The Connected Brewer: Data-Driven Fermentation for Better Beer and Better Business

A Precision Fermentation White Paper

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PRECISION FERMENTATION
Know Your Brew.

Overview

Whether a brewpub, microbrewery, or regional craft brewer, many factors affect how a brewery will thrive. Location, funding, marketing capabilities, competitive environment, local economy, vendor relationships, and staffing are just some of the challenges that each business must manage. But it is impossible to overstate the importance of the quality, consistency and efficient production of the brews themselves. The brew is the main attraction, the driving product, and is at the heart of the brand. Great brewing empowers every other aspect of the business.

The dedication to serving excellent and unique beers has led to an explosion in new craft brewing companies over the past decade. In the US, from 2012 to 2017, the total number of craft breweries has increased by more than 61%*. With the huge increase in craft beer comes many new jobs and personalities in each brewery: Standard hospitality industry positions, mixed together with specialized brewmasters and other brew staff, who must combine creativity with food science and operational expertise, every single day. Creating great beer requires passion for the product but also discipline, reliability, and, above all, attention to detail.

Brewing is traditionally arduous and highly dependent on the expertise and skill of each brewery's staff. But can it be improved, as a process? This paper will examine the most critical factors that impact product quality and production efficiency during fermentation, the typical workflows that brewers use to manage these outcomes, and a look at new paradigms that can help elevate brewing processes. Advancing these processes enables better outcomes for both product and business, and can help individual brewing companies to thrive in today's increasingly saturated and competitive market landscape.

The Challenge: Product Control, Repeatability and Efficiency

The fermentation management process that brewers use today has changed little for thousands of years, but today it has the advantage of some basic measurement tools:

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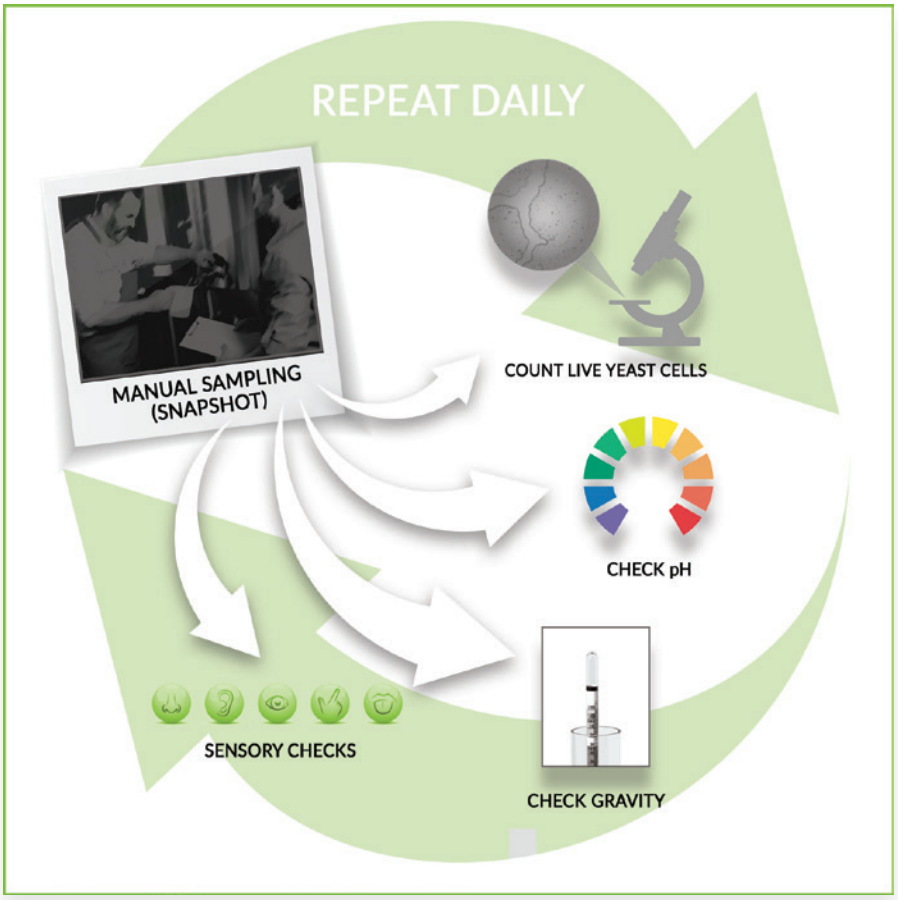
** Number of Breweries, Statistics, Brewers Association, 2017, https://www.brewersassociation.org/statistics/number-of-breweries/*

TRADITIONAL/MANUAL FERMENTATION MANAGEMENT PROCESS



Relying on "snapshot" observations of progress, the success of fermentation interventions can vary widely.

As shown above, trial and error figures highly in the traditional fermentation management process, effectively taking a daily snapshot of the brew's progress. Tasting and other sensory analysis (aroma and color), density/gravity measurement, and chemical (pH, CO_2) assessment, are all methods used to ensure the resulting flavor is both as intended, and also consistent with previous batches of the same beer. Unfortunately, most brewers have discovered the need to intervene during a fermentation (such as pitching more yeast long after the last knockout) or alter the conditions of a fermentation based on an unsatisfactory performance (e.g. changing fermentation temperature, oxygen dose, or yeast pitch rate). Using "snapshot" observations of progress, the success of these interventions can vary widely.

Effects of Manual Fermentation Management

• **Lack of control.** Making changes to any aspect of the fermentation is a very slow and impractical exercise. Since there are so many factors – water chemistry, mash temperature, grain bill, hop selection, yeast strain, pitch rate, fermentation temperature, and finings – changing any single factor will impact the final product, and with no visibility into the fermentation, options for planned changes are very limited. Further, any changes that might help a fermentation are only possible after the fact – once a wort is produced and yeast is pitched, very few options exist to alter the outcome of a fermentation, if one only measures some aspects of the beer occasionally.

• **Diminished Repeatability.** Recreating the same brew over and over again is accomplished today by maintaining the strictest possible management over controllable conditions for each brew, such as water chemistry, wort profile (grain and hops), fermentation temperature, and pitch rate. But what about other uncontrollable or unknown factors? Batches go bad in the fermentation tank for many reasons, and without data to record conditions in detail, the ability to understand and prevent bad outcomes is also very limited.

• **Inefficient Management.** There are many inefficiencies in manual fermentation processes, ranging from the management overhead required to oversee staff with varying experience, to the requirement that a brewmaster or other employee be physically present on-site multiple times during the brewing process, the costly loss of bad batches, the lack of in-house accumulated learning to train new staff, the inability to easily and cheaply develop new beer offerings, and more.

• **"Over-Fermentation" and Other Guesswork.** Over-fermentation is the practice of leaving beer in the tank longer than technically necessary. Although historically, it is the only guaranteed method to avoid under-fermentation – a disappointing and costly error – unnecessarily losing the use of a tank for hours to days is an unfortunate (and also costly) byproduct. But, without visibility into the fermentation process, there is no other reliable method to ensure that a brew is complete.

Batches go bad in the fermentation tank for many reasons, and without data to record conditions in detail, the ability to understand and prevent bad outcomes is very limited.

Why is trial-and-error fermentation management unavoidable? The answer lies in the complexity of fermentation itself and the lack of visibility into driving biological and environmental factors that, if available, could allow a brewer to drive decisions with the analysis of empirical data. Of course, brewers today do rely on some empirical data: primarily temperature, pH, gravity/density and yeast cell concentration. Temperature is often the factor that is typically collected and analyzed automatically, but in isolation, *temperature cannot be correlated with other events inside the fermentation process*. This is a critical point, because although pH and gravity/density can be derived from manual sampling, the data is not continuous and not easily quantified. So, deriving actionable – and better, repeatable – conclusions is not directly possible.

Only a full set of continuous, real-time tank data that depicts the exact conditions for each batch at every stage of fermentation can support an objective blueprint for repeating brews with precision.

The Solution: Real-Time Fermentation Monitoring for Complete Visibility into Each Brew

Real-time fermentation monitoring offers relief from the challenges of traditional, manual brewing management. Gathering and analyzing empirical data collected directly from the tanks throughout the fermentation process provides a brewer with immediate and ongoing insights into each batch that are impossible to obtain through trial-and-error – namely, a direct and fully quantified view of the exact conditions that created a successful (or unsuccessful) product, and thereby the ability to repeat and adjust both controllable and previously uncontrollable factors with great precision.

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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?

pH level

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.

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.

Dissolved Oxygen

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.

Temperature (internal/external)

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.

How Does Real-Time Fermentation Monitoring Help Solve a Brewer's Challenges?

• Control: By measuring the environment within a fermenter, monitoring gives a brewer the opportunity to intervene, should they wish to change a parameter. For example, if pH is too high after an early knockout, the next knockout can be adjusted to normalize the pH. If dissolved Oxygen levels are too low, oxygen could be added. If gravity does not begin to drop during the normal time frame, yeast can be repitched far earlier than if sampling was discontinuous.

• Repeatability: Recording data and providing it back to the user in a convenient manner allows breweries to understand not only the end points of each fermentation (ABV/pH/pressure, etc.), but the manner in which the fermentation proceeded. Watching the process unfold while continuously monitoring gives the brewery the ability to see not just points A & B but exactly how a fermentation went from A to B. This data set is invaluable for reproducing the same conditions in the future.

• Management Efficiency: In the hands of a brewer, automatic data collection and storage helps to allocate resources to other aspects of the work. Lab and QA staff can use the data to improve process or recipe, perform microbiology work, etc. Packaging can be scheduled further into the future, and work schedules can be made more concrete. On-site sampling after hours can be reduced or avoided entirely by off-site monitoring of the data streams.

• Over-Fermentation and Other Guesswork: The end of fermentation can be a subjective endpoint. Beer that satisfies sensory analysis, ABV thresholds, and pH measure can be moved to bright tanks (secondary fermentation), packaged, or sometimes must be left in primary for logistical reasons. Beer that sits in a fermenter or temperature controlled bright tank costs money, both for temperature control and in the unfulfilled potential for producing additional beer. Establishing chemical parameters from sensor data for finished beer minimizes the guess work for establishing endpoints.

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What Are the Benefits of Real-Time Fermentation Monitoring to the Brewing Organization?

Process control

Problems in fermentation speed can often be attributed to an incompatibility between the beer and the yeast tasked with fermenting it. Understanding the need for certain physical parameters to be within defined ranges at particular points within a fermentation allows a brewery to confidently assess whether each fermentation is in line with expectations. When conditions are out of range, brewers can exercise the capability to affect the outcome with mid-fermentation changes, in-process, correcting problems and then continue to monitor the outcomes. Without reliable data, a mid-fermentation correction or addition would not be possible; however, with real-time data at your fingertips, taking action to improve or correct a fermentation is now possible.

Product control

Tighter process control and a deeper understanding of the finished product will allow a brewer to sell or distribute a product with a known chemical/physical profile. This profile can be used as a quality assurance step before each batch is released. This data helps to more precisely replicate a seasonal release or a product brewed at multiple locations, or simply to make your flagship product at its best.

Labor control

Automated sampling has a much lower labor requirement than discontinuous manual sampling. This frees employees to work on other brewery goals, and can also allow a lighter workforce overall. Data from fermentations helps to empower precision in the entire brewery schedule, from brewing all the way to cellaring and packaging.

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Profit control

Measurable benefits to the business are many. Less labor and effort in measurement means less cost and a more efficient labor force. Opportunities to correct minor mistakes before they become major problems means less tank time, which adds up to more fermentations using the same equipment. Precision measurements of physical and chemical parameters gives the brewery the information needed to make the same beer every time to satisfy the discerning consumer. And much more.

BREWMONITOR®

Introducing the BrewMonitor® System from Precision Fermentation: The World's First Real-Time, Comprehensive Fermentation Monitoring Solution

Leverage IoT Technology for Better Product and Better Process

The BrewMonitor System, from Precision Fermentation, is a real-time, end-to-end fermentation monitoring and analysis solution, that is purpose-built to enable brewers to increase quality and profitability through greatly enhanced fermentation-process control. The BrewMonitor System brings the "Internet of Things" (IoT) to the brewing process by collecting fermentation data *from your existing tanks*, and streaming it to your PC, tablet or smartphone, in real-time.

The BrewMonitor System's pre-built dashboards transform your tanks into a powerhouse of insight that finally puts brewing control into your hands – ensuring brewed-product quality, increasing your production options, and saving you time and money.

Critical Measurements

- Dissolved Oxygen
- pH
- Gravity
- Pressure
- Temperature (internal & external)
- Conductivity

Solve Brewing Problems

- Fermentation failures
- Demand outstripping production
- Quality control issues
- Ensured consistency and reproducibility
- Shrinking profits
- Lack of data

For more information about the BrewMonitor System, contact Precision Fermentation:
info@precisionfermentation.com / 919.717.3983

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 entirely replaces trial-and-error measurements and enables excellent product and business outcomes.

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