PROCESS APPLICATION NOTE 1057

Inline monitoring of fermentation processes

Determination of multiple parameters in a fermentation broth for bioethanol production

The concern for the development of alternative and renewable fuels has increased over the past several years. In particular, bioethanol is believed to be a great alternative for fossil fuels since it can be made from products that contain sugar, starch, or lignocellulosic biomass (e.g., kernel corn).

According to the Renewable Fuels Association, 29 billion gallons of ethanol were produced globally in 2019. Ethanol is mainly produced via the process of fermentation. This process transforms sugars within the biomass into ethanol through the use of yeast. Though this process is well established, it is still highly desirable to implement new technologies for cost reduction and process enhancement. It is well known that the quality of the feedstock can vary from season to season which will require ethanol producers to adapt to each batch.

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Process Analytics

INTRODUCTION

Many parameters need to be monitored during ethanol production in order to guarantee high yield and top quality ethanol. Traditionally, the amount of reactants, products, and byproducts are measured in the laboratory after taking a sample out of the process. However, manual laboratory methods can give long response times in case of process changes (e.g., temperature, reaction mixture, moisture levels), and sample preparation (dilution, filtration, pipetting) can introduce errors altering the precision of the analysis. Additionally, it can be quite cumbersome since multiple techniques and/or operating methods are required to analyze the following parameters: ethanol, solids (enzymes), dextrin (DP4), maltotriose (DP3), maltose, moisture, glucose, lactic acid, glycerol, and acetic acid (Table 1).

In any chemical process, «real-time» monitoring allows for optimal process modeling and control, which means enhanced throughput, reproducibility, and productivity.

For instance, tight monitoring and control over the various sugars present (glucose, maltose, DP3, and DP4) throughout the fermentation process is necessary to understand the breakdown pathway of the starch (glucose generation) present in the mash and optimize ethanol production. Understanding the sugar pathway enables the right dosing of «enzymatic mix» and «yeast blend» to the mash in the slurry tanks to accelerate breakdown. Therefore, optimizing the enzyme and yeast blend is crucial for this process. These are the highest consumable costs for ethanol production and significantly affect the rate of production and final yield of ethanol.

Inline analysis provides «real-time» process data, allowing producers to determine the optimal fermentation time (Figure 1) and adjust parameters such as impeller spin rate and tank temperatures to influence the production of more ethanol from the same materials. A reduced fermentation time means being able to carry out more daily fermentation batches, which results in more profits.

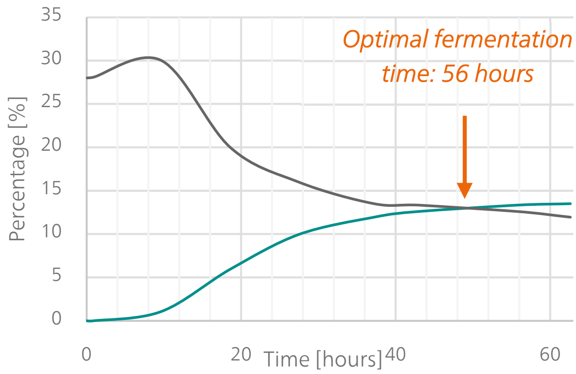

Figure 1. Trend chart for an ethanol fermentation process (green: ethanol, grey: solids [enzymes]).

For optimal fermentation, multiple parameters must be monitored in a safer, more efficient, and faster manner, which is possible via inline analysis with reagent-free near-infrared spectroscopy (NIRS) (Figure 2). Metrohm Process Analytics offers the NIRS XDS Process Analyzer (Figure 3) which enables direct comparison of «real-time» spectral data from the process to a reference method (e.g., HPLC) to create a simple yet indispensable calibration model used to produce quantitative results during the fermentation process.

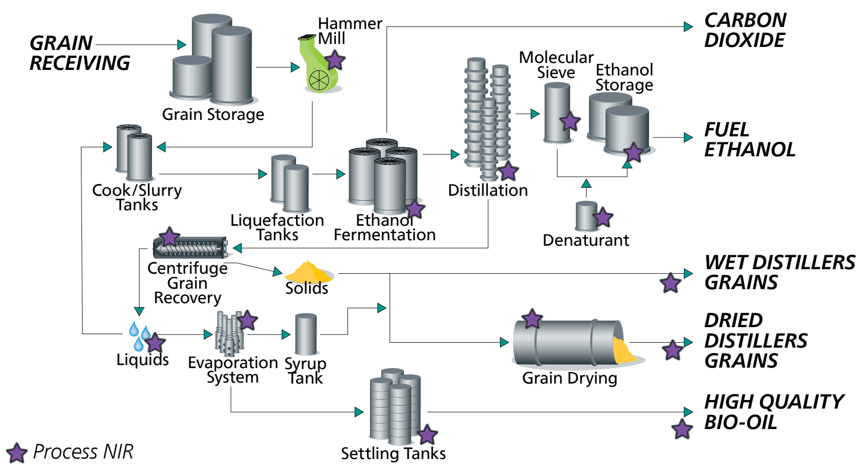

Figure 2. Illustration of a typical dry-grind ethanol process from grains with purple stars noting suggested process NIR analysis points.

APPLICATION

Measurements can be performed directly inline thanks a dedicated immersion probe coupled to microbundle fibers. Such a combination allows the NIR measurement of samples with suspended solids and the presence of bubbles, without requiring filter screens around the probe that may become clogged during the fermentation. Where a bypass or fast loop is available, using a flow cell is recommended so that solid matter can be removed prior to measurements.

TYPICAL RANGES

Table 1. Key parameters to monitor during ethanol fermentation

Parameter	Range (%)
Ethanol	0–15
Glucose	0–8
Maltose	0–7
DP3 & DP4	0–15
Acetic acid	0–0.5
Glycerol	0–1
Lactic acid	0–0.25

Figure 3. NIRS XDS Process Analyzer

REMARKS

An appropriate range of samples covering the fermentation process is needed to build a calibration model. These samples will be analyzed via NIRS and also via a primary reference method. The precision of the NIRS data is directly correlated to the precision of the reference method.

OTHER RELATED DOCUMENTS

- Real-time monitoring of hyaluronic acid fermentation by in situ transflectance spectroscopy.

CONCLUSION

Traditional analysis methods do not provide the sufficient «real-time» information about the fermentation process performance. Inline analysis can provide faster information about the process, which is ideal for rapid feedback and better process throughput (approximately every 30 seconds).

NIRS analysis enables the comparison of «real-time» spectral data from the process to a primary method (e.g., titration, Karl Fischer titration, HPLC, IC) to create a simple, yet indispensable model for your process requirements. Gain more control over your production with a Metrohm Process Analytics NIRS XDS system, capable of monitoring up to 9 process points with the multiplexer option.

BENEFITS FOR NIRS IN PROCESS

- Safe production due to «real-time» monitoring and no exposure of operator to chemical reagents
- More savings per measurement, making results more cost-effective
- Increased product throughput, reproducibility, production rates, and profitability (optimize fermentation time

Analytes:	**Alcohols; Moisture; Carbohydrates**
Matrix:	**Fuels – biogenic; Plant biomass**
Method:	**Process Analysis; Spectroscopy (NIRS/Raman)**
Industry:	**Petrochemicals & biofuels**

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