THE SPECTROPHOTOMETER AND BEER: A LOVE STORY

By Rick Blankemeier
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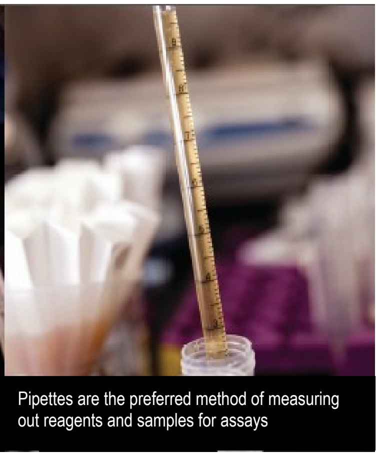
Hopefully, every craft brewer is aware of the serious nature of ensuring the quality of their beer. Many brewers will tell you that instruments like hydrometers, pH meters, and microscopes are absolutely essential to evaluate key quality aspects of beer. However, if you ask the same brewers if a UV-spectrophotometer is an essential piece of analytical equipment in the brewery, the answers can be quite varied.

Some brewers will say that you don't need one at all, while others say a UV-spec isn't for small breweries. The fact is that a UV-spec can analyze more essential aspects of your beer throughout the brewing process than any other single piece of analytical equipment, and for a reasonable price. At Stone Brewing Co., we use the UV-spec to monitor multiple aspects of the brewing process to ensure we're producing consistent beer across our many styles. Our UV-spec has proven to be an invaluable tool that has paid for itself many times over. It's my hope that I can de-mystify this piece of equipment and make it a little less intimidating for craft brewers to use.

The Basics

The UV-spectrophotometer uses discrete wavelengths of light to determine the concentration of certain compounds in a sample. The basic premise is that specific wavelengths of light will be absorbed by substances across a certain distance. The more light absorbed, the more "stuff" there is in the sample. Technical organizations like the American Society of Brewing Chemists (ASBC) have developed procedures and standards to find certain compounds in beer, including iso-alpha acids for bitterness, polyphenols, and free amino nitrogen. Operating a UV-spec is easy, even for the uninitiated. Sample preparation is definitely the most challenging part, although the difficulty level varies by test.

Hach DR 5000 UV-Spectrophotometer



Pipettes are the preferred method of measuring out reagents and samples for assays

UV-spectrophotometers are not cheap, but they don't have to be prohibitively expensive, either. A new UV-spec can be found in the $7,000 to $7,500 range. That price does not include warranties, service contracts, and other accoutrements necessary for the more complicated assays. You will also want to purchase quartz cuvettes, which are around

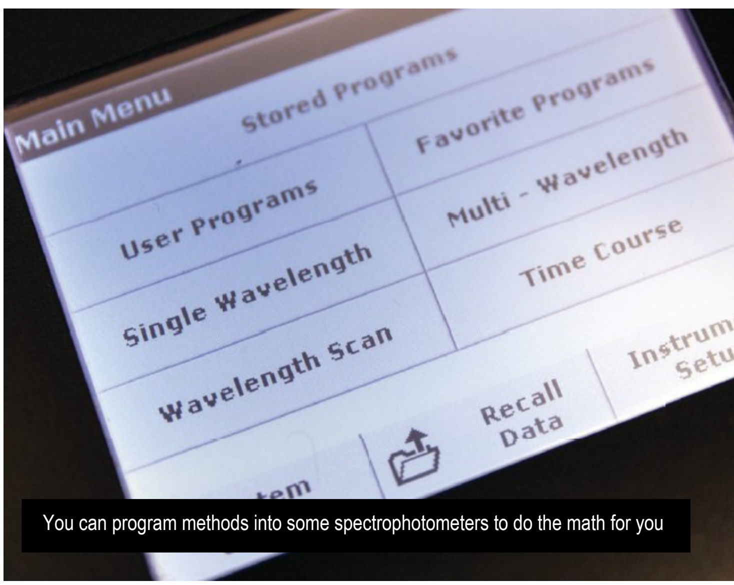
$300 per pair and unfortunately are very fragile. You might have to buy additional pairs over the course of a year as they break or crack. A water bath with the temperature range needed to do free amino nitrogen (FAN) and thiobarbituric acid reactive substance (TBARS) assays costs about $900. Chemicals and reagents also have an upkeep cost dependent upon the amount of testing you do.

The benefits of utilizing a UV-spec far outweigh the upfront costs. The amount you will save per month on bittering hops alone can pay for the UV-spec in less than six months. All it takes is a comprehensive hop utilization study on your brewhouse using the bitterness assay.

Additional studies on the brewing process using a UV-spec can lead to increased code length and shelf stability for your beers. Some distributors require a minimum of a 120-day code length and it’s important to see if the quality of your beer can hold up that long. The TBARS assay can help determine any non-dissolved oxygen-related oxidation issues that might be affecting the shelf life of your beer. It might also lead you to adjust the heating on your brewhouse, saving energy and money. Any added stability to flavor during the course of the code date is beneficial to your company. Fixing these issues can be a long process, but you won’t be able to fix something if you don’t know there’s an issue to begin with—that’s the beauty of the UV-spec! It will guide you toward overall efficiency and quality.

Assays and Empirical Standards

Establishing empirical specifications for each of your beers is essential to maintaining quality and consistency, but what standards are the most important to track? Gravity and pH specifications are used by every brewery, but bitterness and color give you a much better idea of how your beer starts out and evolves over time.



You can program methods into some spectrophotometers to do the math for you


Calibrated chemical pumps help reduce the time of sample preparation

Every brewer must adapt recipes to new hop crop years with varying alpha acid contents and specialty malt lot changes. Monitoring any changes in color or bitterness after a hop crop year shift or specialty malt lot change is essential to keep tabs on the quality of the ingredients in your beer. If issues arise with color or bitterness after a crop year change, you can alter the recipes slightly to get your specifications back under control.

Establishing analytical targets beyond gravity and pH gives you a great advantage when you are ready to increase your brewing capacity, because every system is different. When you decide to make the leap to a bigger brewhouse, or simply increase batch frequency, hop utilization and color will vary. Monitoring the beer for color and bitterness on your smaller-scale batches will allow you to make sure your beer stays consistent no matter the quantity of beer you are brewing.

There are dozens of other tests and assays that can be performed with the UV spec to help improve every aspect of your beer, but I will focus on some of the more common assays used at Stone Brewing Co. It's important to prioritize your brewery's needs and conduct studies accordingly. I have arranged the following assays in order from least difficult to more difficult.

COLOR

This assay (ASBC Beer-10A) works by detecting how much of the yellow spectrum of light is absorbed at 430 nanometers. The more light absorbed, the darker the beer color. The yellow spectrum is the basis for the Standard Reference Measurement (SRM).

Using 1mm cuvettes for color analysis removes the need to dilute darker beer samples

Color might seem like a trivial specification, but it is the first thing that consumers notice about your beer before drinking it. Establishing a color range for your different beers helps diagnose issues that may arise with specialty malt supply changes, grainouts, and filtering. The procedure is very simple; all you need is a sample of decarbonated beer or wort to measure against a water blank. If the beer sample is dark, it can be diluted with equal parts water until the UV-spec can get a reading.

At Stone, we make sure that color is consistent across every facet of the process. To that end, we measure the color of the wort for every brew four days into fermentation and in the bright tank before releasing the beer for packaging. This amount of testing helps us address any issues that might have reared their ugly heads earlier in the process and plan for corrective actions accordingly. In our case, corrective actions usually mean blending two fermenters into a single bright tank. Smaller breweries usually don't have the luxury of being able to blend problem fermenters, but adjustments can be made with the recipes to account for an increase or decrease in color in later brews.

BITTERNESS

At Stone, bitterness is a specification we hold near and dear to our hearts. Bitterness in beer is primarily derived from the isomerization of alpha acids during the boil. The ASBC standard method (Beer-23) for determining the concentration of iso-alpha acids (IAA) requires a liquid-liquid extraction of acidified beer or wort samples in iso-octane (or 2,2,4-trimethylpentane for any IUPAC purists out there). Iso-octane needs to be disposed of carefully in a secondary container and then dumped at regular intervals via a chemical disposal company. The disposal fee is $150 to $200 per month. The cost of chemicals is about the same amount per month, so bitterness testing does cost a fair amount more money than the color assay; however, you'll save money in the end if you can use less hops for intensely bittered brews.

One of the more useful applications of bitterness data is determining hops utilization over the course of the brewing process. Since wort can only take up so many iso-alpha acids depending on the gravity, it's useful to note where one might be getting diminishing returns on bittering hops. If you can determine through extensive IBU testing that you can back off on the bittering hops and still maintain the same range of IBUs, you can save oodles of money and hops contract headaches.

In addition I to keeping track of utilization, we also monitor bitterness three times per brew: first at knockout, then four days into fermentation, and finally at the bright tank. We've noticed that bitterness decreases anywhere from 5 to 20 IBUs from wort to finished beer. We assume the drop in IBUs is due to several factors, including the yeast metabolizing some IAAs during fermentation; another drop can occur during our centrifuge and filtration process, or there could also be polyphenols extracted in the assay. We account for this drop in IBUs by adjusting our recipes on a regular basis.

TBARS

One new area of focus in the realm of brewing science is determining the presence of malondialdehyde (MDA) in wort. MDA in wort indicates the presence of lipid peroxide, derived from unsaturated lipids that are naturally present in wort. Those lipids react to free radicals formed by excessive heating during the boil. Lipid peroxides will degrade after packaging to create additional oxygen and cause oxidative effects in beer. The insidious part about lipid peroxides is that they don't show up on dissolved oxygen meters. This means you could have a low-O_2 product, but it will still become oxidized from the degradation of lipid peroxides. Fortunately, there's a spectrophotometric assay that tests for thiobarbituric acid reactive substances (TBARS) that can determine the amount of oxidative damage present in wort. In this case, it's the amount of MDA. The TBARS assay comes in a convenient kit available from laboratory supply vendors such as VWR International and Fisher Scientific. The typical cost is $300 to $400, and it provides all the reagents you need to run the assay, including the procedure itself.

One big difference with this assay from the previous two described is the need to generate a standard curve using the MDA reagent provided in the kit. The procedure involves measuring the absorbency of graduated increases in MDA and then finding a linear equation that describes the trend. This equation can be generated by using Excel's graphing and trend line features. After you have the equation, you can use the absorbency of your samples to solve for the amount of TBARS present in your wort sample. The results are in ppm of MDA detected in your samples, signifying the amount of oxidation damage to your wort caused by excessive heating. One extra piece of equipment you'll need for this assay is a water bath that can maintain a precise temperature. As mentioned previously, brand new water baths will run around $900, so buying a used one can save you money. It's a wise investment because FAN testing and polyphenols also need a water bath.

Another important note about this assay is that it's quite new to brewing. Very little research has been done to see how much O2 is released per mg of MDA in beer, so there isn't a "concrete" upper limit of MDA to stay below. My recommendation is to establish a baseline for your different beers, and try turning down the heat while maintaining a rolling boil to see if your MDA amounts decrease. We're implementing the same procedure at Stone to see how low we can go with MDA compounds in our beer. So far, we've learned our MDA levels vary significantly from one style to the next.

FAN

Free amino nitrogen (FAN) represents the concentration of bioavailable nitrogenous compounds in wort (ASBC assay Wort- 12). Some of these compounds include amino acids, ammonia, and -amino nitrogen in small peptide chains—everything that yeast needs to ferment at a healthy rate. The good news is that all-malt brewers will have more than enough FAN to make yeast happy during fermentation.

FAN was extensively studied by macrobreweries due to their prodigious use of nitrogen- poor ingredients like corn and rice. Those studies resulted in the use of nitrogen compounds such as urea in their brews. Conversely, craft brewers have the opposite problem. Since most craft breweries use an all-malt wort base, they tend to have higher than recommended levels of FAN. Yeast either leaves the nitrogenous compounds in the beer where they can cause yeast flocculation issues and therefore hazy beers, or the yeast metabolizes FAN into diacetyl.

Excessive FAN levels in wort can lead to all sorts of problems, including flavor and microbial instability. A variety of bacteria and wild yeast love those nitrogen compounds as much as Saccharomyces yeast and can spread infection in your facility. Brewer's yeast and wild yeasts also metabolize excessive amino acids in wort into higher alcohols like isoamyl alcohol, propanol, and isobutanol— all of which cause alcohol heat in your finished product. Typical healthy FAN levels in wort are usually between 150 and 300 ppm. One can also use this assay to find the amount of FAN left over after primary fermentation, which should be at or near zero.

Conclusion

In conclusion, while it may be a significant investment up front, and it may not be the sexiest piece of equipment in your brewery's lab stock, a UV-spectrophotometer can make sure the beer you love stays lovely. It will pay you back over time with a streamlined brewing process and more consistent, higher beer quality.

Rick Blankemeier is the Quality Assurance Analyst for Stone Brewing Co. in Escondido, Calif.

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