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Using the IRmadillo to detect Lactic and Acetic Acid in Ethanol Fermentations

Key Words

- Ethanol
- Lactic Acid
- Acetic Acid
- Bacterial Infections
- Yield Maximization
- FTIR

Abstract

Bacterial contamination in ethanol fermentation tanks can have damaging impacts, in mild cases leading to a drop in ethanol yield, and in severe cases requiring plant slow down or even shut down and sterilization resulting in significant loss in revenue. Detecting the signs of these contaminations early allows the operator to limit the impact and avoid significant losses.

Introduction

Lactic acid bacteria are the most common biological contaminants occurring in the fermentation of corn for ethanol production. The growth of these bacteria reduces the sugar available for conversion to ethanol as well as the micro-nutrients required for optimal yeast growth. This results in reduced ethanol production. In addition, accumulation of bacterial by-products, such as lactic and acetic acid, inhibits yeast growth and may result in a "stuck" fermenter that requires costly slow downs/shut-downs. Infections can be halted or minimized through the use of expensive antibiotics. The sooner an infection is identified, the less antibiotics are required to counter the infection. Early detection of infections is therefore key to maximizing yields and minimizing antibiotic use.

Spectroscopy as an Analytical Tool

Spectrometers allow continuous and detailed measurement of chemical concentrations in real time. The majority of process spectrometers are based on near infrared light, which is fundamentally less informative than mid infrared light. Conventional mid infrared spectrometers (which often use a Fourier transform and so are referred to as "FTIR spectrometers") have sensitive moving parts and fragile fibre probes making them wholly unsuitable for production environments such as ethanol refineries.

The IRmadillo is a process analyser that uses FTIR spectroscopy but with static optics, removing the need for moving mirrors or fibre probes, dramatically improving stability, reliability and ruggedness.

Example Use Case - Lactic Acid Detection

This application note presents data from an ethanol plant in Iowa, measuring the concentration of lactic and acetic acid during fermentation. The plot below (Fig 1) shows measurements over time for five consecutive fermentations. Fermentation one experienced a significant bacterial infection resulting in a spike in lactic acid to 1.4 %w/v (normal is approx 0.2 %w/v) and a spike in acetic acid of approx 0.3 %w/v (normal is approx 0 %w/v). Ethanol at drop was 7 %w/v, well below the normal of approx 14 %w/v. This reduction resulted in a loss of around $110k of ethanol. We can also see that, over the following four fermentations, the levels of lactic acid are elevated, but decreasing, and the ethanol drop value is lower than normal, between 12 and 13 %w/v. Only by the fifth fermentation does lactic acid drop to more normal levels and ethanol at drop return to expected levels.

While this example shows a severe level of infection, the IRmadillo is also capable of detecting far smaller spikes in lactic and acetic acid, of around 0.5 %w/v and 0.2 %w/v, respectively, and with similar levels of accuracy.

With the IRmadillo installed, the operator is able to see the rapid increase in lactic and acetic acid levels and is therefore in a position to correct the course of the fermentation, improving yield very significantly in the first fermentation and also in the following fermentations, albeit to a lesser extent.

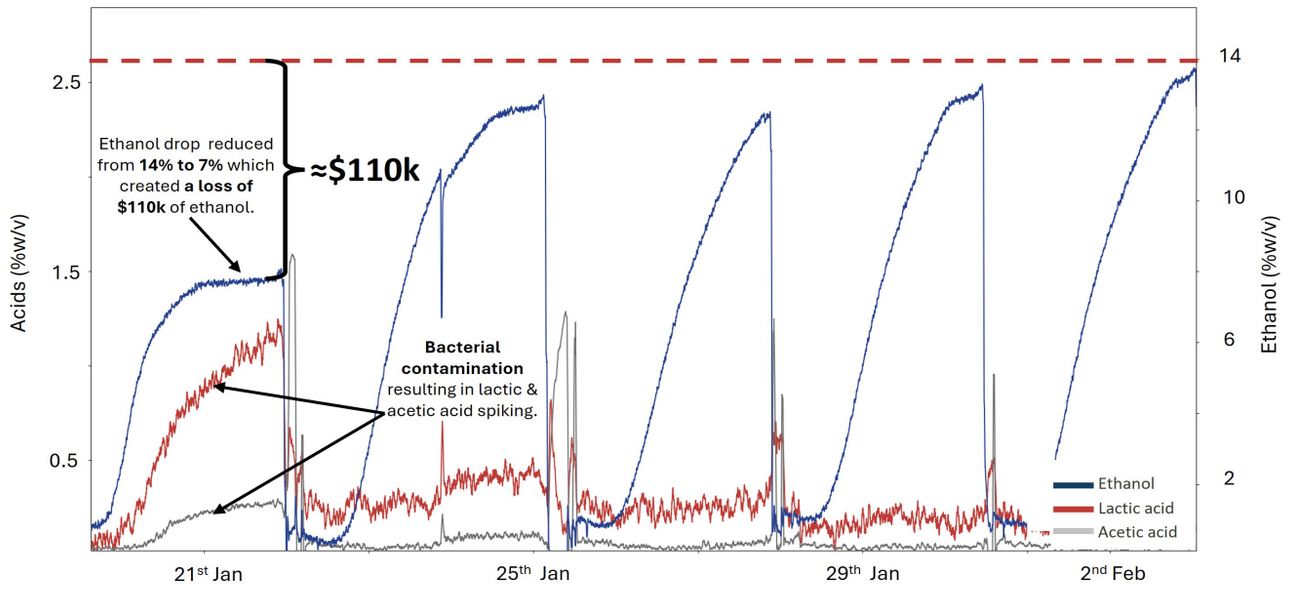

Figure 1: Concentration trace over five consecutive fermentations, showing the results of a bacterial infection in fermentation one with elevated lactic and acetic acid levels and reduced ethanol production. The subsequent four fermentations also show evidence of infection with an ongoing negative impact on ethanol yield.

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Chemical	Range (%w/v)	Accuracy (%w/v)
Ethanol	0 - 15	0.227
Lactic Acid	0 - 1.48	0.050
Acetic Acid	0 - 0.31	0.013

Table 2: Measurement accuracy for species of interest in fermentation.

Conclusion

Bacterial infections, while relatively rare, can be very damaging to process and plant economics when they occur. The ability to manage an infection and minimize its impact on yield relies on catching the infection early while remediation is still possible. The IRmadillo spectrometer has proven to be an accurate early-warning system for bacterial infections, allowing operators to treat the infection early and reduce any loss in yield.

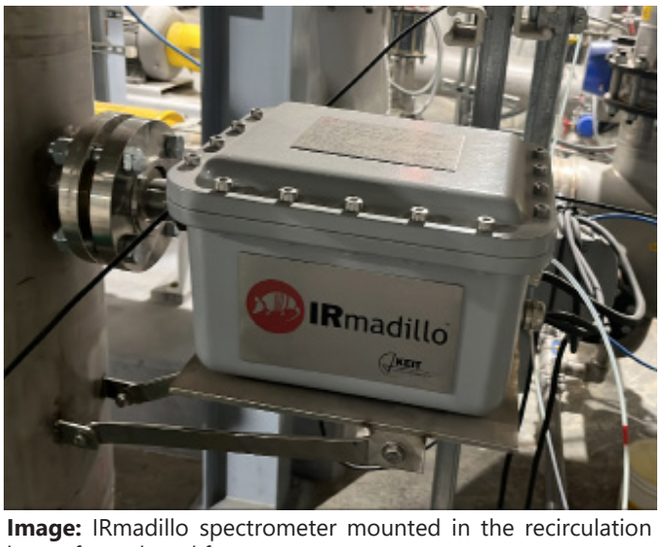

Image: IRmadillo spectrometer mounted in the recirculation loop of an ethanol fermenter

Keep in Mind

The IRmadillo can be calibrated to measure a large range of chemicals at the same time. This work shows the use for lactic acid, acetic acid and ethanol measurements. We also measure sugars, glycerol, FAN and PAN in fermentation but the IRmadillo can also be calibrated to measure in other parts of the process including distillation, liquefaction and propagation.

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