Living Optics

Picking the Perfect Grape with Hyperspectral Imaging

A lot of knowledge, experience, and intuition goes into winemaking. This includes choosing the right time for harvesting. The point when picking the grapes from the vine will lead to the perfect tasting wine.

For millennia, winemakers have debated different methods of finding the sweet spot for harvesting. Tracking the colour, size, and taste of their grapes. Monitoring the local wildlife and looking for an increase in birds and other animals interested in their ripening berries. A traditional method was to harvest precisely 100 days after the first flowers bloom.

But while there may be merit in the methods handed down by previous generations, changing conditions make harvesting time a more difficult and consequential decision that requires a more scientific approach. A bad harvest can have significant financial consequences in the current competitive wine industry. Plus, with climate change affecting weather patterns, the old ways may be becoming less and less reliable. Farmers must adapt to the weather conditions they are given rather than rely on tradition.

Thankfully, analytical methods can provide the data needed for improved harvesting decision-making.

Measuring Grape Maturity for Harvesting

Wine quality is extremely dependent on grape maturity at the time of harvest. Small variations can lead to dramatic drops in quality, and research shows that grape maturity can drop by as much as 10% in a week. Therefore, viticulturists need a quick and reliable method to regularly quantify grape maturity to help find the optimal harvesting times.

There are a number of measurable parameters related to grape maturity that they can track, including:

- Sugar levels, usually measured as total soluble solids (TSS) or °Brix (°Bx)
- Acidity, often expressed as pH and titratable acidity (TA)
- Concentrations of the main organic acids in the berry (e.g., tartaric and malic acid)
- Concentrations of other organic compounds specific to red varieties of grape (e.g., anthocyanin and phenol)

The primary technique for assessing these parameters is picking samples of berries for wet chemistry analysis. Taking measurements of the grape juice itself. This approach is destructive and time-consuming. Farmers have to spend time picking and preparing their samples, and the testing squeezes the grapes for their juice.

Given the time it takes to receive the results from the chemical analysis, there is an inherent lag in the measured and real-world parameters. With a tight window for optimal harvesting and the dramatic swings in quality discussed above, any lag creates significant discrepancies.

Rather than picking and squeezing the grapes to measure maturity, what if we could measure these parameters immediately by just looking in more detail, taking a smarter image of them?

Hyperspectral Imaging – A Faster, Non-Destructive Method of Quantifying Grape Sugar Levels

Hyperspectral imaging uses many more wavelength bands to capture light, seeing things we can't see with just our eyes or a normal RGB camera. This enables spectral analysis that can quantify a range of parameters, including grape sugar levels.

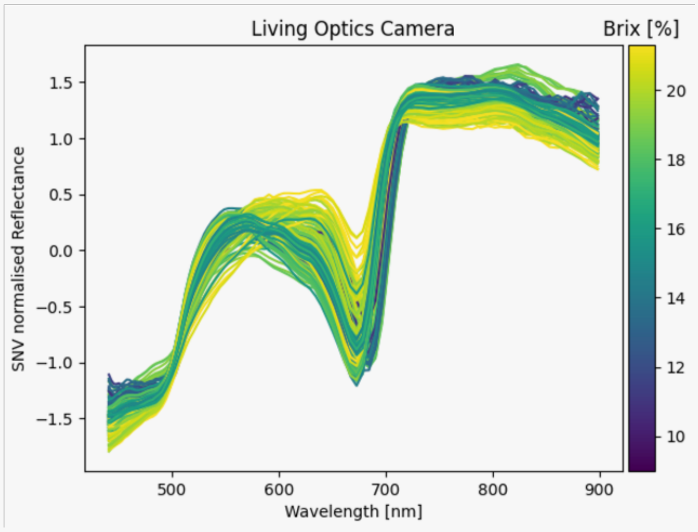
By replacing wet chemistry techniques, hyper-spectral imaging could provide sugar-level data without specialised labour or reagents. The method has the potential for high-throughput, low-cost grape testing that is non-destructive. All it does is image the grape bunches, no squeezing for chemical analysis.

To make this a reality, we validated that the Living Optics Hyperspectral Camera could quantify grape sugar levels non-destructively in the lab, then we proved it can be done as easily and reliably in the field, correlating the spectra from the Living Optics camera to a single Brix value. With 3-4 drops of juice extracted from sampled grapes a handheld digital refractometer was utilised to measure BRIX sugar content with an accuracy of +/-0.2°Bx. These data covered a wide range of 10.2°Bx to 21.3°Bx across the sampled grapes.

Results From the Living Optics Camera

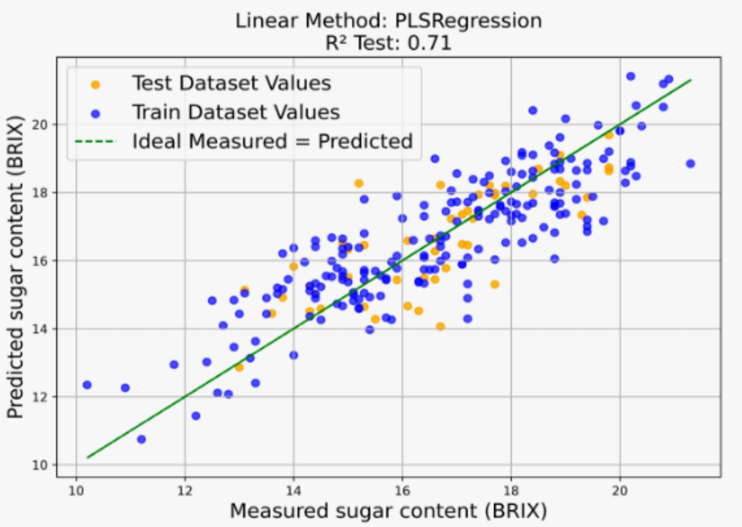
Below is a plot of each grape's mean spectra and the colour associated with the measured sugar content. A number of methods were tested to develop a linear regression model that could convert the spectral data to a Brix value using the refractometer results.

A partial least-squares regression (PLSR) method was chosen to produce the linear predictive model due to the high number of collinear observed variables in the spectral data.



The data we captured were split into training and test subsets (80/20), and the model was trained using the Python Scikit package. The number of components for the PLSR was determined through 5-fold cross-validation, with 8 as the final value.

The PLSR model achieved an R2 score of 0.72 for the training set and 0.71 for the test dataset with an RMSE (root mean square deviation) of +/- 1.24 °Bx. The linear fit for the model is shown in the plot below.



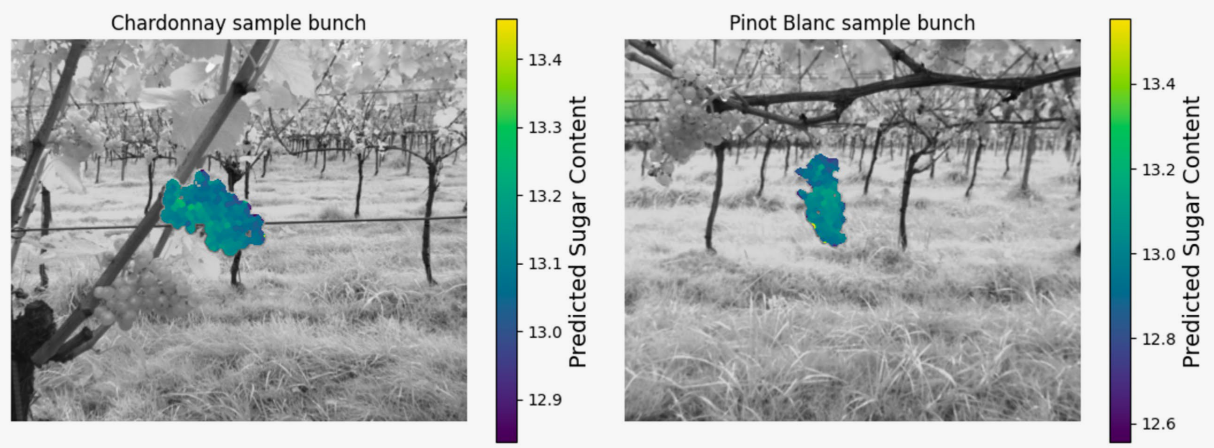
Bringing Hyperspectral Imaging to the Vineyard Rather Than Bringing the Grapes to the Lab.

Results taken in the lab show the feasibility of estimating Brix values for grape sugar content using hyperspectral data. The PLSR model developed has good agreement between predicted spectral Brix values and measured values taken from extracted grape juice using a commercial refractometer.

To get closer to immediate sugar level measurements in the vineyard, we need to move the experiment from the lab to the field. In a partnership with JoJo's Vineyard located in Russels Water, Oxfordshire, we captured hyperspectral data across seven capture periods between May and October 2024, just before the harvest.

In the weeks leading up to harvest, wine grapes were sampled and chemically tested for sugar content and acidity. Prior to picking, these grape bunches were imaged using the Living Optics Camera. 10-15 bunches were picked at random per variety and processed together (all the juice from the bunches combined) to return a single value for sugar content and acidity.

Unfortunately, given the constraints of the testing protocol, a dedicated model for these datasets could not be constructed. However, by applying the model from the lab, we demonstrated the utility of in-field hyperspectral imaging for remotely monitoring sugar content. The image below shows the sugar content prediction model applied to sample bunches of Chardonnay and Pinot Blanc grapes.



While diffuse reflectance hyperspectral imaging for quantifying grape sugar content levels is possible, work is required to extend this methodology to the field. This includes developing a general-purpose model that can estimate sugar content regardless of the environmental factors the image was taken. The goal is to provide real-time, non-destructive sugar content monitoring using portable hyperspectral imagers. The final system could capture hyperspectral data as a handheld device, mounted on a vehicle such as an ATV, or on a robotic platform to enable selective picking that harvests the best-tasting groups for winemaking.