Applying spectral technology to improve winemaking efficiency

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Spectral technologies have been developed for the rapid and simultaneous analysis of sugar and colour levels in red grape homogenates, and of yeast assimilable nitrogen (YAN) and other compositional variables in white juice. The technologies have been extensively trialled in large wineries over several vintages, with useful data obtained in real time. This ongoing work demonstrates the significant potential of spectral analysis to replace many expensive and time-consuming traditional laboratory methods, providing winemakers with opportunities to optimise winemaking processes.

INTRODUCTION

In the current challenging economic climate, one of the strategies that the Australian wine sector can adopt to compete with lower-cost producers is to embrace new technologies to improve winemaking efficiency. Implementing process measurement technology is widely recognised as a key way to reduce operating costs, increase production capacity and improve product consistency.

Process measurement technologies are successfully used by many industries, including beer, soft drink and dairy, but the wine industry has been slow to adopt them, largely due to the lack of demonstrated performance in a winery environment. The lack of real-time analytical data available to winemakers can, therefore, result in either a conservative approach to winemaking or an increase in risk when process decisions are based on limited amounts of objective information.

The Australian wine industry has a clear need for rapid methods to measure grape, must and ferment composition to: determine optimum harvest dates and appropriate remuneration for grapegrowers; identify areas in the vineyard with similar fruit composition to aid batching and streaming of fruit at the winery; assess the need for additions to must (e.g. diammonimum phosphate [DAP] and acid); reduce inputs; and improve control of fermentation to reduce the incidence of problem ferments and improve tank utilisation.

Previous research at the AWRI (AWRI publications #1185, #1340, #1360) has demonstrated that process measurement tools can be used to provide real-time information for winemakers and help reduce costs across a number of operations. Rapid spectral methods have been employed in the last decade by some large wine producers for prediction of a range of grape and wine compositional parameters. However, success in implementing these methods has been limited and the level of adoption across the industry remains low.

Spectral measurement technologies typically have lower operating costs than traditional methods and have the advantage of being able to monitor multiple analytes simultaneously. Previously, the cost of buying instruments has been prohibitive for medium and small-sized wineries. That situation is now changing with the availability of a new generation of smaller and cheaper instrumentation. This new generation technology has recently been used to develop rapid methods for two specific applications: analysis of colour (total anthocyanins) in red grape homogenates and analysis of yeast assimilable nitrogen (YAN) in white juice.

RAPID MEASUREMENT OF COLOUR (TOTAL ANTHOCYANINS) IN RED GRAPES

Some wine producers use red grape colour as an important indicator of grape quality for grower payment purposes. However, the standard analytical method for grape colour employed by industry (AWRI publication #531) can be relatively time-consuming. A rapid method could provide significant savings for wine producers, especially if the method is used to monitor grape maturity as well as final colour levels used for grower payments.

In recent vintages, the AWRI has worked collaboratively with several wine producers to develop calibrations for the analysis of total anthocyanins in grapes, as well as

AT A GLANCE

- Spectral analytical techniques are commonly used for wine analysis, especially in large winery laboratories and contract bottling facilities.
- A new generation of smaller and cheaper spectral analytical instruments makes it possible to analyse juices, grape homogenates and samples taken directly from fermentations, potentially providing winemakers with real-time data to optimise decision-making.
- Advantages of spectral analysis include the ability to analyse several compositional variables simultaneously; minimal sample preparation; and, in many cases, the elimination of the need for laboratory reagents.
- Spectral analysis is reliant on calibrations referenced against standard analytical techniques. The development of such calibrations can represent the greatest technical challenge to the adoption of these technologies.
- The AWRI has been working with industry collaborators to develop robust calibrations used to provide real-time data for a number of grape and wine compositional variables during vintage.

simultaneous measurement of total soluble solids (TSS), pH, titratable acidity (TA), and dry matter, using mid-infrared (MIR) technology. The initial calibration models included data for Shiraz, Cabernet Sauvignon and Merlot, from grapes sourced in South Australia during the 2011 and 2012 vintages. Collaboration with wineries in the Riverina region in 2013 provided a significant amount of additional data; more varieties were included, and the concentration range of the calibration was expanded to include both high and low colour levels (Figure 1).

Validation of this model was carried out in 2014, with Shiraz, Cabernet Sauvignon and Merlot comprising more than 90% of samples in the validation set (Figure 2). For these three varieties, measurement errors in the

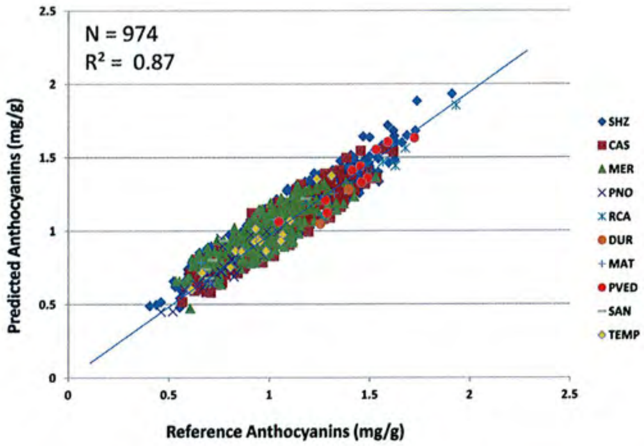

Figure 1. Correlation of anthocyanin values measured using reference method (x-axis) against values predicted using an MIR spectral method (y-axis)

KEY: N= number of samples; R^2=coefficient of determination (a measure of how well a set of data fits a statistical model); SHZ - Shiraz; CSA - Cabernet Sauvignon; MER - Merlot; PNO - Pinot Noir; RCA - Ruby Cabernet; DUR - Durif; MAT - Mataro; PVED - Petit Verdot; SAN - Sangiovese;TEMP - Tempranillo.

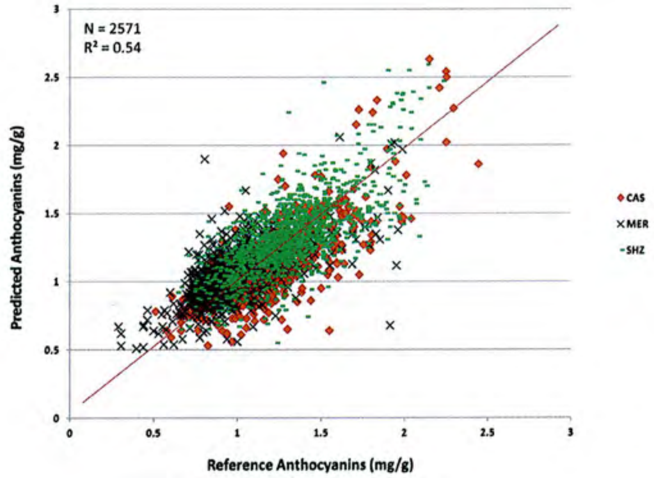

Figure 2. Validation of anthocyanin concentration during vintage 2014. Data shown are reference method (x-axis) against values predicted using an MIR spectral method (y-axis).KEY: SHZ - Shiraz; CSA - Cabernet Sauvignon; MER - Merlot.

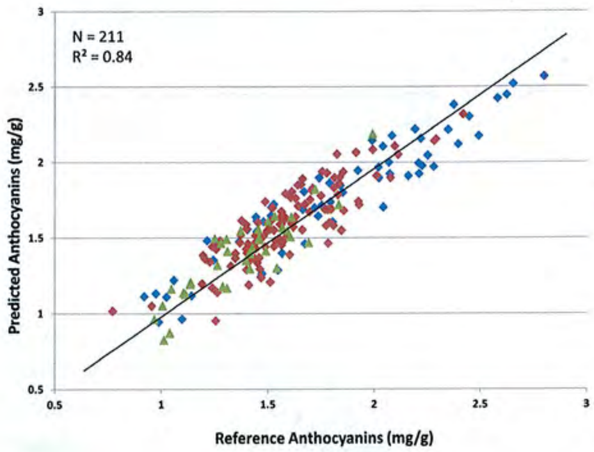

Figure 3. Correlation of anthocyanin values measured using reference method (x-axis) against values predicted using an MIR spectral method (y-axis).

KEY: DUR – Durif; RCA – Ruby Cabernet; PVE – Petit Verdot

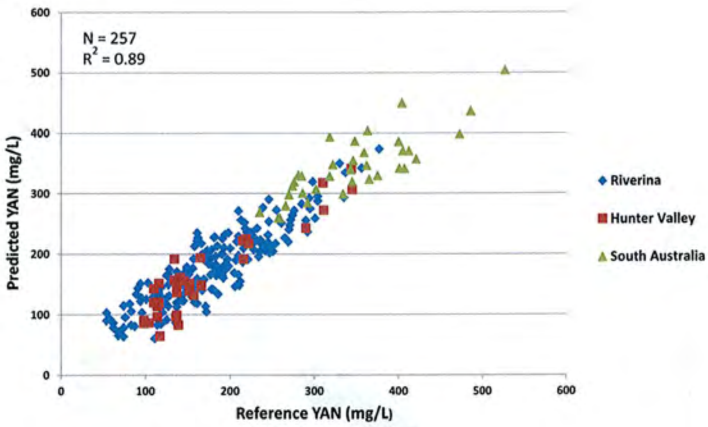

Figure 4. Correlation of 2013 YAN values measured using enzymatic reference method (x-axis) against values predicted using MIR spectral method (y-axis).

spectral predictions were, on average, higher than the stated measurement error for the laboratory reference method.

Although the relative errors in the rapid method are slightly higher than desired, this method could be used to track grape maturity in the vineyard with reasonable accuracy at low cost. The technology is also well suited to streaming grapes, as it gives results in minutes rather than hours. Further work is required to understand the true accuracy of reference methods currently used in industry and how rapid methods might be better tailored to improve the accuracy of measurements.

For varieties with relatively high concentrations of anthocyanins, such as Ruby Cabernet (RCA), Durif (DUR) and Petit Verdot (PVE), the rapid spectral measurement tended to under-predict the true concentration. Consequently, a separate calibration model was developed that allowed more accurate measurement of grape anthocyanins for these varieties (Figure 3). This demonstrates the way spectral calibrations can be tailored to suit specific sample sets.

RAPID MEASUREMENT OF YAN IN WHITE JUICE

Wine compositional variables that are critical to fermentation efficacy include YAN, tannin, alcohol content, pH, titratable acidity (TA) and sugar content (Brix). Some of these are able to be rapidly and easily monitored in a lab environment using standard analytical methods, but some (specifically YAN) require more sophisticated equipment and/or methods. Previous AWRI research has shown that most of these parameters can be monitored using rapid spectral methods (AWRI publications #1185, #1436).

YAN is a measurement of nitrogen from ammonia and amino acids, forms that can be utilised by yeast as nutrients during fermentation. Measuring YAN concentration prior to fermentation is very important because insufficient YAN (<160mg/L) in the juice/must can result in sluggish or stuck fermentations and the production of hydrogen sulfide. Conversely, elevated levels of YAN (>350mg/L) can lead to the formation of undesirable flavour and aroma characteristics in the resultant wine. However, few producers measure YAN on a regular basis because, until now, its analysis was relatively slow and expensive. As a consequence, many producers rely on 'preventative' routine additions of DAP to all juices, which pose the risk of elevating the YAN concentration to undesirable levels, or of incurring unnecessary additive costs.

Recent work at the AWRI has focused on using MIR technology for the simultaneous analysis of white juices for pH, TA, Brix and YAN. Prototype calibrations were developed and the project was extended in the Riverina for further development and validation across multiple vintages (Table 1). Samples were also collected, and calibrations validated, for samples from South Australia and the Hunter Valley.

Table 1. YAN ranges observed for juice samples from various wineries and regions across the 2011-2013 vintages and the proportion of samples that were found not to require a DAP addition.

Region	Winery	Vintage 2011		Vintage 2012		Vintage 2013	
		YAN Range (mg/L)	% juices not requiring DAP addition	YAN Range (mg/L)	% juices not requiring DAP addition	YAN Range (mg/L)	% juices not requiring DAP addition
Riverina	Winery 1	66 - 109	0	61 - 220	13	-	-
	Winery 2	57 - 417	94	109 - 417	84	89 - 534	94
	Winery 3	114 - 505	78	32 - 345	54	50 - 256	41
	Winery 4	69 - 294	68	54 - 424	57	-	-
	Winery 5	-	-	-	-	203 - 406	100
Hunter Valley						98 - 286	43
South Australia						31 - 539	67

The data collected on YAN concentrations in juices across multiple vintages (Table 1) showed that approximately 60% of samples tested did not require a DAP adjustment, even though many producers make routine standardised additions to every fruit parcel without regard to actual YAN concentrations.

Validation results generated during vintage 2013 showed that pH, TA, Baume and YAN could be measured with reasonable accuracy using the rapid spectral method developed. Table 2 summarises the relative measurement errors inherent in the spectral method.

Figure 4 shows the performance of the YAN calibration model for white juices during vintage 2013. The standard error of measurement was 29.4mg/L, with samples from all regions showing good agreement with the reference analysis method. Samples obtained from South Australia tended to exhibit higher YAN levels (ranging from 250-550mg/L), with the rapid spectral method showing higher errors at this level.

The rapid method developed for YAN measurement showed that the level of accuracy was dependent on a number of factors:

- the relative levels of YAN in the samples (lower and higher values were more poorly predicted)
- whether the sample was taken prior to or during ferment (ferment samples exhibited higher levels of variability)
- the region samples were taken from (Hunter Valley samples showed a greater degree of accuracy).

The method developed shows the potential of using MIR technology for semi-quantitative juice monitoring prior to ferment. Even at the early stages of development the accuracy achieved can be used to provide rapid feedback on nutrient status (as low, medium or high) and minimise unnecessary DAP additions.

CONCLUSION

Rapid measurement technologies show significant potential to replace many expensive and time-consuming traditional laboratory methods. With future developments in this area, there is potential that these technologies will be available in cost-effective units in the vineyard or at the weighbridge and applied to real-time process measurements. Previous modelling against the typical costs for a medium to large winery found that rapid

Table 2. Measurement errors observed for multiple parameters in juice samples from various wineries and regions during 2013 vintage.

	YAN (mg/L)	pH	TA (g/L)	Baumé (°)
No. samples	257	250	229	205
Coefficient of determination (R2)	88.8	91.7	95.9	99.1
Standard error	29.4	0.06	0.31	0.15
Validation range	54-527	3.03 - 4.23	2.6 - 9.75	7.9 - 16.3

measurement technologies could cost as little as one-third the cost of traditional methods, including factoring in the cost of the instrument amortised over its lifespan (AWRI publication #1340).

The capability to rapidly and cheaply collect large amounts of compositional data may have significant implications beyond immediate cost savings. Its application might allow important relationships between grape and wine composition to be revealed, allowing the full value of grapes to be realised and targeted wine styles to be achieved with a greater degree of certainty and consistency. Current research at the AWRI on objective measures of grape quality has already identified a correlation between MIR spectra and grape quality grades assigned by a large wine company.

In the future it should be possible to apply rapid methods to set more objective targets for grape composition and wine style, and to assess adherence to such targets during winemaking.

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