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A Simple Fermentation Monitoring and Control System*

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Introduction

Monitoring beer or other alcoholic fermentations usually means measuring extract and alcohol content. While other parameters such as yeast growth, nitrogen source uptake, and flavor development are also relevant, brewers generally sample the fermenting wort intermittently and measure the residual extract off-line. Fermentation is deemed to be proceeding "properly" when the wort attenuation follows the expected pattern and reaches final attenuation levels that are either desired, or when no further attenuation is noticeable.

Here, we present a simple approach for continuously monitoring beer and other alcoholic fermentations by measuring carbon dioxide evolution. CO_2 evolution rates are used to estimate extract consumption and alcohol production in a continuous manner with simple and relatively inexpensive instrumentation (Fermentation Automation Technology, *FermAT*). The technique can be used to "fingerprint" fermentations in a brewery and recognize early, any deviations in fermentation performance.

Materials & Methods

QuantiPerm's FermAT instrument was used for monitoring several brewery fermentations ranging in size between *20-50 bbls*. Laboratory fermentations (*100 mL up to 10 gal*) were monitored using *QuantiPerm*'s FMS system that was otherwise identical to FermATs but designed for smaller scale fermentations. Several ales and at least one lager style fermentation were studied. The FermAT instrument measures carbon dioxide evolution and estimates the amount of ethanol produced stoichiometrically. The amount of real extract is then determined and results are reported in the customary apparent extract units using published correlations. FermAT instrument sends fermentation data wirelessly from the fermentor being monitored to a remote host system. The host software collects data simultaneously from numerous fermentations for plant-wide fermentation monitoring and control over a wireless network.

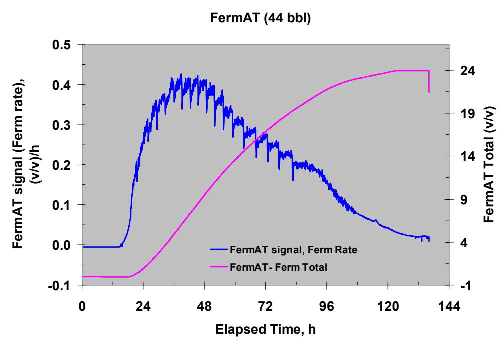

Fig 1. Typical fermentation process "fingerprint." After an initial lag, cell growth and glucose consumption ramps the fermentation off to a peak fermentation rate. Once glucose is exhausted, fermentation shifts to maltose and then to maltotriose with successively falling rates. The times and magnitudes of various features constitute the fermentation fingerprint unique to the specific beer style and the fermentation. The rapid variations in the FermAT signal arise from CO_2 supersaturation being released in semi-regular bursts during the fermentation. The occurrence and frequency of these phenomena are closely related to the fermentation rates, yeast, and the geometry of the fermenting vessel and brew size.

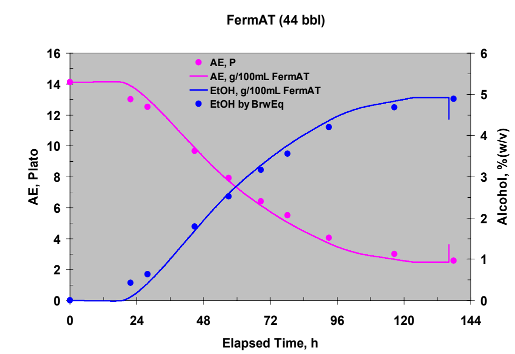

Fig 3. Continuous monitoring of the fermentation of Fig.1 for alcohol production and extract attenuation in real-time. Symbols represent traditional off-line measurements from grab-samples.

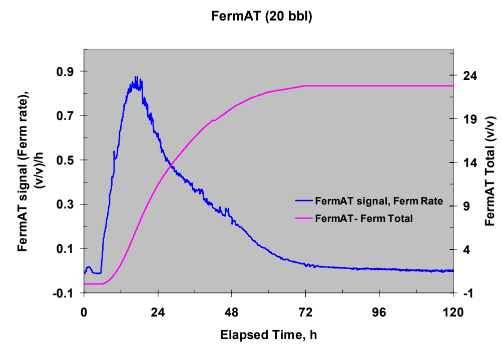

Fig 2. Another example fermentation fingerprint. A faster specific fermentation rate as well as smaller fermentation volume substantially relieved CO_2 supersaturation.

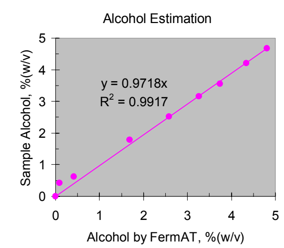

Fig 4a. Typical goodness-of-fit: Alcohol determined by FermAT agrees closely with values determined with off-line analyses.

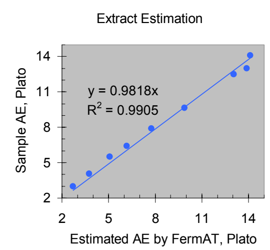

Fig 4b. Typical goodness-of-fit: Extract determined by FermAT agrees closely with values determined with off-line analyses.

Results and Discussion

CO_2 evolution during fermentation is closely coupled to extract consumption and alcohol production. We have found that we can readily estimate alcohol production and extract consumption continuously during fermentation using relatively simple instrumentation *(Figs. 3-4)*.

The technology (FermAT) can bring out a wealth of other information in real time to help control fermentation processes. A fermentation "fingerprint" such as the example shown in *Fig. 1* will diagnose deviations from "normal" fermentations for corrective action. Prolonged lag times can be identified early.

Peak fermentation rates for example, can indicate fermentor over-foaming potential, alerting the operators to the need for corrective action to mitigate the loss of flavors and product, leading to significant cost savings.

Additional potential applications of FermAT system include:

- Automate onset of CO_2 collection from a fermentor while minimizing risk of air contamination.
- Carbonate the beer within the fermentor to any target carbonation without using external (e.g., purchased) CO_2 gas thus lowering costs.
- Control of off-flavors produced during fermentation by selectively controlling supersaturation release and venting from the fermentor.

Conclusions

Monitoring CO_2 evolution using FermAT during fermentation is a powerful tool for real-time fermentation process identification, process and product quality control and overall cost savings.

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* Patent pending