In vino veritas – investigating technologies to fight wine fraud

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Many of the great wines of the world have been subject to claims of substitution or counterfeiting, damaging the reputation of the affected brands and countries of origin. This article describes recent work at the AWRI looking at analytical approaches to determine the origin of wine that could form an important part of global efforts to fight wine fraud.

The Grocery Manufacturers' Association estimates that fraud may cost the global food industry between $US10 billion and $15 billion per year, affecting approximately 10% of all commercially sold food products (Johnson 2014). Wine is an attractive target for fraud both for high value iconic products where demand outstrips supply, and in the high volume section of the market. Wine fraud can involve a variety of different activities, including:

- dilution or partial replacement with an alternative wine or water to increase the overall volume
- substitution with an alternate (cheaper) wine
- artificial enhancement of wine through addition of an unapproved additive to improve colour or aroma
- mislabelling, for example, intentional misrepresentation of country of origin, region, vintage, variety, or production techniques
- misrepresentation of the geographic origin of a product through false customs documents, particularly for bulk shipments
- counterfeiting of rare, collectible or well-known wines
- wine theft and resale through unapproved channels.

In almost all cases, wine fraud is purely economic and does not pose a health risk to consumers.

TESTING THE AUTHENTICITY OF WINES

Efforts to fight wine fraud can be broadly split into two areas:

- developing packaging solutions or other product attributes that can be used during manufacturing or at the point of sale to establish product authenticity
- development of analytical tests which can positively identify the source of a given product.

AT A GLANCE:

- Fraud in the global food industry is estimated to cost between $10-15 billion per year
- Wine fraud can involve product substitution or alteration, mislabelling, counterfeiting or sale of stolen goods
- High profile cases of fraud have considerable potential to damage the reputation of wine producers
- A recent AWRI project investigated the potential for a combination of analytical techniques to predict whether or not a wine was of Australian origin
- A combination of strontium isotope ratios and trace metal concentrations gave excellent results in classifying wines as Australian or non-Australian, as well as indications that it could be used to identify the region of origin of Australian wines
- Greater sample numbers and additional analytes will be needed to develop these promising results into a robust tool to fight wine fraud.

Attempts to establish robust analytical methods to verify a wine's authenticity have been under way for many years, particularly in Europe, with mixed success. Some cases of adulteration and counterfeiting can be easily detected through obvious typographic errors on labels or the poor taste of wine, but others require sophisticated analytical approaches. Given the diverse range of methods used to commit wine fraud, no single solution exists. This AWRI report focuses on recent investigations of analytical approaches to authenticate the inherent attributes of a wine.

COMBINING TESTS FOR MORE ROBUST RESULTS

One possible avenue to produce more robust tools for determining the origin of a wine (or any food or beverage) is to use more than one unrelated parameter. Each parameter must be in some manner influenced by the product's origin, but not necessarily sufficient on its own to provide definitive confirmation. When used in combination, however, they can provide increasingly robust results for the identification of provenance. The AWRI recently completed a proof-of-concept project to investigate whether a combination of different analytical techniques could be used to determine whether or not a wine was made from Australian grapes. A secondary aim was to find out if the chosen parameters could also identify the region of origin of Australian wine.

For the study, 231 commercial wines from major wine regions of Australia were sourced along with 37 international wines from a selection of the major bulk wine-producing countries. The samples were evenly split between red and white wines, specifically Cabernet Sauvignon and Chardonnay, with the exception of the red wines from Tasmania where Pinot Noir wines were chosen. The analytical methods chosen were strontium isotope ratios (namely the ratio of 87Sr/86Sr), the concentration of a range of trace metals found in wine and the wines' spectra in the mid-infrared, near-infrared, ultraviolet and visible regions.

DOES WINEMAKING HAVE A BIG INFLUENCE ON THE ANALYTICAL PARAMETERS?

Isotope ratios are generally not affected by winemaking processes. The relative amounts of trace metals are, however, more likely to be influenced by winemaking. Hence, it was important to understand if the chosen parameters were influenced by winemaking practices. Or, to put it another way, to find out if changes in winemaking practice could cloud the provenance determined using the analytical data.

Statistical analysis of the combined trace metals and strontium isotope data showed that once the influence of elements known to be influenced by winemaking practices (e.g. copper) had been removed, there was essentially no difference between the red and white wine samples. This gives high confidence that wine production practices are having little effect on the chosen analytical measures because red and white wines are made by very different processes.

The various spectral techniques investigated were, however, much more dependent on the organic chemistry of the wine in question and, hence, more open to influence from winemaking style and practice. While the spectral data showed some differentiation based on provenance, it was much less robust than that supplied by the isotopic ratios or trace metal concentrations. As such, the use of spectral measures was not pursued further.

IS THIS WINE AUSTRALIAN?

For the primary question of the study, 'Is it possible to differentiate wine produced in Australia from those produced in other countries?', the first step was to review the strontium ratio data in isolation. Using a simple one-way ANOVA test, a distinct difference was found between the 231 wines produced in Australia and the 37 wines from other major wine-producing countries (Figure 1).

However, while the means were statistically significantly different, the range of results showed a degree of overlap (Figure 2). This suggests that in itself, the strontium isotope ratio of any given wine is not enough to confidently classify a wine as being Australian or not. ▸

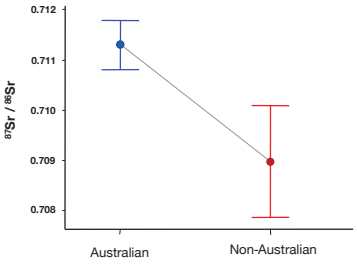

Figure 1. Comparison of the mean value for strontium isotope ratios and 95% confidence intervals for the Australian and international wines.

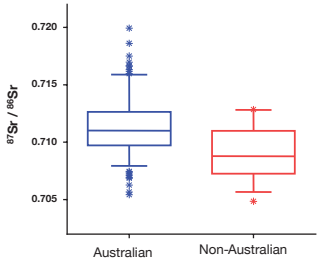

Figure 2. Box plot showing the median and distribution of the strontium isotope ratios for Australian (n=231) and international wines (n=37).

To further strengthen the ability to differentiate the wines, the trace metal concentration data was combined with the strontium ratio data. Statistical analysis showed 11 trace elements (As, Be, Cr, Cu, Li, Ni, Pb, Rb, Sn, V and Zn) were the most promising. The data for copper and tin were removed due to the possible influences from winemaking and packaging processes. The remaining data, in combination with the strontium isotope data, were analysed using partial least squares discriminant analysis (PLS-DA), a statistical technique commonly used to understand the relationships between different sets of data. The rate of correct classification from this analysis was 94.7%, with 187 out of 194 Australian wines correctly assigned, and 30 out of 37 wines being correctly assigned to the 'other countries' group. While not yet 'foolproof', this is a strong result. It is expected that if the data set were increased to include a much larger set of international wines and an increased range of Australian wines, then a robust classification tool could be developed, particularly if further unrelated analytical measures (such as the stable isotope ratios of other elements such as boron or lithium) were included.

WHERE IN AUSTRALIA IS IT FROM?

As an extension of the above study the data was next used to determine if it was possible to identify the Australian wines' region of origin using similar techniques. Australia has 67 defined geographical indicators. However, the limited nature of the dataset meant that it was not practical to try to achieve this level differentiation and, instead, analysis was conducted based on the eight production zones represented by the wines in the set. After statistical analysis it could be seen that there was significant grouping of the different production zones (Figure 3) in the PLS-DA data.

Further inspection of these results suggested they were intimately linked to the underlying geology of the regions being studied. This was confirmed by overlaying geological and soil data on the zones and combining those with similar underlying geology. Using this information, it was possible to allocate 85% of wines to their correct region. The strong influence of geology is promising as it suggests that the dataset is likely to become more robust and allow for even more detailed differentiation as the number of wines and regions analysed increases and other geologically-based parameters are introduced.

WHERE TO FROM HERE?

It is clear that the approach of using a combination of unrelated analytes such as stable isotope ratios and trace metal concentrations has potential for determining the provenance of wines, both at the country and regional level. The project also suggests that there are unique characteristics derived from the various Australian wine regions, and that they differ from the rest of the world.

This study provides the basis for a database and methodology to evaluate the provenance of wine labelled as Australian. However, to provide a truly robust tool the dataset needs to be extended significantly to provide the levels of confidence required in the case of disputes. This extension will need to include a much larger group of international wines and a range of other analytes such as other stable isotope ratios, to help further differentiate wine from regions around the world and within Australia. It will also be important to investigate the effect of varietal and vintage changes. A further target will be to develop analytical methods to identify the variety of grapes a wine has been made from. This will require different analytical approaches from those outlined here, with DNA and protein analysis techniques likely to be investigated.

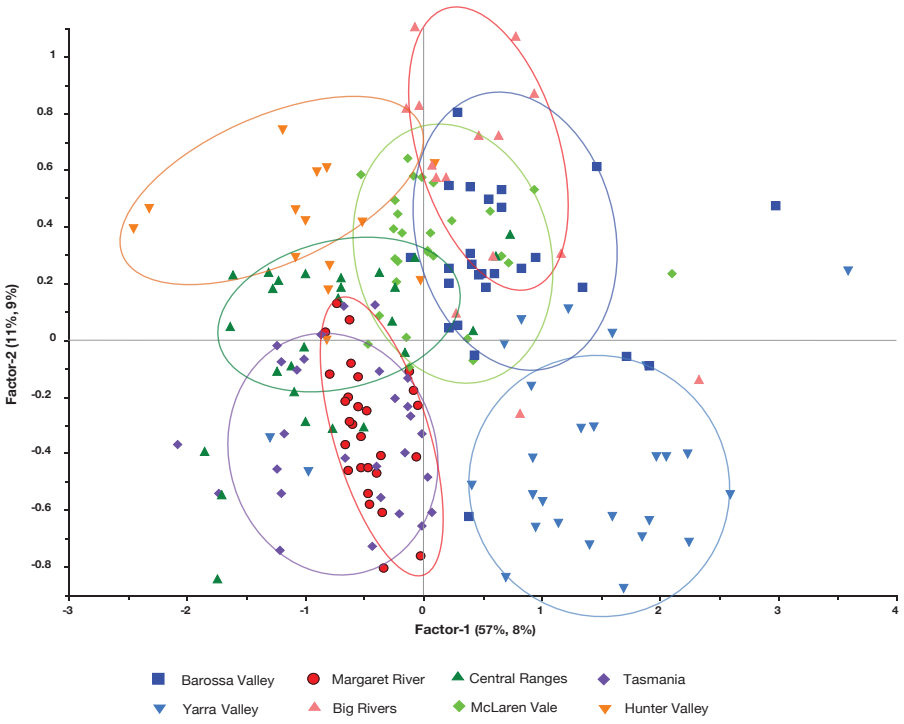

Figure 3. Grouping of Australian wines by production zone after statistical analysis of trace metal and strontium isotope data. Dotted ellipses are for clarity of groupings only and are not statistically derived.

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