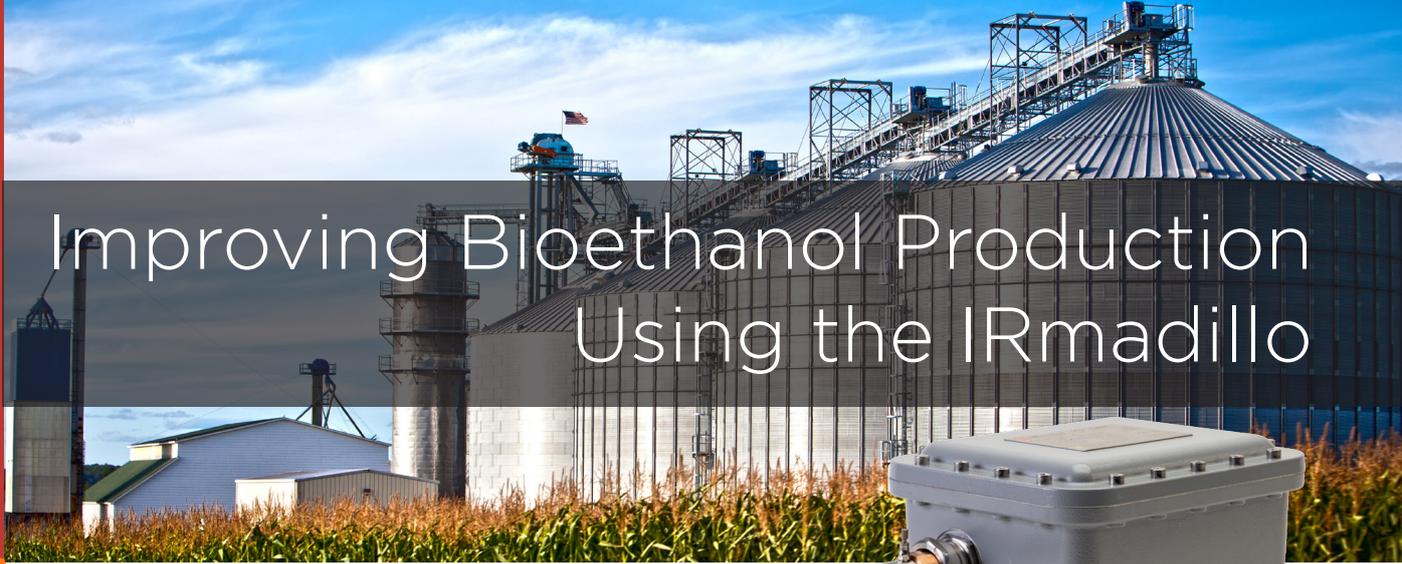


Improving Bioethanol Production Using the IRmadillo



What is it?

The IRmadillo is an in-line process analyser based on infrared light. It works by using a technique called FTIR spectroscopy to monitor the concentration of different chemicals with great accuracy in real time.

One thing that makes it different to other FTIR analysers is that it is robust. It's built to last. Not only last, but it installs directly into your process lines & vessels and performs continuously in any production environment. Fit it and forget about it!

Real-time tracking of sugars, ethanol & acids in fermentations

The IRmadillo monitors what's going on in your fermentation as your sugars convert into ethanol in real time.

There are three main ways you can benefit from better fermentation monitoring with the IRmadillo:

- **Improve your yield**
- **Improve your capacity**
- **Improve your productivity**

It's well known that once the yeast has finished consuming sugars to produce ethanol, it starts consuming the ethanol it's produced – this is eating into your profits. Knowing when the yeast has finished is key to maximising profitability.

The problem with HPLC sampling, because of the time delays in getting a lab result and frequency of sampling, you're never entirely sure if the fermentation has finished until you can either see the ethanol concentration stabilise or decrease over two extractions.

Imagine the cost savings of knowing your fermentation status immediately.

Spot problems early, and fix them

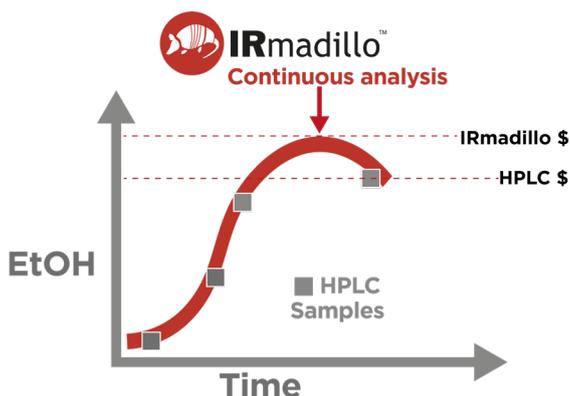
The IRmadillo lets you see exactly what's going on in your process. If something goes wrong, you have time to fix it and not lose the batch.

Monitoring lactic acid levels: If lactic acid rises early on, it may indicate potential contamination. If you've spotted an infection early; you're much more likely to be successful in resolving it with antibiotics. You can also be much smarter with your use of antibiotics, driving down costs.

Monitoring endpoint: You can ensure fermentation is finished at the optimum point so that sugars are fully converted to ethanol (not lactic/acetic acid byproducts) and that there is no residual fermentable sugar left.

Measure sugar composition in mash: Real-time analysis of your mash allows consistent and accurate feed of sugar amounts to fermenters and optimal enzyme dosage. For example, you may see your DP4 isn't breaking down into DP3 and maltose as quickly as expected: if the enzyme is unhappy, or wasn't added, then that's a batch wasted. If you can spot it quickly enough with the IRmadillo, you've got time to fix it and optimise your main fermenter yield.

Detection of 'stalled' fermentations – You see glycerol levels spike: stressed yeast is always bad. This is your alert to double check everything is as it should be; if not, you've got time to resolve it and save the batch.



"The IRmadillo mid-infrared spectrometer is the most robust instrument that we have seen in the market for real time monitoring of ethanol fermentation."

Julian Parra, Engineering and Technology Manager

Pannonia Bio

Maximise efficiencies through trustworthy, real-time results

You may well be running your own improvement programs to maximise production and efficiency. But without a trustworthy, on-line measurement, improving fermentation performance may be slow and almost impossible.

The IRmadillo gives you the level of information you'd expect from a lab measurement, but coupled with on-line analytical capabilities, it provides you continuous updates. This means you can make a change and get real-time updates on what it does to your process.

What will I see when I use it?

The IRmadillo software contains its calibration and runs the measurement in real time. This means you'll get an update on chemical concentrations (normally in %wt but that can be changed to whatever units you're used to using) over the whole process.

The graph below shows an example sucrose fermentation over 20 hours to give a representation of the output. These batch trends can then be exported into text files for further analysis by your team for process optimisation if needed.

The IRmadillo will also send concentration data to your DCS or SCADA in real time. The standard communications protocols are OPC-UA or Modbus (TCP/IP and RS-485 and RS-232 are all supported). Additional protocols are available if needed.

How do I insert the probe into my process, and what about cleaning it?

The IRmadillo is fitted with a diamond tipped probe, meaning it can happily survive clean in place (CIP) practices with caustic washing. It is rated to ~ 300 psi, so will withstand direct contact with the caustic wash stream. It has an operating temperature range of up to 220°C (over 400°F) if you needed to steam sterilise.

There are a variety of different ways to seal the probe in your tank, but a simple port and flange assembly will seal the probe into your tank or vessel. We can also supply an intermediate ball valve to add an extra level of protection should you ever need to remove the probe mid-way through a fermentation.

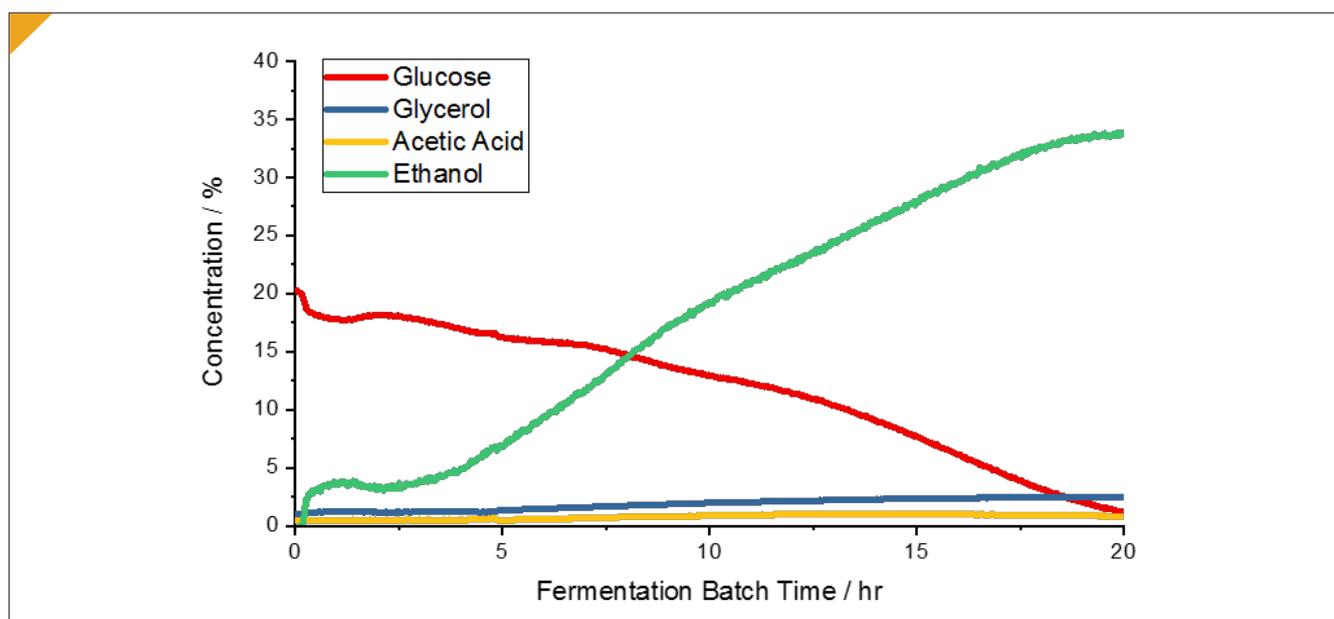
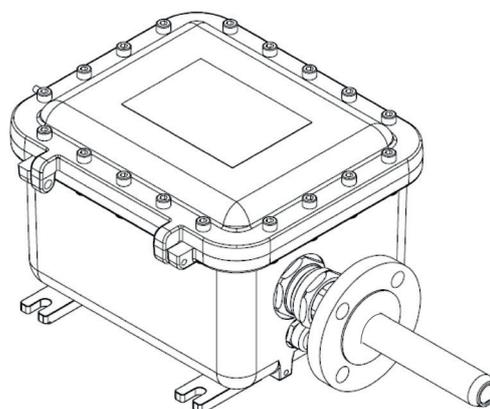


Figure 1: Sucrose fermentation process monitored over 20 hours with the IRmadillo. You can clearly see the change in concentrations of glucose, glycerol, acetic acid and ethanol over production time.

I tried FTIR before and it didn't work...

Don't confuse FTIR (mid-infrared) with FT-NIR (near infrared). Infrared light comes in a few different wavelengths, and there was a big push a few years ago to get near-infrared instruments (FT-NIR) into production facilities.

Near infrared is very different to the mid-infrared light that the IRmadillo uses (FTIR). FT-NIR instruments don't actually look directly at the chemical bonds, but at "overtones". This is a bit like trying to recognise someone from their shadow rather than looking at their face. It gives you a rough idea who it is, but to get full understanding you need the full picture.

We give an example of this in the graph below, showing a comparison of the IRmadillo with an FT-NIR instrument monitoring glucose, fructose and ethanol during a sucrose fermentation.

The FT-NIR has much bigger error for the glucose and ethanol, and cannot monitor the fructose at all. This means it would never be able to differentiate between DP4+, DP3 and maltose - while the IRmadillo can clearly distinguish between the sugars and all other components.

What's the performance of the instrument?

The exact performance depends on the process you use, but a typical error of measurement is shown below.

Chemical	Measurement error / %wt
DP4+	0.90
DP3	0.35
DP2/Maltose	0.45
DP1/Glucose	0.36
Lactic Acid	0.015
Glycerol	0.06
Acetic Acid	0.0064
Ethanol	0.68

The IRmadillo does not try to out-perform HPLC for error and detection limits, but it can give so much more information over a much shorter time. It also tells you when to take an extract for HPLC - using your staff much more efficiently and effectively.

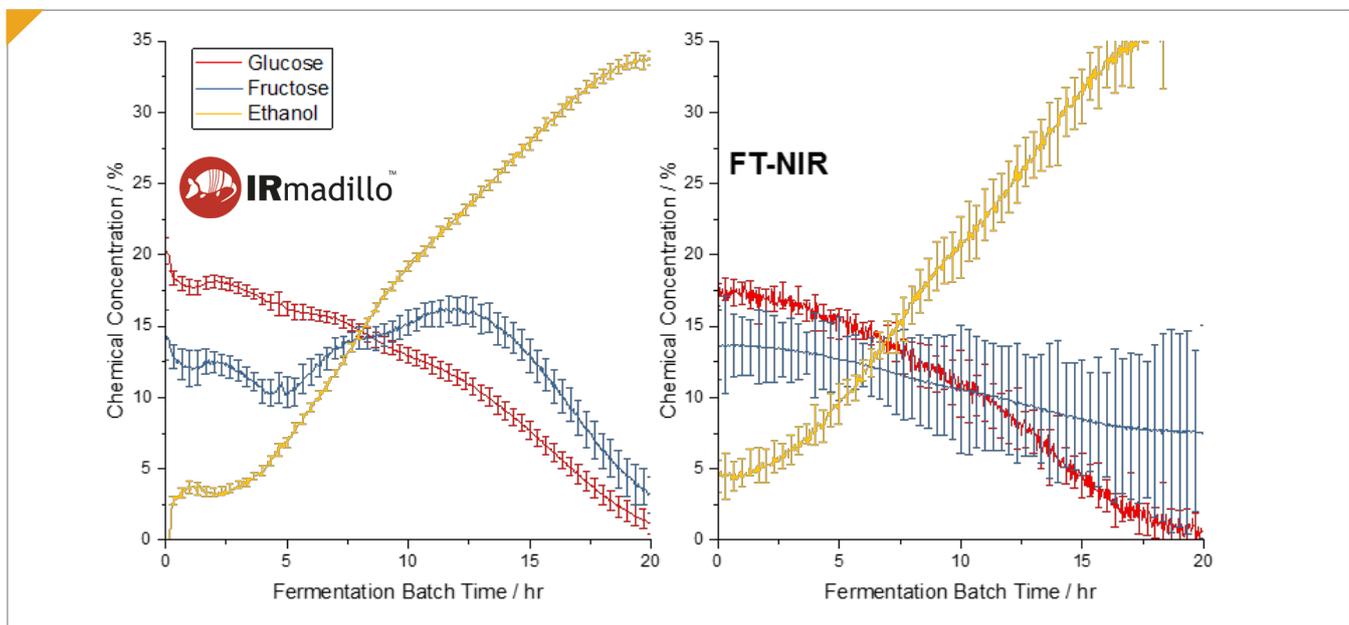


Figure 2: Comparison of the mid-infrared IRmadillo vs. near infrared (FT-NIR) monitoring a fermentation process. Note the much larger error bars on the FT-NIR analysis (right) making differentiation nearly impossible between glucose (red lines) and fructose (blue lines), while the IRmadillo (left) clearly defines each component.

