Measuring fruit quality

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Introduction
The ability to objectively measure fruit quality is an important requirement to further enhance the Australian wine industry's reputation for production of competitively priced, high-quality wines. Objective quality measures will allow vineyard managers to target required quality levels and will allow rewards for quality, in terms of quality-related grape payment systems. The large areas of new plantings coming on stream will apply a correction to the fruit supply/demand situation, placing further urgency on the requirement to determine quality levels. The correct signals need to be made via the fruit pricing structure and this can only be done if rapid fruit quality measurement methods are available.

This paper will discuss some parameters which have potential for assessment of fruit quality. It focuses on rapid testing methods, using near-infra-red spectroscopy (NIRS).

Fruit quality assessment methods
Brix
Total soluble solids (degrees Brix or Baume) is a well-established parameter for basic fruit quality assessment. Depending somewhat on variety, growing region and the style of wine to be made, fruit is required within certain maturity ranges. Although variation due to sampling is always an issue, testing by refractometry is fast and accurate, making it useful for pre-harvest, field testing and testing at the point of delivery. Although fruit must achieve target ripeness to maximise quality, maturity does not guarantee quality. This concept is supported by the empirical observation that, for a given region and variety, fruit harvested early in the season tends to produce better quality wines than fruit achieving the same Brix later in the season. A second order of quality measurement is required.

End-use
Historical data on end-use (i.e., the type of wine the fruit ultimately produces) is a useful way of targeting fruit from specific vineyards. However, with an end-use grading system, it is difficult to objectively assess fruit at the point of delivery. Determining end-use category after vinification requires fruit to be processed as separate parcels and is to a degree dependent on the wine making process.

Viticultural parameters
Observations that can be made in the vineyard (e.g., crop load, fruit exposure, berry size, leaf area/fruit ratio, cane development etc.) may be useful for segregation of vineyards but are no guarantee of ultimate quality and are difficult to apply at point of delivery.

Glycosyl–glucose
Flavour, anthocyanins and phenolic compounds in grapes tend to be glycosylated. Measurement of total glycosyl-glucose (GG) offers a method for estimating these important parameters (Williams et al. 1995; Iland et al. 1996). For fruit from a specific vineyard, GG increases with maturity, but for fruit from different vineyards but within the same Brix range, large variations in GG have been observed (Francis et al. 1998). Surveys have also shown a correlation of the sensory quality of wines with the initial fruit GG concentrations; thus it appears that GG can provide a second order of quality discrimination over Brix. However, the current GG assay is relatively complex and time-consuming, making practical application difficult.

Colour
Good colour extraction is a quality that winemakers seek when making red wines and there is objective evidence that wine quality does indeed correlate with colour. Somers and Evans (1974), in a study of Southern Vales wines, demonstrated that wine colour density correlated with the quality rating. However, this study demonstrated no correlation of total anthocyanins with wine quality; perhaps a reflection of the fact that the samples were commercial wines from a variety of producers, with varying degrees of expression of colour in the form of ionised anthocyanins.

A correlation of colour density with wine quality rating has also been demonstrated with BRL Hardy post-vintage wine quality allocation tastings. For samples of Riverland/Sunraysia Shiraz from the 1998 vintage, there was a strong correlation of wine score with colour ($R^2 = 0.69$). For the same wines, there was also a degree of correlation of alcohol strength with quality score ($R^2 = 0.46$), validating the use of Brix as a quality parameter for fruit, but indicating the requirement for a second level of discrimination.

Winemaking will have some influence, but with controlled vinification, fruit colour correlates with wine colour. This was demonstrated in studies of Riverland Shiraz, with winemaking on a semi-commercial scale (Botting et al. 1996; Francis et al. 1999) and with a number of grape varieties using small lot winemaking (Iland 1987).

Anthocyanins are the major source of GG in red grapes; thus GG correlates with total anthocyanins in red grapes. More data from the Riverland Shiraz trial showed that grape GG and colour predict wine quality equally well (Francis et al. 1999). The assay for colour (as total anthocyanins) is less complex than the GG assay, thus colour would be more viable as a quality test in a commercial situation. However, GG offers the only option with white grapes.

Rapid fruit analysis by near infra-red spectroscopy (NIRS)
Colour (total anthocyanins) may be easier to assay in comparison with GG, but the procedure is still laborious and
NIRS has gained a strong foothold in food and beverage industries as a rapid assay method for raw materials and in process control (Osborne et al. 1993). NIRS relies on the unique spectral signals that all organic compounds have in the near infra-red region of the wavelength spectrum (700-2500 nm) and with the availability of chemometric software packages, analysis can be performed with little or no sample preparation. The development of the initial NIRS calibrations may be difficult, as there is a requirement for a large sample set with corresponding analyses performed by the standard method. Asuming an NIRS calibration is available, routine testing is simple and can be performed in less than a minute.

NIRS has been applied to testing of many analytes of relevance e.g. Brix, alcohol, organic acids, protein, amino acids, phenolics (Batten et al. 1995), but to date has only gained acceptance in the wine industry as a method for rapid alcohol analysis. We have demonstrated that NIRS can be applied to the simultaneous analysis of Brix, pH and colour in grape homogenates.

Samples were homogenised with a high speed laboratory homogeniser (25,000 rpm) then scanned in reflectance mode with an NIRS systems 6500 spectrophotometer, using the wavelength range of 400–2500 nm (this includes part of the visible spectrum as well as the near infra-red region). The rate-limiting step in this process was the homogenisation (approximately 2–3 minutes), with the scanning taking less than 30 seconds. Figure 1 shows an example of absorbance spectra of Cabernet Sauvignon homogenates. Characteristic colour related peaks can be seen in the visible region (400–700 nm), absorbance is relatively low in the transition region but increases further into the NIR region.

Using spectra from a large number of samples and laboratory data for colour, Brix and pH, calibrations for these parameters were developed with the Vision chemometrics package (NIRS systems). Figure 2 shows a correlation plot of NIRS predicted colour versus colour measured by the standard laboratory method. The correlation was high (R^2=0.96) and was linear over a wide range of colour values. The standard error of the colour calibration was similar to the reference laboratory method that was used to prepare the NIRS calibration.

Calibrations were also obtained for Brix and pH (Table 1). NIRS predicted Brix was of sufficient accuracy for vineyard maturity assessment but may not be adequate for grape payment (standard error was 0.23° Brix). The Brix calibration was prepared using only the NIR part of the wavelength range (>800 nm), to avoid co-variance due to correlation of Brix with colour.

Although the data shown for pH calibration used the full wavelength range (Table 1), the pH calibration was strongly weighted to the visible region, suggesting that the pH calibration may be influenced by colour changes in anthocyanins. This may also explain why the chemometric method for colour measurement can measure total anthocyanins independent of sample pH, compared with the standard laboratory method, where colour measurements must be made at a very low pH.

The calibration data shown for colour used the full wavelength range, but good calibrations could also be obtained using only the visible and the first part of the NIR region. This puts these calibrations within reach of relatively cheap silicon diode array instruments, which can cover the required wavelength range, but not the full wavelength range of the instrument used in these experiments.

Fibre optic probes are an option with this type of technology. This would enable faster sample throughput and would enable the ‘instrument to be brought to the sample’ rather than vice versa: a critical application for this would be testing of fruit in receive bins.

The data shown in Table 1 relates to calibrations produced from Riverland Cabernet Sauvignon grapes. A major disadvantage of NIRS methods is that a calibration can be sample matrix dependent. In this situation, a calibration may be specific to grape variety, vintage and region. Any matrix variations can be compensated for, somewhat, by incorporating all variations in the calibration set, provided that the

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**Table 1. Calibration data for NIRS measurements on 225 Cabernet Sauvignon grape homogenates. R^2 values refer to correlation of reference method values with NIRS predicted values. SECV refers to the standard error of cross validation obtained from samples not included in the calibration set and indicates the ability of the NIRS calibration to predict unknown samples.**

<table>
<thead>
<tr>
<th>Analyte</th>
<th>R^2</th>
<th>SECV</th>
<th>Wavelength range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>0.964</td>
<td>0.06</td>
<td>416-2482 nm</td>
</tr>
<tr>
<td>Brix</td>
<td>0.996</td>
<td>0.23</td>
<td>800-1800 nm</td>
</tr>
<tr>
<td>pH</td>
<td>0.939</td>
<td>0.06</td>
<td>416-2482 nm</td>
</tr>
</tbody>
</table>

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**Figure 1. Absorbance spectra of two Cabernet Sauvignon grape homogenates in the wavelength range of 400-2500 nm**

**Figure 2. Correlation plot of NIRS predicted colour versus colour measured by the standard laboratory method in Cabernet Sauvignon grape homogenates (R^2=0.96)**
accuracy for any individual sample type is not compromised. Alternatively, software is available which can choose a subset of calibration spectra that match the test sample and optimise the calibration for a particular matrix. Matrix variation can be used to advantage, as it may be possible to determine variety and region for unknown samples, based on spectral differences.

Colour can be an important quality parameter in red grapes but this option is not available for white varieties. GG may be useful here. Preliminary data has suggested that NIRS can be used for rapid GG assay in white grapes but further work is required in this area (Gishen and Dambergs 1998).

A further area of potential is NIRS determination of mould contamination. This has been demonstrated in other crops (Batten et al. 1995). It may be possible to distinguish mouldy from sound fruit by NIRS, but it may be difficult to produce a quantitative NIRS calibration, as a quantitative reference method is not readily available.

Nitrogen status of the fruit may also be an important quality parameter. NIRS has been used for measurement of total nitrogen and amino acids in plant tissues (Osborne et al. 1993). Knowing the nitrogen status of the incoming fruit may assist with making winemaking decisions and may also be applied to a fruit quality formula.

Measurement of wine quality by NIRS

Chemometrics has the ability to interpret NIRS spectra to produce quality scores, by correlating with sensory scores. This has been applied, for example, to sensory grading of rice and tea (Batten et al. 1995). Preliminary data with commercial wine allocation tasting panels and with wine show samples has demonstrated potential in this area. It may therefore be possible to objectively measure wine quality. Some difficulties in this area may again be due to matrix variation, relating to vinification method (e.g. use of oak). Also NIRS cannot directly measure compounds at very low levels, thus some basic wine faults that have a profound sensory effect on quality may not be detected by NIRS.

Conclusion

Brix alone is not adequate for segregation of fruit into quality grades. Colour in red grapes, expressed as total anthocyanins, offers a further level of quality grading and can be measured rapidly by near infra-red spectroscopy (NIRS). Simultaneous measurement of Brix and pH can also be done; thus NIRS has the potential to be a powerful fruit quality assessment tool. NIRS also shows potential for GG analysis of white grapes and for detecting negative quality markers, such as mould contamination.

The instrumentation used for the work described here represents a large capital outlay and is reasonably complex, but with this background data, more cost-effective, simple instruments could be developed for general use in the industry.

Acknowledgments

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References


