Fermentation process of Federweißer investigated *via* Mid-IR and UV-Vis Spectroscopy

In this Application Note, the fermentation process of *Federweißer*, a fresh wine, is investigated using Mid-Infrared (Mid-IR) spectroscopy, revealing the formation of alcohol through characteristic ethanol peaks.

Authors

Andrea Teuber[1],
Alexander Novikov[2],
Tatiana Sakharova[2],
Boris Mizaikoff[3],
Dr. Viacheslav Artyushenko[2],
Dr. Stefanie Foerster[2]

[1]Art Photonics
Sedanstraße 14, 89077 Ulm,
Germany

[2]Art Photonics
Rudower Chaussee 46, 12489 Berlin,
Germany

[3]Hahn-Schickard
Sedanstraße 14, 89077 Ulm,
Germany

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Introduction

In early autumn, shortly after the grape harvest, a light, slightly sparkling young wine known as *Federweißer* becomes available. Traditionally made from white grapes, it can also be produced from red grapes - though in that case, it is rarely known as *Federroter*. As a result, *Federweißer* has become the general or umbrella term used for both variants of such beverage.

Federweißer is characterized by its ongoing fermentation process, during which natural sugars are converted into alcohol by yeast. Because the wine is unfiltered, it appears cloudy. The alcohol content varies as fermentation progresses, typically reaching up to 11% by volume. To slow down this process and preserve the beverage, it should be stored upright in a cool, dark, and oxygen-free environment - commonly in a fridge.

Interestingly, *Federweißer* bottles are sealed with a special screw cap that lacks an inner sealing insert. This design allows carbon dioxide gas, generated during fermentation, to escape - preventing pressure buildup. However, this also means the bottles must always be stored upright.

Figure 1 Exemplary Laboratory Setup with Bruker Alpha, Fiber Coupler for Bruker Alpha and Diamond ATR Fiber Probe.

To monitor the fermentation process, Mid-Infrared (Mid-IR, MIR) spectroscopy combined with fiber-based spectroscopy offers a powerful, non-destructive solution with no need for additional sample preparation. In this study (see **Figure 1**), we used the Fiber Coupler Accessory from art photonics, integrated with a Bruker Alpha spectrometer, to enable fiber-based MIR measurements. A diamond ATR (Attenuated Total Reflectance) fiber optic probe was employed for direct measurements. This setup allows access to the unique molecular fingerprint region of the sample, providing detailed and reliable insights into the fermentation process in-situ in real time. Spectral acquisition was performed with 2 cm^{-1} resolution and 64 scans, no baseline correction applied.

Interestingly, by combining Mid-Infrared (MIR) spectroscopy with Ultraviolet-Visible (UV-Vis) spectroscopy, additional complementary spectral information can be obtained. UV-Vis spectroscopy can be used for obtaining information about origin of the grapes or ingredients such as flavones/non-flavones or glucosides. For UV-Vis measurements, a transflection probe from artphotonics was used, where the optical path length can be adjusted.

To monitor the fermentation process, a fresh *Federweißer A* (aka *Federroter*) was purchased on day 1 and measured on days 2, 6, and 22. This sample was stored at room temperature without cooling. A second sample, *Federweißer B*, was initially stored in a fridge for one day before following the same measurement schedule.

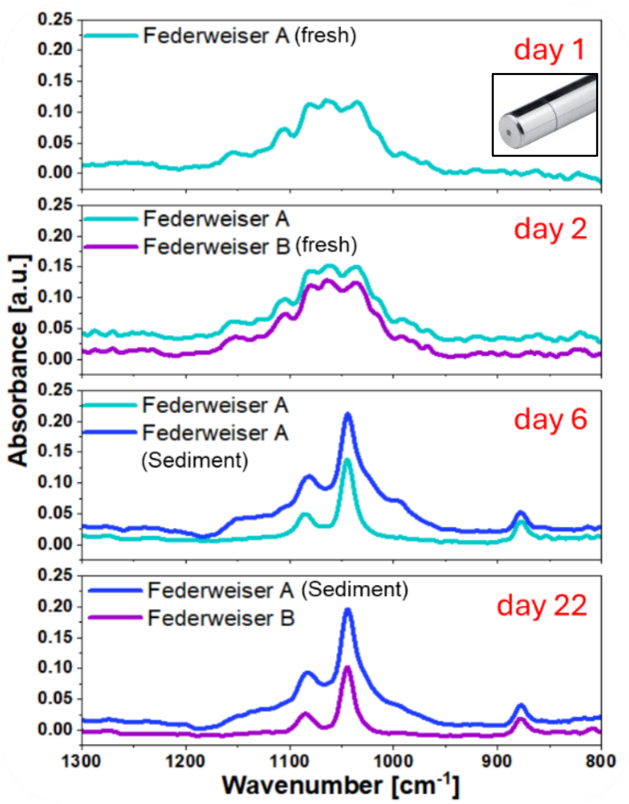

Figure 1. Monitoring the fermentation process of Federweißer via MIR spectroscopy. ATR probe tip is shown in the insert.

Figure 2 shows the spectral evolution over time. The formation of ethanol is evident by the appearance of characteristic ethanol peaks at 1084 cm^{-1}, 1043 cm^{-1}, and 876 cm^{-1}, which become clearly visible by Day 6. This indicates that the fermentation of sugar to alcohol occurs between days 2 and 6.

In **Figure 3**, the UV-Vis spectra of the freshly opened Federweißer can be seen. Initial measurements were challenging due to excessive bubbling in the freshly opened bottles, which interfered with light transmission. Once the bubbles disappear, characteristic absorption features of red wine become apparent.

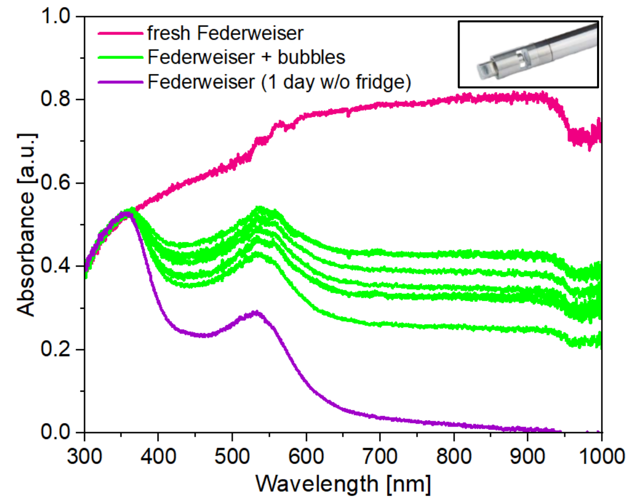

Figure 3. UV-Vis spectra of *Federweißer* during fermentation. Transflection probe tip is shown in the insert.

Since both MIR and UV-Vis measurements were performed in parallel using separate fiber probes, a more integrated approach can be used for future studies. The use of **Fiber Combi Probes**, which combine MIR and UV-Vis capabilities in a single unit, offers several advantages. These include a significantly reduced system footprint and the ability to perform simultaneous measurements on the exact same sample volume, improving data correlation and simplifying setup, especially in space-constrained environments such as bioreactors.

Conclusion

The fermentation process of *Federweißer* can be monitored using a combination of Mid-IR and UV-Vis fiber spectroscopy. When integrated into a single fiber probe, this dual-technique approach provides a compact, efficient solution ideal for in-line monitoring in biotechnological and pharma applications. The ability to obtain complementary molecular and compositional information in real time makes this method highly valuable for fermentation analysis and process optimization.

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artphotonics.com

Find out more at **artphotonics.com**

art photonics GmbH
Rudower Chaussee 46
12489 Berlin Germany

Phone +49 (0) 30-6779 887-0
sales@artphotonics.com
www.artphotonics.com