Leveraging Data-Driven Fermentation Performance Management

Day-By-Day Performance Considerations Revealed By Real-Time Fermentation Tank Monitoring

A Precision Fermentation eBook

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"The high-gravity imperial stouts have been notoriously difficult for us to pull off. There's a lot of timing and skill involved, as we manually stop the fermentation and kick it off again, and watching the graphs really helps me figure all of that out. Recently, when one of these beers stalled, I saw it as it happened.... It stalled at 1.056, and I needed it to get down about 20 more points. I was able to pitch more yeast into it to get it back on track, but watching the gravity graph further, I could see the new yeast was consuming too much, so I was able to see that I had to take steps to stop the fermentation."

- Rob Qualls, Head Brewer, City Built Brewing Company, discussing the impact of real-time fermentation data

Introduction to Data-Driven Fermentation Performance Management

BrewMonitor is the industry's first real-time, comprehensive fermentation monitoring and analysis solution, purpose-built to enable brewers to leverage automatically sampled, real-time fermentation data across seven measurements – dissolved oxygen, gravity, pH, pressure, liquid temperature, ambient temperature, and conductivity – live-streamed to any internet-connected smartphone, tablet or PC. By capturing and recording exponentially more data per fermentation than has ever been available before*, this technology enables brewing personnel to achieve many new creative, operational and business objectives. The main practical advantage of automated tracking is increased control – control of problems that arise, control of batch-to-batch consistency, control of the labor required to ensure success, control of costs, and more. But at the heart of this sea-change in fermentation management for breweries is unprecedented access to scientific understanding about fermentation performance and the ability to act on clear and complete data.

Adoption of the BrewMonitor system by forward-thinking breweries around the globe has grown at a brisk pace, and this has provided Precision Fermentation's brewing and data science team with a look at fermentations in tremendous volume and detail. This visibility offers an opportunity to begin to discuss fermentation *performance* as never before, based on conclusions drawn from the examination of data from a wide variety of fermentations, different geographical regions, varied brewery sizes, and from many beer styles and brewing techniques.

This ebook explores what we have learned so far, through the lens of performance-impacting factors at each step of the fermentation process. It summarizes the key considerations and recommendations from our team at each major step of fermentation, broken down into "Day Zero" (i.e. before you pitch your yeast), "The First 24 Hours," and "Day Two to the End of Fermentation." By necessity, the conclusions below presume brewers' access to data that is only possible through some form of intensive data collection. Yet, commercial interests aside, it is our hope that this first-of-its kind breakdown of fermentation performance, gained from our extensive fermentation data analysis capabilities, will help shine a useful light on the issues that all brewers, brewery owners, QA professionals and other beer operations personnel face every day.

**Approximately 14,000 individual data points collected for an average fermentation*

Definitions: What Fermentation Data Does a Brewer Need?

To understand the practical impact of your brewing conditions and methods on the final product, end-to-end visibility into the chemical and physical properties of each fermentation offers the key data that a brewer needs to make informed decisions. These can include: more precise control over output, more options to correct batches before they go bad, greater repeatability, increased efficiency and much more. But exactly what fermentation data is needed? Here, we break down the "why" behind each component of the dataset that our system collects.

Dissolved Oxygen (DO)

DO is both a necessary supplement for yeast health and a problematic infiltrator of finished beer. Knowing how much oxygen is consumed by yeast is informative for measuring the health and vitality during fermentation, and understanding how much oxygen is left in the finished product is a good indicator of beer stability.

pH

Offers insight into the efficiency of yeast metabolism of sugar into ethanol. Understanding pH is critical to giving an ideal flavor profile, and for providing yeast with the ideal fermentation environment.

Gravity

A measure of the available fermentable carbon molecules in solution. Gravity levels indicate the sugar left in solution for yeast to convert to ethanol. Seeing the rate of gravity change, in high resolution, provides insight into yeast health and fermentation performance. Knowing exactly when the yeast fully attenuates the beer means that the brewer can know the exact moment that primary fermentation is complete.

Pressure

A measure of how much gas is building up in the fermenter. Pressure is a useful parameter to analyze together with gravity to determine the consumption of fermentable sugars during fermentation. When tracked in conjunction with other parameters it can also be a useful indicator of mechanical processes influencing the beer – dry-hopping, for example.

Temperature (Liquid/Ambient)

Temperature is sensed as yeast produces beer. Yeast respond to the environment, and its metabolic rate and flavor compound production are direct consequences of the fermentation temperature. In this way, knowing temperature can help control the flavor/aroma profile of a beer as well as the fermentation ability of a strain. Also, knowing the internal/external temperatures allows a brewer to observe efficiencies and inefficiencies in fermenter temperature control systems.

Conductivity

Conductivity is the measure of solution's ability to carry an electrical current. While a particular conductivity value is not necessarily important for beer flavor or quality per se, it is an important data point to understand the contents of a beer as fermenting progresses. In a complex organic solution like beer, conductivity offers enhanced insight into the metabolic efficiency of the yeast tasked with producing the finished beer.

LEARN MORE ABOUT BREWMONITOR

Getting Your Weekends Back with Real-Time Fermentation Monitoring

BrewMonitor gives you a number of valuable data points the minute you turn it on. And, once you've okayed your starting levels and pitched your yeast, you can practically set it and forget it. As Denver Smyth, head brewer and owner of Western Red Brewing in Poulsbo, Washington, has discovered, automatic digital readings mean he can track his fermentation from home instead of driving 30 miles to and from the brewery every Saturday and Sunday to take gravity readings, as was his custom:
"My favorite thing is when I pitch a yeast on Friday night, I can leave and I don't have to come in because I can see exactly what's happening. Now it's pretty rare that I run to the brewery on a Saturday or Sunday at all."

Learn more: precisionfermentation.com »

Day Zero – Before You Pitch Your Yeast

While most brewers take a gravity reading, and maybe a pH reading before they pitch, if you monitor gravity, pH, dissolved oxygen and conductivity in real-time, you get a much more robust baseline for your wort, and it also provides answers to some key performance questions at the outset:

- If you're trying a recipe for the first time, do the numbers match your predicted values?
- For repeat batches, do the numbers fall within specifications?
- If not, what can you do about it — now — before you risk losing a batch or time in your tank?

Let's look at the monitored readings one by one.

Gravity

The first question to ask at this point is the usual one: did I hit my target gravity? If not, how far over or under am I? How will that affect the outcome of the beer and its consistency with previous batches? Tracking these answers can help figure out solutions to any future irregularities.

pH

Some breweries monitor pH but not all. If the pH level is too high, you can take a representative sample of the wort, adjust the pH to the desired point, then scale the volume of acid added to the whole batch – and then add that volume to the fermenter. After you've run a few batches, do you notice pH showing up as a recurring problem? This may indicate that you need to acidify your mash with some acidulated malt or phosphoric acid. Consider adjusting your brewing-salt additions to increase or decrease the pH in future batches. These techniques will prevent you from having to rely on adding acid after brewing.

Dissolved Oxygen (DO)

Most small brewers do not measure DO at this stage, if ever, but it is impossible to overstate the potential consequences of out-of-spec DO on yeast health, the production of flavor-active compounds, and overall fermentation performance, i.e. stalled fermentations or fermentations running longer than planned.

Over-oxygenation can prove toxic to yeast. If more oxygen is present than needed for the production of fatty acids and sterols, which is the reason we add oxygen, it can lead to DNA damage, rapid aging of yeast, poor fermentation performance and a reduction to the number of possible re-pitches. In addition, excess O2 can cause the formation of pre-staling compounds which reduce the shelf life of finished beer.

On the other hand, with too little oxygen the yeast may not be able to produce enough fatty acids and sterols, reducing their growth as they run out of components for making extra cell membranes during cell division. Even if the total growth is sufficient, your yeast may lack the ability to remodel the cell membrane as acidity and ethanol levels increase, reducing overall viability and health for repitching. If yeast haven't been pitched yet and the fermentation vessel has a carbonation stone in place, some O2 may be scrubbed off by bubbling CO2 through the wort.

Conductivity

Conductivity is a quantity most brewers do not measure despite it being a critical indicator of wort quality, given that it measures the combination of the salts and other charged compounds — proteins, amino acids, organic acids — within. If conductivity is out of range, this may indicate issues with water chemistry and or/mash problems. (Have you changed grain suppliers? Is there harvest to harvest variation? Do the grain specs match?)

Conductivity also indirectly measures the buffering capacity of the wort, meaning how much it can resist pH change within a limited range. Out-of-spec conductivity can compromise fermentation as the growth environment for the yeast will change in ways you don't want. For instance, decreased conductivity may indicate decreased Free Amino Nitrogen (FAN), which will have a negative effect on yeast growth and fermentation performance. When buffering capacity gets exhausted, conductivity will change as yeast acidify the wort, use up amino acids and fatty acids and start to produce organic acids.

DAY ZERO: ADDITIONAL CONSIDERATIONS FOR BREWING MULTIPLE BATCHES

If you're fermenting multiple batches at once, each successive batch addition should change your readings in a predictable way. So what are we looking to see here? We often see a fast rate of fermentation on the first knockout, which slows after the second. This is normal. Though we're still working to pinpoint an explanation, we suspect this happens because the concentration of yeast is getting diluted to the expected level.

Do you oxygenate the next knockout? Yes, but only if the wort DO has NOT dropped to zero. Before you perform the next knockout, don't forget to do your due diligence by cell counting to ensure you have the cell density to support another round.

The First 24 Hours – Preventing Later Headaches

Traditionally, most brewers don't know whether their fermentation has taken off until they come in the next morning and check for activity in the blow-off bucket. Through real-time fermentation data collection, instead you can know if everything is really on-track by being alerted when dissolved oxygen hits zero, pH gets down to 4.5, and gravity drops by 1°P. To take extra care, you can check the data for human error two-to-six hours after the pitch. This way, if your readings are out-of-range, you can troubleshoot to determine whether, for example, the blowoff valve was opened and the chiller was turned on.

Let's look at typical readings and performance considerations for the first 24 hours.

The DO should drop below 1 ppm and remain there for the rest of the fermentation. If it takes more than approximately 12 hours for DO to drop, you have an indication that you may have underpitched the yeast or that yeast health is otherwise compromised.

Gravity

By day 1, you should see some movement in gravity, depending on the style of beer. Most ale fermentation will have dropped, though it's normal for some lager strains to not have begun fermentation yet. If the gravity of your ale hasn't moved at all, it would be best to check the other indicators of yeast activity.

Dissolved Oxygen (DO)

The oxygen should have been consumed by the yeast at this point, with the possible exception of lager fermentations. The DO should drop below 1 ppm and remain there for the rest of the fermentation. If it takes more than approximately 12 hours for DO to drop, you have an indication that you may have underpitched the yeast or that yeast health is otherwise compromised. The exact timing, of course, depends on your strain.

If this happens, it is a good idea to pull some samples to check your cell counts and health. Do you need to add more yeast? If you were planning to repitch this yeast, it may be time to start planning alternative sources to prevent compromising future batches.

pH

Using BrewMonitor for tracking, we typically see a rapid pH drop, falling around 0.5-1.5 pH in about a day, dependent on style and yeast activity. As a general rule, we look for the pH to drop below 4.5 within the first 24-36 hours. Though this guideline may not be a hard rule for all styles of fermentations, we know that if the pH hasn't dropped past 4.5 and DO is still present, you risk growing enteric and other pH-sensitive bacteria. Even more importantly, consistency is key – it is very important to compare this early pH data set to preset benchmarks from prior fermentations of the same beer. The earlier and more frequently you monitor this, the earlier you can rectify any issues by adding more yeast and the lower the chance you'll have to dump the batch.

Pressure

To keep the yeast healthy and promote brewery safety, we check the pressure reading (or set an automatic alert in BrewMonitor) for a reading that exceeds 10 PSI. A number that's too high could indicate the blowoff valve is closed or blocked. Excess pressure will increase dissolved CO2 levels and can become toxic when it combines with increased pressure on the cells. If you rely on the pressure release valve to vent it will likely react too late to save the yeast.

Look out now for unexpected slowing or stalling or, conversely, whether fermentation is progressing too fast. These could be signs of an under- or over-pitch, or yeast that weren't as healthy as initially thought. In addition to alerting to possible problems with the fermentation, this should also prompt you to potentially rethink your repitching options.

Temperature

The fluid temperature should remain constant depending on the cooling jacket settings. We use BrewMonitor's alert function to inform us when to make any scheduled temperature changes or for temperatures that go 39°F over or under target to let us know right away that there is a cooling problem potentially created by chiller trouble or a stuck solenoid.

Conductivity

When fermentation kicks off, the generation of CO2 in the wort will cause the conductivity reading to drop slightly. This is not a change in the conductivity of the wort, simply an indicator of CO2 production and therefore a confirmation that fermentation is underway. We view it as the virtual equivalent of the bubbling airlock.

If fermentation goes off-track you don't have to wait until too late to do something. You can rescue a batch or plan for how to deal with it long before you might have otherwise. You may lose a batch or know you won't have yeast to repitch but you can save days of wasted time by being forewarned.

Day Two to the End of Fermentation

At this point in your fermentation you can more or less sit back, relax (as much as any brewer can, given everything they have to do) and, if you're running a monitoring system, wait for automatic alerts. After the first 24 hours everything should be on track and progress should very closely match your benchmarks. It gets a little trickier for one-offs but you can always let yourself be guided by a closely related batch, like a wort with the same yeast and similar gravity but different hops.

What to Watch Out For #1: Pace of Fermentation

Look out now for unexpected slowing or stalling or, conversely, whether fermentation is progressing too fast. These could be signs of an under- or over-pitch, or yeast that weren't as healthy as initially thought. In addition to alerting to possible problems with the fermentation, this should also prompt you to potentially rethink your repitching options.

Any of these possibilities would also flag the need for greater attention to sensory testing and forced aging before release. Is the beer's flavor and aroma still matching expectations? Will it age the same as expected?

If you're spunding, keep a close eye on gravity and, if you're running a monitoring system, set alerts accordingly. You may want to close the blowoff

valve as soon as the density line starts to become asymptotic. Similarly, setting up your monitoring system's targeted gravity alerts can help you avoid excessive delays in dry-hopping or help you make sure to harvest yeast for repitching at an optimal window.

What to Watch Out For #2: pH

Benchmark your pH changes. Some beers will be more heavily buffered than others because of higher gravity, for instance, or use of water modifications, so each beer will be different but pH should continue to trend downward as fermentation progresses. Toward the end of fermentation, the pH should start to drift upwards again as some of the organic acids get consumed as tertiary carbon sources. We most often see this inflection point happen slightly before gravity reaches terminal. The pH should continue to rise after primary fermentation ends, with the exact terminal point dependent on the specific beer in question (typical range is anywhere from pH 4.6 to 4.8). If, for example, the pH continues to drop after reaching terminal gravity, this could indicate possible contamination by an acid-forming bacteria and require further investigation. Some beers may fall outside of the ranges specified here, however, so throughout this entire process, once again, it is important to compare your current fermentation against a benchmark dataset for the same beer in order to track variations against your norms.

What to Watch Out For #3: Refermentation

If you're dry hopping or adding fruit keep an eye out for unwanted refermentation. With the use of a monitoring system, brewers may discover that gravity is dropping more variably than expected after the hop or fruit additions. This can happen for reasons as subtle as the particular hop crop year, source, age and use of T45's versus T90's.

If you're dry-hopping for biotransformation or hopping after terminal, a density measurement will help determine if there are still enough yeast in suspension to ensure sufficient yeast activity to clean up hop creep and any oxygen added by the hops. You may want to pay close attention to the amount of time it's taking to get to terminal gravity, as creep may happen slowly and need days or weeks to be sure.

Monitoring and Performance Notes

The factors detailed here have been pulled from a range of fermentations across many beer styles, and illustrate the ways we've found real-time, high-frequency data collection to be impactful to brewers seeking to manage the fermentation process with greater efficiency and control. While these notes represent a wide range of fermentation profiles, we recognize that specific beers will have their own unique fingerprint that can be monitored, analyzed, and reacted to in real time. The best way that your data can alert you to issues in real time or help you manage processes like yeast harvesting, spunding, or dry-hopping efficiently is with a clear comparison against previous datasets from the same beer.

For any size brewer, the data from your monitoring system should allow for better timing of standard processes within fermentation, detection of the unexpected when it arises, and act as an early warning system for potential complications and starting the troubleshooting process. If everything looks good it will provide you with a very precious commodity – peace of mind, and a more restful night's sleep.

BREWMONITOR®

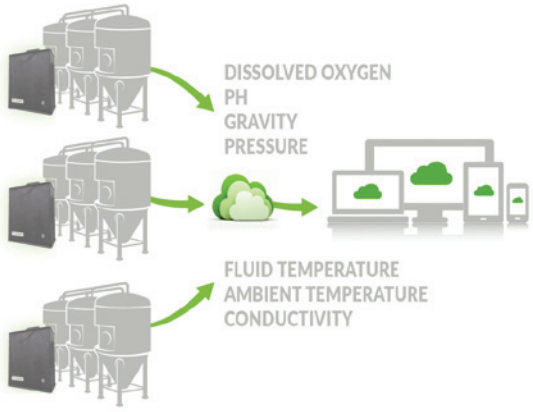
Streamline Operations with Real-Time Fermentation Monitoring & Analytics

The BrewMonitor System is a real-time fermentation monitoring and analysis solution, purpose-built to enable brewers to increase quality and profitability through enhanced fermentation-process control. BrewMonitor collects fermentation data from your existing tanks in real-time and streams it to any PC, tablet or smartphone, 24-7.

The BrewMonitor System breaks new ground with productivity tools that dramatically simplify yeast vitality assessment and quality control analysis. With just a few mouse clicks or taps on your smartphone, your fermentation tank data is transformed into a powerhouse of actionable insight – helping your team ensure consistency, prevent fermentation problems, reduce labor, and lower costs.

Total Visibility: Any Time, Any Device

The BrewMonitor Sensor Hub attaches easily, cleans easily and live-streams critical data to your web-enabled devices.

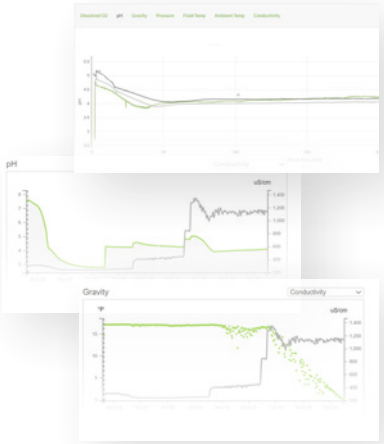


Quality Control Processes, Simplified.

Get immediate, actionable information to inform your most important production decisions:

- *Batch-to-Batch Quality Analysis* helps easily ensure consistency and improve the quality of your operational processes.

- *Yeast Vitality Trends* accelerates yeast vitality assessment for more timely repitches, prevention of stalled fermentations and more, saving time and cost.



For more information about the BrewMonitor System, contact Precision Fermentation:
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About Precision Fermentation

Precision Fermentation Inc. offers a groundbreaking, real-time monitoring solution that dramatically enhances control over the fermentation process for producing brewed beverages and other fermented products. Precision Fermentation's flagship product, the BrewMonitor System, helps ensure complete product consistency, increases manufacturing efficiency and enables greater business profitability. Together, the solution's sensor-array device and web-based software suite continuously live-streams data from an active fermentation, offering complete fermentation process visibility and control that replaces trial-and-error measurements and enables excellent product and business outcomes.

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