



Long Trail Brewing Uses Headspace Sampling to Improve Beer Taste and Production Efficiency

Long Trail Brewing Company is a microbrewery located in Bridgewater Corners, Vermont that produces the second best selling draft beer in the state of Vermont. "Beer production is very simple but it gets complicated when you

try to make it the same every time," said Bill Yawney, Quality Assurance Manager for Long Trail. "Our philosophy is that people drink beer because they like the taste so we focus on identifying and ensuring the presence of positive attributes that provide the great taste that keeps our customers coming back for more. A modern headspace trap, gas chromatograph/mass spectrometer (GC/MS) from PerkinElmer helps us monitor the taste of our beer and ensure that our process is working correctly. We also use these instruments in the product development process to deliver a world class beer flavor."

Challenge

Andy Pherson founded Long Trail Brewery in the basement of the old Bridgewater Woolen Mill in 1989. The company was named after a hiking trail that runs the length of Vermont. Long Trail's flagship beer is Long Trail Ale, a Dusseldorf-style Altbier. Long Trail Ale is Vermont's best selling craft beer and Long Trail draft is outsold in the state of Vermont only by mega-brewer Anheuser Busch. The Long Trail Visitor Center receives an estimated 72,000 visitors each year, making it one of the state's top tourist attractions. The company now distributes its beer to 13 additional states in the Northeast and Mid Atlantic regions. Founder Pherson retired in 2006 and the company is still privately owned.

"The owner of this company had the vision that analytical instruments could play a critical role in our process control, quality assurance and product development," Yawney said. "He gave me the job of selecting the right instruments and implementing them in our brewery. I interviewed four companies and quickly narrowed the choice down to PerkinElmer and one other. I selected the PerkinElmer TurboMatrix headspace trap sampler and Clarus 500 Gas Chromatograph (GC) with a Clarus 500 mass spectrometer (MS) detector because they offer several significant advantages. The headspace trap repeatedly pressure cycles samples to extract as much vapor as possible, resulting in detection limits up to 100 times lower than standard methods. The GC's programmable pneumatic control makes it possible to control and monitor all injector, detector and auxiliary gases electronically, substantially reducing the time needed to measure and set flows. The mass spectrometer has, not only the ability to quantify compounds, but the ability to identify them, as well."

Solution

Headspace sampling is the state-of-the-art method for sampling the aroma of beer and other food products. The beer sample is placed into a vial and sealed. The vial is heated to release the vapor into the headspace or empty area of the vial. The vapor is then extracted and analyzed using gas chromatography.

At equilibrium the concentration in the headspace phase is proportional to the original concentration in the sample. Determining the concentration of the headspace phase enables the composition of the sample to be established. Polar compounds in beer are more soluble in water than in air so only less than 0.5% of the compound in the sample may pass into the headspace. The headspace trap technique can enhance detection limits by injecting the entire headspace volume into the trap, pausing to allow the headspace to refill with vapor and repeating the injection process several times.

Long Trail uses a number of different detectors with the PerkinElmer Clarus GC, a flame ionization detector (FID) and a mass spectrometer. The FID has certain specific uses, however, the mass spectrometer is the primary detector able to detect beer defects such as acetaldehyde, dimethyl sulfide and vicinal diketones such as diacetyl and 2,3-pentanedione. It is also used to analyze volatile aldehydes, ketones, carbonyl and furfural compounds, some of which are involved in beer staling. The mass spectrometer can measure many beer attributes, as well, such as higher alcohols, esters and hop aroma compounds.

Outcome

Acetaldehyde has the taste and aroma of green apples or grass that, like many other compounds, provides a positive taste at low levels but can cause a negative flavor at higher levels. Acetaldehyde is reduced to ethanol by yeast during secondary fermentation. It is important not to remove the yeast too early from a fermentation to allow the process to complete. Acceptable levels are typically in the range of 1 to 20 parts per million (ppm).

Dimethyl sulfide contributes to the taste of ales at the right level but it's important to avoid excessive amounts because it produces to an unpleasant cooked cabbage aroma. Long Trail typically sets a maximum level of 50 parts per billion (ppb). Analysis results are used to fine-tune the process, particularly the boiling time and the venting system, to meet this specification.

Diacetyl is a naturally occurring compound that provides a buttery flavor that can cause problems at higher levels. Beer naturally produces diacetyl as it ferments, often to excessive levels. As the beer sits in the fermenter, yeast reabsorb the diacetyl, reducing it to acetoin. The human threshold for detection of diacetyl has been reported to be between 50 and 100 ppb. Acceptable levels of diacetyl are dependant on the beer style. In lagers, it is generally considered a defect above the threshold, yet, it may make a positive contribution to the flavor profile of some ales and is vital to some barrel aged styles.

The time it takes for yeast to reduce diacetyl in the conditioning period is called the diacetyl rest and is important information with regards to brewery throughput. "At Long Trail, the ability of the PerkinElmer GC/MS to measure diacetyl reduction over time has allowed us to maximize product throughput with confidence that diacetyl reduction has progressed to our desired targets. Previously, we based this solely on information from beer science journals and taste testing."

Long Trail uses the GC to measure the floral bouquet of hops. A wide assortment of compounds give hops their particular flavor and the GC/MS can identify and quantify many of them. The analytical data is then calibrated against human perception in taste tests. This type of analysis has been particularly valuable in ensuring that the company's two breweries produce beer with exactly the same flavor.

The GC is also used to evaluate other flavors. When Long Trail had to switch suppliers of orange peel it compared the old and new suppliers' products and determined the appropriate use rate for the new supplier's product. Long Trail switched from a coarse to a fine coriander mill and discovered by quantitative analysis that less of the fine coriander needed to be added to its product to deliver the same flavor.

Understanding what makes beer go stale

Long Trail also is engaged in a project to model the compounds that cause beer to go stale. When beer is exposed to oxygen, aldehydes and other carbonyls turn into compounds that produce unpleasant flavors. Modern fillers produce bottled beer with only 30 ppb of oxygen, however, staling compounds can form from a combination of heat and time alone. The key to improving beer shelf-life is to minimize the levels of precursors in the first place. The approach is to

heat abuse product and compare it to fresh product in order to determine which compounds are involved in staling. This will hopefully lead to the ability to predict staling by analyzing the levels of precursors in fresh product. Additionally, process changes could be made to minimize the amounts of the precursors, once identified.

Long Trail uses GC results to guide its product development efforts. "In one case, our goal was to make a well designed thin brown ale." Yawney said. "Our in-house tasters did not like our first try so we compared it to our competition with the GC and found that our ester profile was too strong. We made process changes that resulted in a less pronounced ester profile and in-house taste testing rated the revised product as superior to the competition. It is then typical for Long Trail to use the GC/MS to evaluate production size trials of laboratory R&D produced recipes.

"Breweries around the world have been using this type of analytical equipment for years, much of the time to monitor beer defects. What makes Long Trail's approach unique is our focus on beer attributes," Yawney concluded. "With an eye on potential product defects, focusing on the positive organoleptic qualities of this wonderful substance means we are focusing on the enjoyable experience we wish for all our customers and the reason they purchase our products."



View from the Long Trail mezzanine where you can follow a self guided tour of the brewery.



Boiling wort in the brew kettle as viewed through the port for hop additions.

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