions can be affected by room temperature, humidity and altitude. These meters should

be used at normal room temperatures and humidity. Each batch of test strips needs to be calibrated to the meter. This is done automatically in most cases, but follow the directions with your meter. Store your meter and test strips in a place protected from dust, fluids, and extremes of temperature and humidity.

Meter Use

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You will need to become familiar with the basic operation of your glucose meter. Most meters operate with a similar procedure in that you remove a test strip from it's protective foil and insert it correctly into the meter. Insertion of the test strip will turn the meter on automatically, give a notice of calibration, and then ask for a sample. With most meters follow these simple directions:

- Open a test strip being careful to only touch it in the middle.
- Slide the test strip into the meter. Follow the directions that come with the glucose meter to insure you put the correct end of the test strip into the meter and that the correct side of the strip is up, otherwise the meter will not give a reading.
- When the meter indicates it is ready for a sample, dip the extended end of the test strip about ½ inch into the syrup dilution and hold for about 5 seconds or until the meter indicates the sample has been activated.
- Move the meter to a horizontal position with the test strip in place and wait for the reading to appear on the screen

The reading that appears on the screen will either be a number, or it may say Hi or Lo. Here you will need to read the manual that came with the meter to know at what number the meter begins reading Hi or Low to understand what range they represent. The reading on the screen should be given as mg/dL or milligrams per deciliter. Most meters read glucose concentration in whole blood. Some meters convert these reading to glucose in blood plasma, which is 10-15% higher. Our recommendations are based on the whole blood readings.

The mg/dL readings on the meter will need to be multiplied by 0.02 to get the percent of invert sugar. The chart at the end of this section uses this conversion. Bulletins on specific confections will recommend percent invert sugar ranges for best results.

Accuracy and Repeatability

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Repeatability means the meter will give the same reading when you sample the same solution again. Accuracy means how closely the meter reading is to the actual glucose amount.

The Food and Drug Administration regulates the quality and manufacture of blood glucose meters and test strips. However, the accuracy of affordable meters is 10-20%. This means that if you test your meter, repeated readings can be very different and still be within the accuracy tolerances of the meters. For instance if the invert sugar level in the sample were exactly 1% and your meter read 50mg/dl it would be perfectly correct but you should expect readings to vary between 45 and 55mg/dl if you took a number of reading from this same sample. At these low sugar levels this amount of variation is completely acceptable and gives you a close enough knowledge of where the invert sugar levels are in your syrup to make good blends and confections. You should understand though that as the invert sugar

levels increase the 20% variation also becomes a bigger number. A 10% invert sugar solution (500 mg/dL) could give a reading between 450 and 550mg/dl.

You should check your meter periodically with repeat measurements on the same sample (with different test strips) to get an idea as to what to expect. Be sure that the sample is well mixed. Test Quality Control Solutions can be obtained from some pharmacies or the meter manufacturers if you need to check a suspect meter. Despite their limitations, these meters are a big improvement over the Clinitest tablets or not measuring at all.

Testing Barrels

Testing Barrels

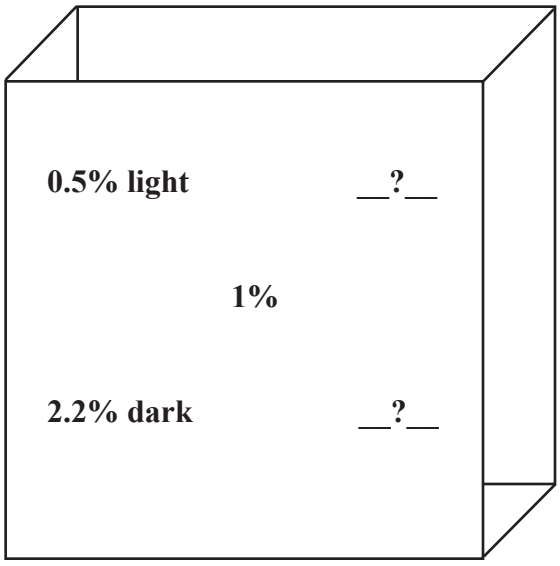
Once the syrup is in a barrel the invert sugar level will be stable unless a bacteria or yeast fermentation becomes active or the syrup is heated again. An invert sugar test can be run on barrels or other storage units as they are stored or a small sample can be held out from each barrel and all samples tested soon after the season so that the syrups can later be selected for use making confections or blending without further testing being necessary. Or testing can be performed on a batch of syrup being canned.

Blending

Blending for Optimal Invert Sugar

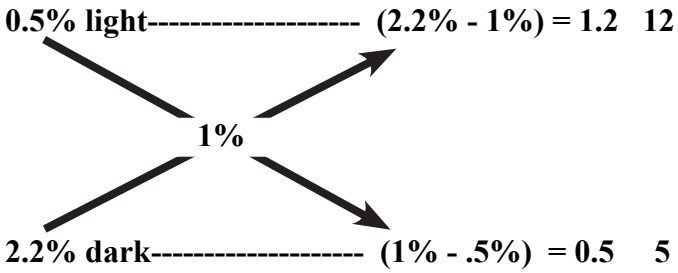
Determining the proportions of two syrups of known invert levels to obtain a blend with the desired invert sugar level can be done very simply, quickly, and directly using alligation. The method is best explained by example, so let's use two syrups with invert sugar of 0.5% and 2.2% to obtain a blend with an invert sugar level of 1%. For simplicity we will call the 0.5 syrup "light" and the 2.2% syrup "dark". Alligation determines the proportion by weight of each that should be blended.

Visualize alligation in a simple box diagram. In the upper and lower left-hand corners write the % invert sugar of the two syrups to be blended; in the center of the diagram write the % invert sugar of the desired blend.



Subtracting across the two diagonals provides the proportion (by weight) of each syrup required to produce the desired invert sugar percentage. Always subtract the smaller number

from the larger, irrespective of its location. The proportion (by weight) of each syrup to be blended is the number located directly across from it in the diagram. In our example:



The resulting ratio is 1.2 units of the light syrup with .5% invert sugar to each .5 units of the dark syrup with 2.2% invert sugar. To further simplify this, change the ratio to the simplest whole numbers. In this case it would be 12 to 5.

If both of the syrups have similar density, the unit of the ratio can be what ever is the most convenient for you. You could blend it as 12 pounds of light with 5 pounds of dark or 12 cups of light with 5 cups of dark, or 12 barrels of light with 5 barrels of dark. If blending syrups of different densities, like syrup and water, weight only, not volume, should be used. Once you have tested the syrups with the glucose meter blending using alligation is simple and very helpful in making the most consistent confections.

Be especially careful of strong flavors in dark syrup if blending is necessary as these flavors will become more pronounced in the final product.

Doctor Solutions

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Some confections need higher than normal invert sugar levels to make the desired product such as the shelf stable maple cream or maple suckers or hard candy made completely from maple syrup (no corn syrup or glucose sugar added). If syrup with high invert sugar level is not available it can be created using a "processing aid" that converts sucrose to glucose and fructose. Usually all or most of the sucrose is converted to create a "doctor" or additive solutions.

To 1 gallon (4.4 liters) of standard-density maple syrup add 2 ½ liquid ounces (80 ml) of Invertase (an enzyme that causes the conversion of sucrose to invert sugars). Invertase may be purchased from many confection manufacturers and stored according to directions. Stir the mixture thoroughly and allow it to stand at room temperature (65°F or 18°C) or above for several days. This will convert the treated syrup to between 60% and 67% invert sugar. It would be nice to be able to test the syrup to get an exact invert level, but at these high amounts you are out of the testing range of the 1 in 10 dilution. Also, the 20% accuracy of the meter is not good enough at these high levels. You can get a general sense of whether the invertase converted the sucrose, but you will need a 1 to 400 dilution to get within meter range.

Heating syrup treated with invertase above 140ºF will inactivate the enzyme and the sugar conversion will stop. Heat-treat the doctor solution above 140-160ºF before adding to an untreated syrup because it will convert sucrose in the untreated syrup.

The alligation method can be used to create a desired invert sugar level by blending the doctor solution with the lower invert syrup.

Another convenient type of processing aid is an acid salt such as cream of tartar (potassium acid tartrate). Adding ½ teaspoon (2.5 ml) of cream of tartar to 1 gallon (4.4 liters) of low-invert syrup just before it is boiled for candy making will cause sufficient acid hydrolysis or inversion of the sucrose to form the desired amount of invert sugar. Cream of tarter is available in the spice section of most grocery stores. The difficulty here is that testing can only be done after the fact and the results may not have produced the exact level of invert sugars you were expecting.

In summary, when making maple confections we recommend that you:

- Measure and record the invert sugar levels of your stored syrups
- Pick the best syrup for a confection based on the invert sugar levels
- Or, blend syrups to get the invert sugar level you want
- Where high levels of invert sugar is needed use a processing aid, measure the results, and blend in the right amount to get the invert levels you want.

» Table

(US)	1 - 10 invert
mg/dL	invert %
20	0.4
30	0.6
40	0.8
50	1
60	1.2
70	1.4
80	1.6
90	1.8
100	2
110	2.2
120	2.4
130	2.6
140	2.8
150	3
160	3.2
170	3.4
180	3.6
190	3.8
200	4
210	4.2
220	4.4
230	4.6
240	4.8
250	5