Refractometers

Author: Colin KaminskiIssue: November 2003

Take your brewing light years ahead. In our guide to refractometers, we'll show you how to measure your wort's gravity based on how it bends light.

When looking for consistency in brewing, one of the hardest things to achieve is a reproducible starting gravity. Variations in mill gap, mash temperature, mash thickness, water pH and water salts all play an important role in hitting a consistent starting gravity. One problem with measuring wort gravity during the sparge or boil with a hydrometer is the need to quickly cool a sample large enough for your hydrometer. I was using a one-liter flask in an ice water bath when a friend suggested trying a refractometer. I thought this would be the magic bullet because I only needed a couple of drops of wort to make it work. I quickly found out that while refractometers are very convenient, they require a few mathematical corrections in order to be accurate.

Refractometers are most often used in brewing to obtain quick measures of the specific gravity of unfermented wort. With a little more effort, however, you can obtain information about fermented worts — including finding the alcohol level in your beer and the original gravity from a finished beer! The math involved can be challenging, but there are software programs available that will do the math for you.

Fortunately I found there were many people before me that had done all of the homework in order to make this a convenient instrument to use. Jeffrey Donovan of Sausalito Brewing Company has written a wonderful program called ProMash that — along with numerous other things — includes a refractometer calculator for brewers. I use this program all of the time. Louis Bonham has also searched the professional literature and disseminated a lot of information on refractometry to the homebrewing community.

What is a Refractometer?

A Brix refractometer is an optical instrument that measures the sucrose concentration in a sucrose and water solution as a function of the index of refraction of the solution. The kind of Brix refractometer that most brewers use does not contain any electronic components.

Refraction is what makes a pencil look bent when it is dipped in a glass of water at an angle. The index of refraction is technically the ratio of the speed of light in a vacuum divided by the speed of light in the sample. It is equal to the sine of the angle of incidence (the angle that the light enters the water) divided by the sine of the angle of refraction (the degree to which the light appears bent) of a beam of light. In equation form it is: RI = sin(I)/sin(r)

If you were to stick a pencil in a series of glasses holding increasingly concentrated sugar water, you would see the pencil apparently bent to a greater degree as the sugar content rose. A refractometer makes this measurement very easy and converts the index of refraction to Brix, which is equal to percent sucrose. The refractometer uses the sample to bend light, projecting a line onto a reticule made up of lines and numbers, allowing us to measure of the angle in which the light was bent.

A refractometer looks like a little telescope. You lift a window and place a drop of fluid inside, wait 30 seconds to allow the refractometer to become thermally stable (also letting the sample spread across the plate uniformly) then read the result in Brix. Brix can be approximately converted to specific gravity (SG) by a simple equation:

SG = 1 +(0.004 x Brix)

Most people just remember the multiply by four rule. Take the Brix reading, multiply by 4 and this will give you specific gravity in "gravity points." For example, if you read 11 Brix, multiplying that by 4 yields 44, which corresponds to a specific gravity of 1.044.

A slightly more accurate conversion formula is:

SG = 1.000019 + [0.003865613(Brix) + 0.00001296425(Brix) + 0.00000005701128(Brix)]

Using this formula, a Brix reading of 11 yields a specific gravity of 1.043.

Choosing a Refractometer

There are many types of refractometers. The type brewers use is the type fruit growers use to measure the sugar concentration in fruit to see if it is ripe. It usually measures 0 to 30 Brix (1.000 to 1.120 SG) and this is a useful range for homebrewing applications. It is important not to get one that measures battery acid or some other chemical solution as it will require unavailable equations to convert to Brix and will likely measure the wrong range of refractive indeces.

Refractometers are available with or without automatic temperature compensation (ATC). ATC is a nice luxury, but not necessary if you use a temperature compensation chart. (In simple refractometers, ATC is done optically — it is not an electronic effect.) They cost anywhere from $75 to $300 depending on quality and features as well as country of origin. I have used the less expensive models with good results. Since the sample has a very small mass compared with the refractometer, it is only the temperature of the refractometer that is important in getting an accurate reading.

Using a Refractometer

Using a refractometer is very simple. You calibrate the refractometer by cleaning the window and placing a drop of distilled or RO water on the glass. Close the cover and make sure the glass has no dry spots or air bubbles. Wait 30 seconds. Hold the refractometer level with the window pointed toward a light source and look into the eyepiece. The meter will show a line between blue and clear. This line will correspond with a scale on the side of the viewing screen. This is where the reading is taken. Then adjust the calibration screw until the meter reads 0 Brix. Once the meter is calibrated, clean the window, place a drop or two of the sample on the window and read the value through the eyepiece.

Temperature Calibratio

If you are using a model with ATC, you can simply use the reading you have. If you do not have ATC, then you must use a chart included with the refractometer to get the compensated reading. You simply use the ambient temperature and the reading to get a value that must be added or subtracted from the reading to make the compensation. Do not use any temperature corrections when calibrating your refractometer. Instead, ensure that the calibration is made when the meter is at the correct temperature, 68 °F (20 °C) for most meters.

Understanding the Reading

If a sample is simply sucrose and water, you can take a refractometer reading directly. If, however, you are testing wort — which is mostly maltose — you must make a correction that I call wort calibration.

Wort Calibration

Measurements of the specific gravity of wort using a refractometer will not agree with the measurements of gravity using a hydrometer. Brix refractometers are meant to measure the percentage of sugar in a pure sucrose solution. Since wort is not simply sugar and water, you need to make a small correction because of the non-sugar components of the wort. The correction factor is different for different breweries. Beers that are very dark or have a very high starting gravity may also require a different correction factor. To calculate your correction value, measure the specific gravity with your refractometer. Then chill a sample of your wort and measure the gravity with a hydrometer. Convert the hydrometer reading to Brix using the equation: Brix = (SG-1)/0.004. Then divide the reading of the refractometer by your actual hydrometer reading. You should have a number between 1.02 and 1.06. If you do this for several worts and average them, you will get a number that you can use for your brewery. ProMash defaults to 1.04 and this is the number I use. Once you have this number, divide all of your subsequent refractometer readings by your calibration number to get the actual reading. For example, if your reading is 14.6 Brix then your corrected reading is 14.04 Brix (14.6/1.04=14.04). Then, we can convert the measurement in Brix to specific gravity.

Once you've calibrated your refractometer and measured your wort correction factor, you can obtain a measurement of your specific gravity quickly, without having to cool enough wort for a hydrometer sample. You can use the refractometer to measure the gravity of your wort during run-off to help you to decide when to stop sparging. Likewise, you can quickly obtain your gravity anytime during the boil to determine if you need to keep boiling your barleywine or if adding water to your best bitter is in order.

With careful use, a 0–30 Brix refractometer is precise to within 0.2–0.3 Brix. As such, it is less precise than a good hydrometer. However, it can provide a quick measurement of gravity to within about one "gravity point" at times when cooling the wort for a hydrometer sample would take too much time.

Measurement of ABV

This is where it starts to get complicated. Fortunately Louis Bonham did a great job of researching this method for homebrewers. You need to take a reading with the refractometer as well as a hydrometer and use this equation:

$$ABV = [277.8851 - 277.4(SG) + 0.9956(Brix) + 0.00523(Brix2) + 0.000013(Brix3)] \times (SG/0.79)$$

In this equation, Brix is the Brix reading of your refractometer and SG is the specific gravity reading from your hydrometer.

If you try this, it is important to take very careful readings. Degas the sample in a blender or by pouring it between two glasses until it does not foam. Make your reading at as close to 68 °F (20 °C) as possible. If your hydrometer is calibrated in Brix, use the longer formula I cited earlier to convert it to SG. This equation fits very well with the data points. Measure-ment of ABV can be made to within 0.3% if you are careful.

Apparent and Real Extract

What your hydrometer reads is the apparent extract (AE) of your beer. The real extract (RE) is the actual percentage of sugar unfermented. You can measure this by taking the refractometer reading and converting it to refractive index with this equation:

RI = 1.33302 + 0.1427193(Brix) + 0.000005791157(Brix2)

Then you need to plug the refractive index (RI) into this equation:

RE = 194.5935 + 129.8(SG) + RI[410.8815(RI) - 790.8732]

I like to know the RE as I find it correlates better with the perceived sweetness than the AE. If you want to find out the gravity of a fermenting wort and you have previously measured the OG, you can take a refractometer reading from just a couple of drops of fermenting beer and put the results into an equation to get the specific gravity of the beer. This has the advantage of allowing you to find if fermentation is complete without having to gather enough for a hydrometer reading.

It is also possible to find the starting gravity of a fermented beer. Say you have a bottle of Samuel Smith's IPA and you are looking for the starting gravity. You can take a refractometer reading and plug the value into yet another formula. (I use ProMash to make these two calculations.)

I would highly recommend a refractometer as a way to read wort gravity quickly while sparging and boiling --- and measuring the ABV of your finished beer. While the equations can be daunting at first, they can be undertaken by anyone with a little high school math. Alternatively one can use brewing software like ProMash or make a spreadsheet to solve them.

Colin Kaminski recently became the Master Brewer at Downtown Joe's Brewpub in Napa, California.