Stream 4.4: Establishment of regional nodes of the AWRI

1. Abstract:

The formation of regional nodes was part of the AWRI's response to the call for national R, with regional D and local E including 'regional adaptive development', which was made by the Primary Industries Ministerial Council (PIMC) in 2005. The concept was later formalised by the PIMC in 2009, in the National Primary Industries RDE Framework Wine Sector Strategy. The instigation of this stream occurred concurrently with the instigation of Stream 2.3 in 2008, and the formation of the Industry Applications Group within the AWRI, with the staff of three of the nodes being members of the Industry Applications Group.

Nodes were established in Tasmania in July 2008 (initially on a 0.2 FTE AWRI-funded basis relating to the work reported here, and on a full-time basis from July 2011 as a 50:50 collaboration between the AWRI and the Tasmanian Institute of Agriculture (TIA)); the Riverina in November 2010; southern Victoria in January 2012 (which was not funded as part of the AWRI/GWRDC 7-year Investment Agreement); and the Hunter Valley in September 2012.

The following objectives of the stream have been achieved:

- Enhanced collaboration between the AWRI and regional partners in R, D and E.
- A strengthened knowledge and skills base of industry personnel based in regional areas.
- Enhanced adoption of best practice grape growing and winemaking principles and research outcomes.
- More active dissemination of the latest research outputs in regional centres.
- Enhanced ability within the AWRI to make informed decisions on state or regional technical issues and research priorities.
- Enhanced access of regional partners to state-of-the-art analytical services.

The following outputs have been delivered by the stream:

- The development of research which had identified a viable enzymatic alternative to bentonite fining into a workable winemaking process modification.
- A web-based tool for the simultaneous measurement of tannin and several other characteristics related to grape and wine phenolic composition.
- A fermentation modelling tool which facilitates optimisation of fermentation performance to maximise wine quality and provide early warning of problem fermentations, as well as the ability to manage refrigeration use in order to reduce power consumption and the price paid for electricity.
- Analytical methods for a number of grape and must compositional variables, which provide more rapid measurement, and have greater scope, than previously available techniques.
- Extensive understanding of the kinetics and physical conditions which govern the extraction of phenolics during the production of Pinot Noir red wines, including a technique utilising microwave treatment of must to allow full phenolic extraction pre-fermentation – a technique which in all probability is also applicable to other grape varieties.
- An evaluation of the efficacy of using grape stalks and marc for the production of renewable energy.
- The development of methods and tools to enhance the production of bottle-fermented and lees-aged sparkling wines.
- Insights into the links between Hunter Valley sub-regional soil types and phenolic profiles in Semillon wines, to provide objective information that supports the marketing of Hunter Valley Semillon wines.
- More effective collaboration with, and support for, regional industry groups on emergency response issues, such as smoke taint and *Botrytis* infection.

Early work in Stream 2.3 sought to understand potential barriers to adoption which were likely to be encountered. The successful strategy adopted in response was the model of regional nodes, working in close collaboration with industry partners to facilitate concurrent development and adoption. Many of

the research outputs produced by Stream 2.3, have been taken through the development and adoption process via the nodes. This has provided the wine sector with an extensive suite of knowledge, methods and tools, which has improved, streamlined, and reduced the cost of production processes. The efficacies of the outcomes have been demonstrated in commercial settings and extensive industry adoption has occurred.

2. Executive summary:

The rationale behind Stream 4.4 was to address the call by the Primary Industries Ministerial Council (PIMC) for regional D and local E including ‘regional adaptive development’; a concept later formalised by the PIMC in the National Primary Industries RD&E Framework Wine Sector Strategy (Department of Agriculture, Fisheries and Forestry 2012). The formation of the nodes was pursued concurrently with the instigation of the Stream 2.3, with the staff of three of the nodes being members of the Industry Applications Group within the AWRI.

The synergistic regional nodes/Industry Applications strategy (as detailed in this stream and Stream 2.3) was to add value to the outputs of previous and concurrent research by further developing those outputs into industry applicable knowledge, methods and tools. The broad objective was to foster adoption of that knowledge, methods and tools in order to improve the economic and environmental sustainability, profitability, and competitiveness of the Australian wine sector. A two-stage process was instigated whereby research outputs selected for development via the regional nodes were based on priorities identified by each region, and were assessed against their potential to improve and streamline production processes, while reducing cost and maximising wine quality. Project staff then worked with grape and wine producers, often including those with which the development work had been conducted, to ensure adoption of the resulting technology.

The successful development and industry adoption of many of the extensive outcomes which have been made available to the grape and wine sector via Stream 2.3, would not have been possible without the nodes. Much of the development work described here has been conducted in close collaboration with industry partners, where wine producers have allowed the AWRI access to their production sites for use as laboratories in which new knowledge, methods and tools can be fully developed and adapted to best meet industry needs. The ability to work in close collaboration with industry partners in their production facilities, allows project staff to gain in-depth knowledge of the imperatives that need to be met if a technology is to be widely adopted by industry. This also guided the development of the new technologies described here in order to make them compatible with existing processing systems used by different producers.

Several outcomes are considered to be ground-breaking, and two raise the potential for fundamental changes in the way white and red wines are produced. Firstly, research which had identified a viable enzymatic alternative to bentonite fining was developed into a workable winemaking process modification. This technique makes it possible to render white, sparkling, and rose wines ‘heat’ or ‘protein’-stable pre-fermentation, through a relatively simple enzyme addition combined with heating. This technique provides a profound increase in production efficiency and reduction in cost, compared with traditional batch bentonite fining.

Secondly, extensive understanding of the kinetics and physical conditions which govern the extraction of phenolics during the production of Pinot Noir red wines has been achieved by the Tasmania node. This includes a technique using microwave treatment of must to allow full phenolic extraction pre-fermentation – in all probability a technique equally applicable to other grape varieties. The ability to achieve full and potentially a more controlled and quantifiable extraction of phenolic compounds from grape skins pre-fermentation would allow red wine to be pressed and then fermented without skins. This technique would not only dramatically increase winery efficiency and reduce costs, but would also potentially allow a new degree of control of red wine fermentation, which might enable the development of novel wine styles.

Several of the research outputs taken through the development and adoption process via the nodes were those that had emerged from previous research into the application of spectroscopy in the grape and wine sector. A number of novel spectroscopy tools have been developed, including:

- A rapid web-based tool for the simultaneous measurement of tannin and several other variables related to grape and wine phenolic composition, known as the WineCloud™.
- Several analytical methods for grape and must compositional variables which allow more rapid measurement and have greater scope than previously available techniques, including for the analysis of yeast assimilable nitrogen (YAN). This allows the concentration of nitrogen during fermentation to be optimised to achieve maximum wine quality.

Other outcomes of the stream include:
- An evaluation of the use of grape stalks and marc as a source of renewable energy. That work has provided objective data on which business cases to invest in electricity-generating equipment can be based, and at least one tender for the construction of such a plant has been released during the life of this project.
- A fermentation simulation tool which allows optimisation of fermentation performance and early identification of problem fermentations, as well as the ability to manage refrigeration use to reduce power consumption and the price paid for electricity.

The efficacies of the technologies discussed here have been demonstrated in commercial settings, and, for some, development is complete, while for others further industry evaluation and adaption will be required before a fully evolved product is available for widespread industry adoption.

For some of the technologies, extensive industry adoption has already occurred in spite of the strong industry downturn which coincided with the instigation of the strategy to establish regional nodes and form the Industry Applications Stream 2.3. Additionally, most of the technologies could be further developed and extended to provide even greater value to industry, and the investment required to do so would be marginal compared to the value generated.

Early work in Stream 2.3 sought to understand potential barriers to adoption which were likely to be encountered. The successful strategy adopted in response was the model of regional nodes, working in close collaboration with industry partners to facilitate concurrent development and adoption. The AWRI's network of regional nodes has been crucial to the success of the AWRI's development and adoption strategy, but were established relatively late in the AWRI's7-year RD&E Plan. Consequently, their full value has yet to be fully realised.

Many of the outputs of this stream are suited to web-based application, the efficacy of which has been demonstrated with the phenolic analyses made available to industry via the WineCloud. It is recommended that the WineCloud be extended to incorporate the fermentation simulation model described here, as well as a module which allows users to conduct advanced statistical benchmarking of their own data, against the vast library of data which would be held in the WineCloud.

Potential also exists to extend the concept of modelling beyond fermentation to other parts of the grape and wine production process, and to incorporate such models into the WineCloud. However, to be of maximum value, such modelling requires real-time data to be available on which to base predictions and assessments of the conditions of a wine, compared to known standards or specifications. An opportunity therefore exists to invest in the development and adoption of process analytical technologies which have been tailored to the requirements of the grape and wine sector, in order to gather such data in an automated way, and feed it into models in real time. The regional nodes would be an ideal mechanism to manage the development and industry adoption of such technology.

Affiliation	Area of support/contribution
Keith Tulloch Wine	Support for Hunter Node office

Affiliation	**Area of support/contribution**
Tasmanian Institute of Agriculture	Funding and support for Tasmania Node
Riverina Institute of TAFE	Support for Riverina Node office
CAMO Australia	BevScan software
Jeffress Engineering	BevScan hardware
De Bortoli Wines	Grape and wine process efficiency, ferment simulator, rapid measurement of grape and wine attributes, Grape and wine portal, Proctase field trials
Casella Wines	Ferment simulator, rapid measurement of grape and wine attributes, grape and wine portal
McWilliam's Wines	Ferment simulator, rapid measurement of grape and wine attributes, grape and wine portal, grape and wine process efficiency
Riverina Wine Grapes Marketing Board	Rapid measurement of grape and wine attributes, grape and wine portal
Westend Estate	Rapid measurement of grape and wine attributes, grape and wine portal
Warburn Estate	Rapid measurement of grape and wine attributes, grape and wine portal
University of Adelaide	Energy from winery by-products
Frogmore Creek	Pinot Noir regionality through process modification
Winemaking Tasmania	Pinot Noir regionality through process modification; BevScan in bottle ferment monitoring
Pressing Matters	Pinot Noir regionality through process modification
Joseph Chromy	Pinot Noir regionality through process modification
Tamar Ridge	Pinot Noir regionality through process modification
Pirie Tasmania	Pinot Noir regionality through process modification, BevScan in bottle ferment monitoring
Jansz Tasmania	Monitoring sparkling wine development using BevScan
Springvale Wines	Pinot Noir regionality through process modification
Wynns Coonawarra Estate	Grape and wine composition
The Yalumba Wine Company	Monitoring sparkling wine development using BevScan, Proctase field trials
Bruker Instruments	Bruker Alpha Calibration Development
Bimbadgen	Grape and wine process efficiency, ferment simulator, Semillon regionality, rapid measurement of grape and wine attributes, grape and wine portal
Brokenwood	Grape and wine process efficiency, ferment simulator, Semillon regionality, Rapid measurement of grape and wine attributes, grape and wine portal
McWilliam's Mt Pleasant	Grape and wine process efficiency, ferment simulator, Semillon regionality, Rapid measurement of grape and wine attributes, grape and wine portal
Oakvale	Grape and wine process efficiency, ferment simulator, Semillon regionality, Rapid measurement of grape and wine attributes, grape and wine portal
Poole's Rock	Grape and wine process efficiency, ferment simulator, Semillon regionality, Rapid measurement of grape and wine attributes, grape and wine portal

Affiliation	Area of support/contribution
Glandore	Semillon regionality project
First Creek	Semillon regionality project
Thomas Wines	Semillon regionality project
Peppertree	Semillon regionality project

3. Background:

In 2005, the Primary Industries Ministerial Council (PIMC) called for regional D&E including ‘regional adaptive development’; a concept later formalised by the PIMC in the National Primary Industries RDE Framework Wine Sector Strategy, (http://www.daff.gov.au/agriculture-food/innovation/national-primary-industries). It was against this background that the Establishment of Regional nodes of the AWRI stream was instigated. It was pursued concurrently with the instigation of the Industry Applications Stream, (Stream 2.3), with the staff of three of the nodes being members of the Industry Applications Group within the AWRI.

The AWRI is a national organisation based in Adelaide that services the entire, and increasingly geographically diverse, Australian wine sector. However, due to the logistics involved, it is difficult for grape and wine producers from outside South Australia to have as much involvement in AWRI research, development and adoption activities, as producers situated closer to Adelaide. This was a driver for creating regional nodes, and was a project included in the AWRI’s industry endorsed Business Plan Towards 2015.

Additionally, facilitating the industry adoption of research outcomes becomes more difficult without dedicated personnel available at the industry interface, as they are in South Australia, and it was also clear that regional and state organisations were valuable partners in identifying research and development priorities.

The purpose of establishing the nodes, therefore, was to facilitate effective two-way interaction and flow of information for the mutual benefit of the AWRI and the regional wine industry. This allowed development and adoption projects to be conducted in close collaboration with regional partners, and the presence of AWRI personnel in regional areas on a full-time basis allowed distinct regionally-specific priorities to be fully embraced.

4. Stream objectives:

The broad objective of this stream was to establish a series of regionally-based nodes of the AWRI to achieve the following:

- Stronger collaboration between the AWRI and regional partners in R, D and E activities.
- Strengthening of the knowledge and skills base of industry personnel based in regional areas through their ability to more fully interact with the AWRI’s core activities.
- Increased adoption of best practice grape growing and winemaking principles through regional hosts having access to constantly updated AWRI content for use in teaching programs.
- More active dissemination of the latest research outputs in regional centres, in a manner that facilities their rapid adoption and application.
- Enhancement of the AWRI’s ability to make informed decisions on state or regional technical issues and research prioritisation through provision of information from the nodes.
- Enhanced access of regional partners to state-of-the-art analytical services.

5. Methodology:

The regional nodes have been strategically located, and the profile of node managers carefully tailored to the needs of each region. The relative mix of RD&E experience of the individual node managers differs according to regional priorities and needs, and node staff actively facilitate the access of regional personnel to the AWRI's other capabilities which might not be directly represented at each node.

Development projects to be pursued by the nodes are selected on the basis of their potential to provide the most valuable understanding, methods, or tools for industry; their best-fit to regionally-defined priorities; and the applicability of resulting technologies to the broader grape and wine sector. Each node has a single staff member, and in each case they participate on the local regional industry association's technical committees in which regional R&D priorities are set. By working in continual contact with AWRI staff in Adelaide, node staff members are able to inform the discussions of regional priorities with regard to new research findings, the achievable scope of proposed projects, and the technical capabilities required and to ensure that appropriate scientific rigour is applied. Once projects have been selected, they are in most cases planned and project managed by Adelaide-based Industry Applications Group staff, in conjunction with the node managers.

Much of the development work described here has been conducted in close collaboration with industry partners, where local wineries were used as laboratories in which new knowledge, methods and tools were fully developed and adapted to best meet industry needs. The close collaboration with industry partners and the use of local production facilities, provided in depth knowledge of the imperatives that need to be met, if a technology is to be widely adopted by industry.

As well as being an ideal vehicle through which to conduct development, the nodes are also ideal for fostering adoption of new technologies. Because of the efficiency of the industry applications/regional nodes model, adoption often occurs concurrently with the adaptive development process, and the industry partners who have collaborated in development work are often early adopters of the new technology.

The adoption strategy pursued through the nodes is to foster first-mover adoption by node collaborators, and then encourage adoption to spread to other producers in that region. Many of the technologies developed by this stream are relatively complex and potentially represent a major shift in the way grapes and wines are processed and analysed; consequently a hands-on approach to fostering first mover adoption has been necessary. However, those wine producers which have been intimately involved in the adaptive development process are also the best able to recognise the value of the new technology, and so are also best placed to become early adopters and provide endorsements of the value of the technology to others.

Once a degree of first-mover adoption has been achieved, case studies of the adoption fostered within the nodes have been taken to other producers and regions via the node network and via the AWRI's extension activities, prompting further adoption.

Regular industry meetings and seminars are held in the regions hosting nodes, to keep producers informed of project progress and outputs, and feedback received in these fora is used to guide the future direction of the work. Regular meetings are also held with regional associations, other industry groups, and other research providers, to ensure that project priorities and outcomes are efficiently communicated and opportunities for collaboration are maximised. Additionally, fortnightly teleconference meetings are held between the node managers and the Industry Applications staff in Adelaide, during which the progress and directions of projects is discussed, and future activities are planned.

Operation of the nodes, and the conduct of node projects, relies heavily on AWRI staff members in Adelaide who provide high-level industry consultation relating to strategic planning and priority setting, as well as project coordination and logistical and service support. They also actively facilitate interaction among the nodes to ensure that they act synergistically, and plan and coordinate joint-node activities. Grape and wine analysis associated with node projects, as well as data analysis, is also performed in Adelaide, and Adelaide-based staff members are involved in writing and/or edit publications based on node outputs, and working to extend outcomes beyond the regions in which nodes have been established. Node managers also have an extension function, actively facilitating the transfer of knowledge generated by other research projects conducted at the AWRI to their region, and directing calls for technical advice or assistance received from their region, to the most suitable AWRI staff members in Adelaide.

6. Results and discussion:

Goal 1: Development of tools to improve process measurement and control

Outputs include:

- Rapid measurement of yeast assimilable nitrogen (YAN) levels in juices and ferments using spectral methods, to facilitate enhanced quality control and ferment management.
- Application of rapid spectral technologies to the analysis of sugar and colour maturity levels in grape homogenates.
- Application of spectral measurement to sparkling wine production; techniques for assessing phenolic profiles of fruit for sparkling base wines, and for monitoring in-bottle fermentation; and the development of attributes related to wine storage and lees-ageing.
- The AWRI Ferment Simulator - a tool which models fermentation kinetics to optimise fermentation performance, and manage and reduce power use and the price paid for electricity.
- The WineCloud; a web-based tool to measure tannin, colour, and other phenolic parameters in red grapes, fermentations and wine:
    - Practical application of the WineCloud grape portal, to measure tannin, colour and phenolics in red grapes to increase knowledge on the impact that viticultural techniques and geological factors can have, in relation to vintage effects.
    - Practical application of the WineCloud wine portal, to measure tannin, colour and phenolic profiles in red wines and fermentations, allowing the impact of different winemaking factors, especially maceration techniques, to be investigated and employed.

Rapid measurement of yeast assimilable nitrogen (YAN), to improve wine quality and fermentation management

Spectroscopic methods can be used for rapid prediction of a range of grape and wine composition parameters, and a number of methods have been developed under this stream using affordable, 'off-the- shelf' spectroscopy instruments (Shah et al. 2010, Cynkar and Wilkes 2011).

One specific application developed using a Bruker Alpha mid-IR instrument, has focused on the simultaneous analysis of juices for pH, titratable acidity (TA), sugar content (Brix) and yeast assimilable nitrogen (YAN), using mid-IR spectroscopy (Table 1). Prototype calibrations were developed and, following establishment of the AWRI Riverina Node, the project was extended into the Riverina for further development and validation across multiple vintages. More recently, the work has been extended further to include Tasmania and the Hunter Valley via the AWRI nodes in those regions, although industry feedback indicates that insufficient YAN is not considered a problem in Tasmania.

Measuring YAN concentrations prior to fermentation is very important as insufficient YAN (<160 mg/L) in the juice/must can result in sluggish or stuck fermentations and the production of hydrogen sulfide. Conversely, elevated levels of YAN (>350 mg/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 required a relatively time consuming two-stage wet chemistry assay. Rather, many producers rely on 'preventative' routine additions of diammonium phosphate (DAP) to all juices, which poses the risk of elevating the YAN concentration to undesirable levels. Data collected on YAN concentration in juices across multiple vintages collected by this project (Table 1), has shown that the proportion of samples that do not require a DAP adjustment can be extremely high. The rapid YAN method clearly shows the value of this instrument for juice monitoring, providing rapid feedback on nutrient status to winemakers; avoiding the cost of unnecessary DAP additions, while optimising wine quality by directing additions only to when and where they are needed.

Table 1. YAN ranges observed for juice samples from various wineries and regions across 2011-13 vintages. Table also indicated the proportion of samples that did not require a DAP addition.

Region	Winery	Vintage 2011		Vintage 2012		Vintage 2013	
		YAN range (mg/L N)	% of juices not requiring DAP addition	YAN range (mg/L N)	% of juices not requiring DAP addition	YAN range (mg/L N)	% of 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

Application of rapid spectral technologies to the analysis of sugar and colour maturity levels in grape homogenates

The Australian wine industry has a clear need for rapid methods for measuring grape composition in order: to determine optimum harvest dates; to identify areas in the vineyard with similar composition; and for the assessment of grape quality for appropriate payment. For analysing large numbers of samples, potentially hundreds per day as might occur at a commercial harvest receival weighbridge, spectroscopic methods have been employed in the last decade by some of the large wine producers for grape colour analyses as an indicator of grape quality.

The direct cost of spectroscopic analyses is much lower than traditional ‘wet chemistry’ methods, due to the absence of the need for reagents, and less time required to conduct the analysis. However, the initial cost of buying instruments such as FOSS6500, which can be used for grape colour assessment, has been too high for medium and small-sized wineries.

However, with a new generation of small size and cheaper instruments now available, that situation is changing. Under this stream, a Bruker Alpha mid-IR instrument has been used to develop simultaneous measurement of a number of grape composition parameters. Robust calibrations have been developed for total soluble solids (TSS), total anthocyanins, pH, TA, and dry matter in grape homogenates. 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 (NSW) in 2013 provided a significant amount of additional data; more varieties were included, and the concentration range of the calibration was expanded towards lower values.

These rapid measurements could replace the expensive and time consuming traditional laboratory methods and could ultimately be extended to measurements using hand-held devices during grape berry ripening and at harvest.

Application of spectral measurement to sparkling wine production; techniques for assessing phenolic profiles of fruit for sparkling base wines, and for monitoring in-bottle fermentation and the development of attributes related to wine storage and lees-ageing

UV-Mid-IR spectral analysis of sparkling wine base samples has shown that differences in phenolic profiles can be tracked with UV spectra (Donachie et al. 2011); this has been reflected in differences seen in commercial premium sparkling wines in a number of formal tasting sessions.

Wines from Champagne and other parts of the world can be discriminated from Australian sparkling wines spectrally. This has highlighted the value of using these rapid methods to provide a chemical fingerprint of sparkling wines. Such fingerprints can be used to identify and investigate compositional differences which lead to stylistic differences in the wines. They can also be used as objective targets of wine style which can potentially be used during production to guide winemaking towards achieving targeted styles.

Trials carried out in collaboration with a number of sparkling wine producers in Tasmania have shown that secondary fermentation and retention of CO_2 can be tracked with visible and short wavelength near-infrared spectroscopy fingerprinting methods, using the BevScan^{TM} in-bottle spectroscopy instrument developed under Stream 2.3. This could be a particularly valuable application of that technology, avoiding cost-prohibitive destructive testing, especially in scenarios where wine value is high (Dambergs 2012c).

BevScan fingerprinting has also been used to discriminate among sparkling wines stored at different temperatures, which can provide insight into the use of temperature changes to manipulate the autolysis process and influence the formation of desirable sensory characteristics. BevScan has improved the understanding of how these characters develop over time and what influences the speed of development, thereby providing opportunities to streamline the production of sparkling wines, with potentially high economic impact.

Development of lees-aged attributes in bottle post-tirage has also been tracked using UV spectroscopy. Spectral analysis of sparkling wine samples has shown that differences between wines treated with different pectolytic enzymes can be effectively monitored, and that those UV fingerprints could be used to predict sensory ratings in sparkling wines that are directly linked with autolysis characters.

The AWRI Ferment Simulator - a tool which models fermentation kinetics to optimise fermentation performance, and manage and reduce power use and the price paid for electricity

Winemakers recognise that fermentation is a critical area in the winemaking process, where quality can be enhanced or lost quickly and suddenly. Therefore there is a demand for tools which enhance winemakers' ability to monitor their fermentations, and to give greater control, and more confidence in the final wine outcome.

Current fermentation management practices place huge demands on winery resources, ranging from daily sample collection, laboratory analysis and winemaker tastings, to infrastructure constraints such as equipment availability, energy and water use, and refrigeration capacity. Process efficiency is further impacted when stuck or sluggish fermentations occur, with additional resources and logistical management being required as a result.

The ability to reliably and accurately monitor and control fermentation in real-time is crucial to minimising operating costs whilst realising maximum wine quality potential (Muhlack 2008a). That need has been recognised by the development of the AWRI Ferment Simulator: a spreadsheet-based tool designed to provide wine producers with the capability to monitor and predict wine fermentation performance.

The AWRI's novel Ferment Simulator has been developed over several vintages, with input from industry collaborators in the Hunter Valley and Riverina regions. The tool has undergone extensive field testing over a number of vintages using commercial-scale fermentation data sourced from multiple sites and has been found to predict commercial fermentation performance reliably after 2-3 days worth of data are available. Input from industry has been sought on the relative importance and practical use of a variety of fermentation conditions as fermentation management tools, such as temperature, yeast type, wine type, nutrient levels, agitation regime and fermenter size, and the simulator uses a complex set of calculation algorithms to predict ferment trajectory in relation to those various fermentation conditions. (Muhlack 2012a).

The system was developed using commercial-scale fermentation data sourced from multiple sites over several vintages, and provides automated and early warning of fermentations which are likely to be extended, or to stick, once 2-3 days worth of data, related to the fermentation's progress, are available (Figure 1). The simulator also provides the means for real-time control in order to achieve quantified compositional targets, such as residual sugar, colour, and tannin concentrations, and allows for refrigeration demand to be calculated for an entire tank-farm for several days in advance according to weather forecasts. That feature allows winemakers to plan their refrigeration use in order to avoid exceeding their contracted electricity supply on very hot days, thus avoiding punitive electricity tariffs.

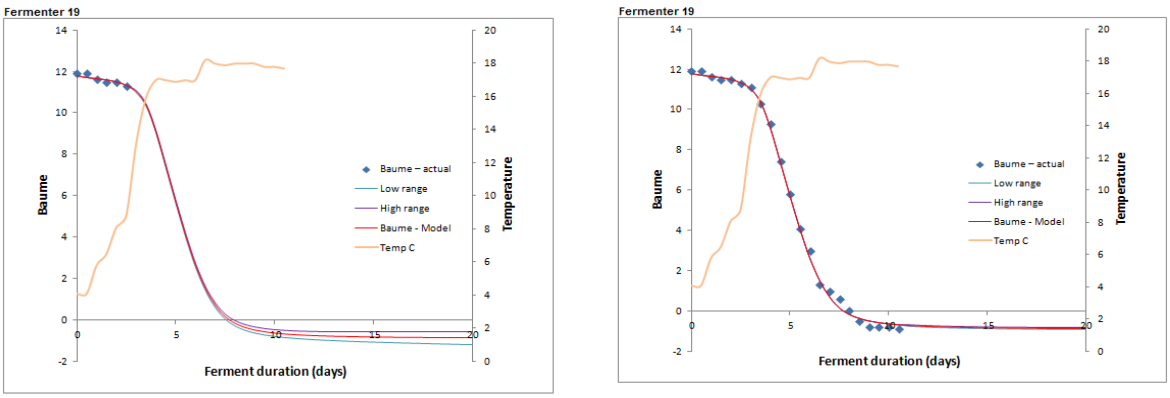

Figure 1. A commercial ferment profile predicted by the AWRI Ferment Simulator after three days of Baumé data has been collected (left image) compared against the actual ferment profile achieved after eleven days (right image).

The WineCloud — a web-based tool to measure tannin, colour, and other phenolic parameters in red grapes, fermentations and wine

To many winemakers and those in the wine trade, phenolic compounds are the attributes which define the intrinsic value of red wines, being a major influence on their colour and textural properties. Until now, however, they have been difficult to measure, and therefore not well controlled during winemaking. The technology to measure phenolic compounds is widely available. When combined with methods for the more rapid analysis of grape compositional variables (also developed under this stream) there is the potential to substantially increase the understanding of the relationships between grape and wine composition. These tools inform the way grapes are selected and paid for, and allow more objective target specifications to be set.

In 2005 the AWRI conducted a review of tannin research which concluded that the available analytical methods were too complicated, not specific or not suitable for wine tannins, and that there was no simple method available to aid industry trials and decision making. The AWRI responded by developing the methyl cellulose precipitable (MCP) tannin assay for red wines, which was a major simplification of previous methods.

However, an industry survey conducted under this stream in 2008 revealed that while the majority of respondents wished to be able to measure tannin and other variables related to phenolics, they wanted faster and simpler analytical methods. Consequently a rapid spectral (UV-Vis) method for predicting colour, tannin, and phenolics in red wines and in fermentations was developed, which was correlated with the MCP assay (Dambergs et al. 2011a, 2011b, 2012b). That capability was delivered to industry through a web interface called the AWRI Tannin Portal, to provide a simple measurement tool that could be employed by wine producers using their own equipment (Dambergs et al. 2011a, 2011b, 2012b).

In response to Tannin Portal user feedback, and as a result of industry trials which identified links between grape colour and tannin, and wine colour, the tannin portal was extended with the inclusion of a number of additional variables of wine phenolic composition. The concept was further extended to allow for the analysis of grapes as well as wines, and the combined portals were renamed the 'WineCloud'.

WineCloud can be further extended as new methods become available. It provides industry with a simple and rapid method to gather data from wine processing and targeted winemaking trials improving decision making to achieve specific target attributes for their wines. For instance, it has been used by producers to obtain objective process data to assess the impact of winemaking variables such as maceration technique and yeast type, and has provided some early insights into links between grape and wine tannins.

The platform also contains a suite of tools that allow simple graphical representation of data such as grape maturity trends; attribute profile charts; and fermentation trajectory plots, as well as an extensive database of grape and wine data, against which users are able to benchmark specific attributes in their own grapes and wines by a combination of vintage, variety, and region.

Practical application of the WineCloud grape portal, to measure tannin, colour and phenolics in red grapes, to increase knowledge on the relative impact of viticultural techniques and seasonal conditions on grape composition at vintage

Recent developments in generating predictive models for tannins, phenolics and anthocyanins in grapes (Dambergs et al. 2011a, 2011b; 2012b) have led to the creation of the WineCloud Grape Portal (Dambergs et al. 2012a; Smith et al. 2011). This provided industry with a convenient and innovative tool which can be used to understand the impact that viticultural techniques and geological factors can have, in relation to vintage effects.

A number of small-scale vineyard trials, conducted in South Australia and through the Tasmania node, have highlighted the impact that soil type, clone, rootstock selection and weather patterns can have on anthocyanins, tannin and phenolics in red grapes during ripening (Smart et al. 2010, Smart and Dambergs 2012). This allowed producers to tailor grape compositional profiles by modifying or manipulating plantings, adjusting viticultural treatments and selection of appropriate vineyard sites.

The WineCloud was also used to understand the phenolic load in various tannin components in grape skin, seed and stalks. Analysis of grape fractions revealed that the highest concentration of tannin by weight occurs in seeds, followed by stalks, then skin. Small ferments performed with grape fractions (seeds or skin) removed or added back, showed that grape pulp influences tannin extraction, through binding of tannins to grape sub-cellular material (Sparrow et al. 2012a). Work in this stream also showed that extraction of skin tannin can be enhanced by selectively macerating skins during fermentation. Small-scale trials with selective and targeted maceration of skins indicated enhanced extraction of the more desirable skin tannin in relation to less desirable seed tannin (Sparrow et al. 2012b).

Practical application of the WineCloud wine portal, to measure tannin, colour and phenolic profiles in red wines and fermentations, allowing the impact of different winemaking factors, especially maceration techniques, to be investigated and employed

The WineCloud wine portal provided opportunities for rapid measurement of tannin, colour and phenolic compounds in red wines and ferments. It provided critical wine chemistry information that would otherwise not be available, in a timely and cost-effective manner.

The kinetics and physical conditions which govern the extraction of phenolics during the production of Pinot Noir red wines was a focus at the AWRI's Tasmania node, operated in partnership with the Tasmanian Institute of Agriculture (TIA). Pinot Noir is a difficult variety to use for red wine production due to its unusual phenolic profile and low concentration of colour (anthocyanins); consequently, it is very important that the red pigment is efficiently extracted and stabilised during the maceration/fermentation process. Although Pinot Noir grapes have high tannin concentrations, information held on the wine portal demonstrates that Pinot Noir wines tend to be low in tannin (Figure 2). This anomaly is most likely due to Pinot's low ratio of skin-to-seed tannin, when compared with other varieties. Seed tannin is more difficult to extract than skin tannin, and tends to be extracted later in the fermentation.

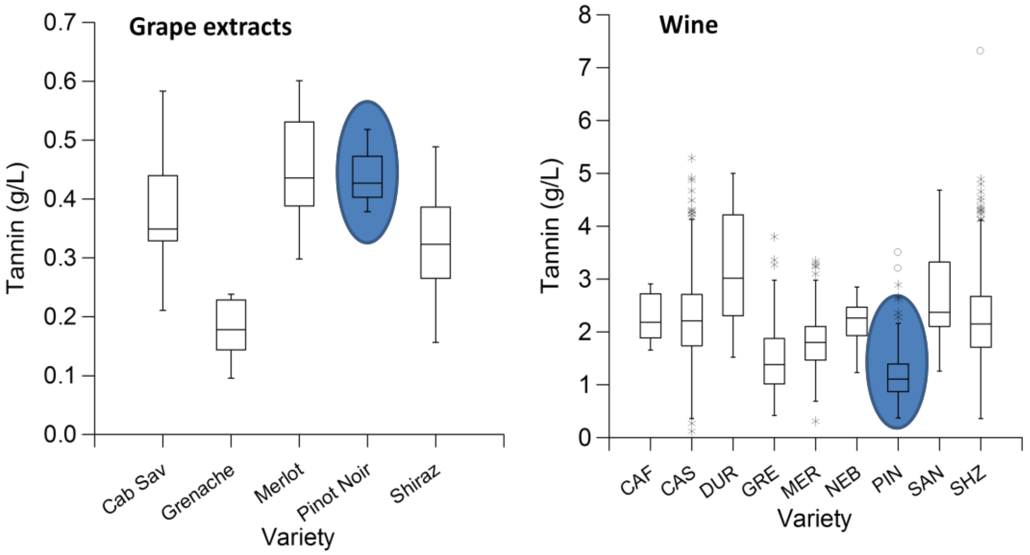

Figure 2. Tannin concentrations in grape extracts and wine; box plots indicate the spread of values; median is indicated by the horizontal line; 50% of samples are within the box; whiskers indicate upper and lower quartiles; symbols indicate extreme outliers. CAF= Cabernet Franc; CAS= Cabernet Sauvignon; DUR= Durif; GRE= Grenache; MER= Merlot; NEB= Nebbiolo; PIN= Pinot Noir; SAN= Sangiovese; SHZ= Shiraz. Pinot Noir data are highlighted with blue ovals.

Using the WineCloud wine portal as a key monitoring tool, a number of trials were undertaken to identify key vineyard and winemaking processes and variables that have the ability to impact on colour, tannin and phenolic profiles of red wines. Trials using small-lot winemaking methods showed that, for example, wines made using a 45-day extended maceration were low in free anthocyanins, but high in pigmented tannins, which are more stable colour compounds (Figure 3). Other trials demonstrated that by manipulating maceration methods, tannin levels in Pinot Noir wines made from the same batch of fruit could be increased four-fold (Dambergs 2012d). This has implications not only for grape varieties that are low in skin tannin (such as Pinot Noir), but also for addressing deficiencies in fruit composition due to undesirable vintage conditions and extreme weather events.

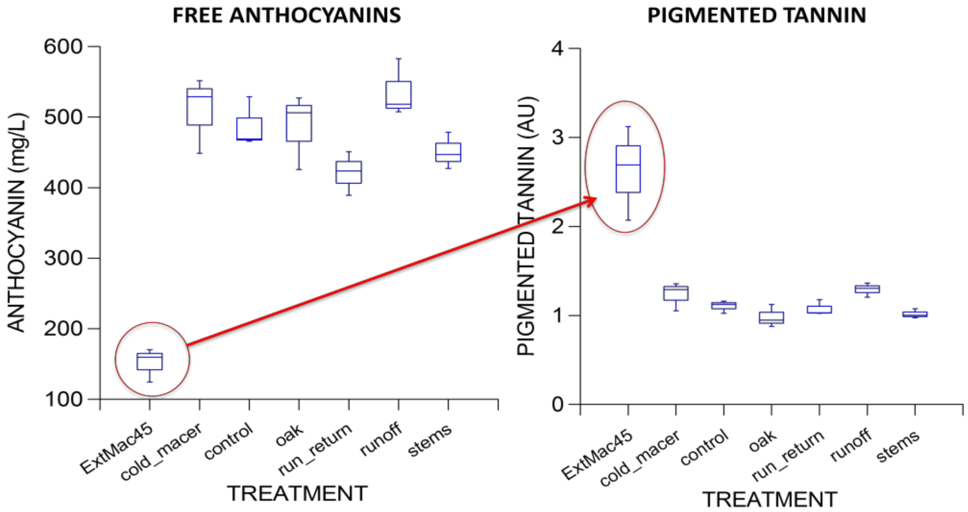

Figure 3. Total tannin and pigmented tannin for extended maceration (ExtMac45), cold maceration, control, oak addition, juice run off and return, juice runoff (without return) and stem additions to Pinot Noir ferments. Extended maceration data are highlighted in red.

The wine portal has also been used to understand the impact of different yeasts on resultant colour and tannin profiles in Pinot Noir red wines (Figure 4). Wild ferments are being used by an increasing number of Pinot Noir makers to create complexity and express 'microbiological terroir'. Under controlled conditions, wild ferments finished with EC1118, showed lower tannin concentrations than RC212 (a commonly used strain for Pinot Noir) and EC1118 fermentations. Similarly, an attempt to mimic 'wild-yeast' fermentations in a controlled way, by fermenting with the non-*Saccharomyces* strain *Torulaspora delbruekii* and finishing with EC1118, also resulted in lower tannin concentrations than with RC212 (Carew et al. 2012).

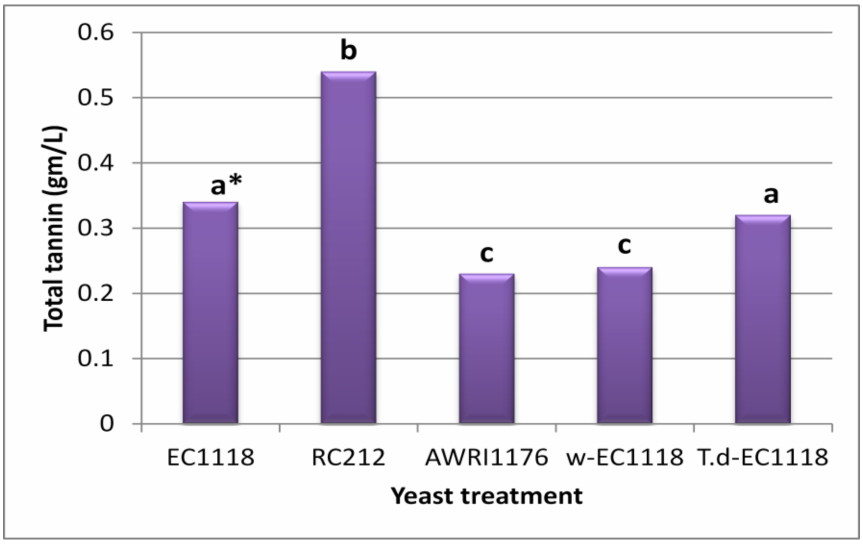

Figure 4. Tannin concentrations in Pinot Noir wines fermented with RC212, EC1118, *Torulaspora delbruekii* followed by EC1118 (T.d-EC11188) and wild ferment followed by EC1118 (w-EC1118). Different letters indicate a significant difference between treatment averages.

Goal 2: Evaluate the potential of renewable energy technologies to reduce carbon liability and offset grid supplied electricity for wine producers

Outputs include:

- Technical and economic evaluation of the use of grape stalks and marc to produce electricity

Rising energy costs are increasingly impacting on the bottom-line profitability of wine producers, and opportunities exist for the wine industry to mitigate increasing costs through energy efficiency and renewable energy technology. A focus area of this stream has been to identify process efficiency improvements and strategies for reducing and transforming energy inputs (Muhlack et al. 2009a, 2008b).

The assessment of the viability of biomass power generation using grape marc was carried out, utilising a 'Young Innovators and Scientists Award' from the Department of Agriculture Fisheries and Forestry Bureau of Rural Sciences. The award funded a preliminary study of grape marc combustion and gasification for renewable power generation and was undertaken with support from the University of Adelaide School of Chemical Engineering and Constellation Wines. Outcomes of this research indicated that this is an approach that could be used by the wine industry to reduce grid-supplied power consumption (van Eyk et al. 2009).

The potential savings in grid-supplied energy and emissions are significant; perhaps as much as 75% depending on the technology employed. The capital payback period, coupled with the transformation of a waste stream into a valuable resource, are attractive. However, due to uncertainty around the specific performance of currently available biomass power generation plants, and the high capital costs, it is unlikely that the wine industry will move forward in this area until real-world case study data from a pilot or commercial-sized winery installations become available.

In the meantime, so-called 'low-tech' solutions and existing small-scale process improvement solutions offer a transitional answer. That is, application of established process knowledge that can be used now to achieve efficiency gain. The AWRI's Riverina Node continues to explore technologies which have the potential to add substantial value and competitive advantage to the Australian wine sector in the future, across the entire value chain (Muhlack 2008b).

Work in this stream has also sought to ensure industry awareness of technologies on offer in regional Australia. Potential process services within the winery, where high impact and/or low cost improvements are typically achievable include: refrigeration control, process heating and waste heat recovery, insulation, hot water generation, air compressor performance, lighting and wastewater treatment. Alternative low energy wine processing strategies, such as floatation, in place of cold settling and centrifugation can also provide energy cost savings in certain circumstances (Muhlack 2008b).

Process opportunities in each of these areas have been presented through the AWRI's extension vehicles, as well as at local technical briefings conducted through the regional node network. Fact sheets and calculators have also been developed to assist producers in evaluating the impact of different energy efficiency strategies, which are available for download from the AWRI website: http://www.awri.com.au/industry_support/environment/

Goal 3: The development of methods to increase processing efficiency and reduce processing costs

Outputs include:

- Proctase - a viable alternative to bentonite for the protein-stabilisation of wine
- Microwave treatment of red must to allow full phenolic extraction pre-fermentation

Proctase - a viable alternative to bentonite for the protein-stabilisation of wine

Bentonite clay is used as a fining agent in the production of white, sparkling and rose wines in order to remove proteins that could otherwise form unsightly haze after the wine is bottled. While it is a very effective way to remove those proteins, the bentonite fining step is cumbersome, tends to tie up tank time, causes volume and quality loss, and presents waste disposal challenges. Bentonite is also very abrasive, causing accelerated wear on winery equipment such as pumps and centrifuges. Although in-line dosing of bentonite is currently used by several of Australia's largest wine producers due to its lower cost and efficacy on a large scale, most Australian wineries do not have the necessary infrastructure to consider this process modification.

Through Stream 2.2, the AWRI has sought alternatives for preventing haze formation, reducing the cost of bentonite treatment and/or removing the proteins via means other than bentonite. The research has focussed on two areas; understanding the mechanism of haze formation and the proteins responsible, and using that knowledge to find solutions to the problem. Proctase, a commercially available mixture of two acidic proteases produced from Aspergillus niger (EC no. 3.4.23.18 and 3.4.23.19), was identified as a potential bentonite alternative. Bench-scale trials demonstrated that at elevated temperatures it was effective at removing the proteins responsible for haze formation.

Field trials coordinated by the Riverina Node and Industry Applications staff in Adelaide, were conducted under this stream with three industry partners in the Riverina and South Australia during the 2011 and 2012 vintages. These trials assessed the potential of Proctase to remove heat unstable proteins from white juices (Robinson et al. 2012, Marangon et al. 2012). The trials demonstrated that flash pasteurisation treatment of white juice at 75^{o}C in the presence of Proctase was effective at removing the haze-forming proteins (Chitinases), resulting in a protein stable wine.

A review of the regulatory environment surrounding the use of acidic protease enzymes in winemaking, has highlighted that the enzymes present in the Proctase formulation are listed synonymously (carboxyl proteinase or EC no. 3.4.23.6) as approved winemaking additives in the current Food Standards Code (1.3.3). The AWRI is currently progressing formal recognition of this from Food Standards Australia and New Zealand (FSANZ), through an update to the Code.

Detailed economic analysis was conducted to compare operating costs between Proctase and bentonite treatments (both batch and in-line dosing).The study took all relevant processing conditions into account, including flow rates, temperatures, heating and refrigeration energy, heat exchanger losses, pumping requirements and Proctase purchase costs. To compare batch and in-line bentonite addition, wine volume and downgrade losses were included, together with filtration and centrifuge performance, as well as energy and labour requirements. Results are shown in Figure 5.

In-line bentonite treatment costs were similar when compared with the Proctase treatment. This suggests that if suitable equipment is available for in-line bentonite dosing, this option offers some advantages when processing juices or wines with lower protein concentrations. Considerable capital investment is associated with in-line bentonite dosing, however. Consequently, this method is cost prohibitive for all but the largest commercial wineries.

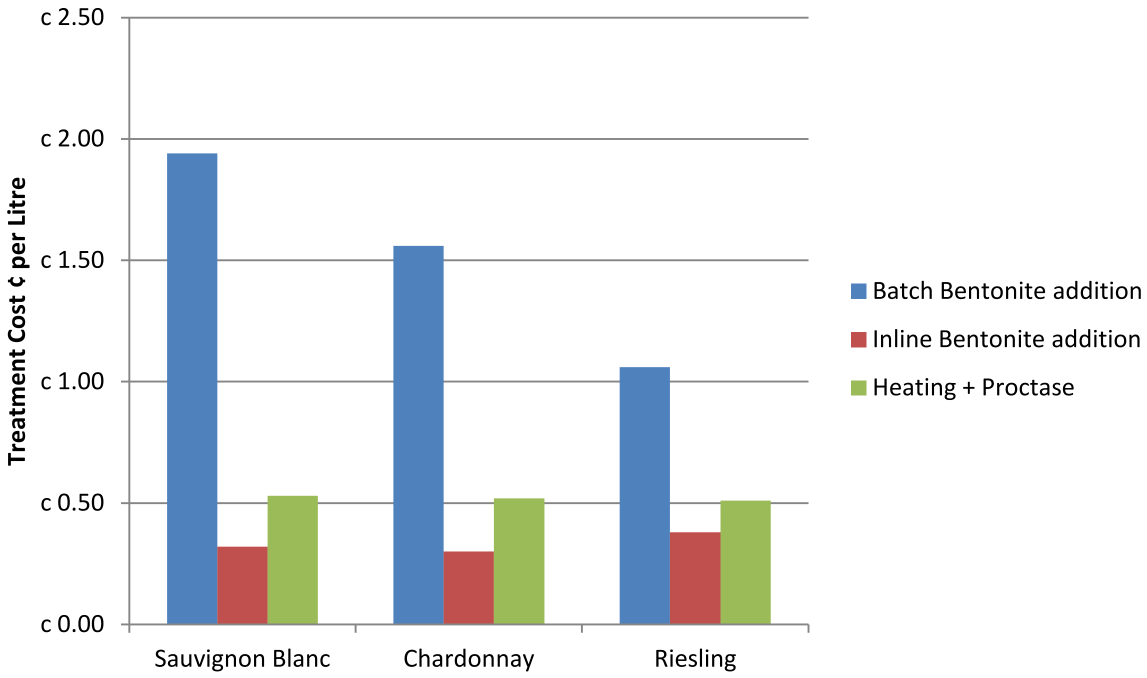

Figure 5. Economic analysis of Proctase treatment, compared with batch and in-line bentonite addition for Sauvignon Blanc, Chardonnay and Riesling juices (treatment cost in cents per L).

Microwave treatment of red must to allow full phenolic extraction pre-fermentation

The impact of microwave treatment of Pinot Noir must has been investigated by the Tasmania node. The technique allows apparently full and potentially a more controlled and quantifiable extraction of phenolic compounds from grape skins, pre-fermentation (Figure 6). The technique, in all probability, is equally applicable to other grape varieties. The ability to achieve full phenolic extraction with as little as three hours of skin contact time, would allow must to be pressed at that point and the wine fermented off-skins. That ability would not only dramatically increase winery efficiency and reduce costs, but would also potentially allow a new degree of control of red wine fermentation, which might enable the development of novel wine styles (Carew et al. 2013 p, in press).

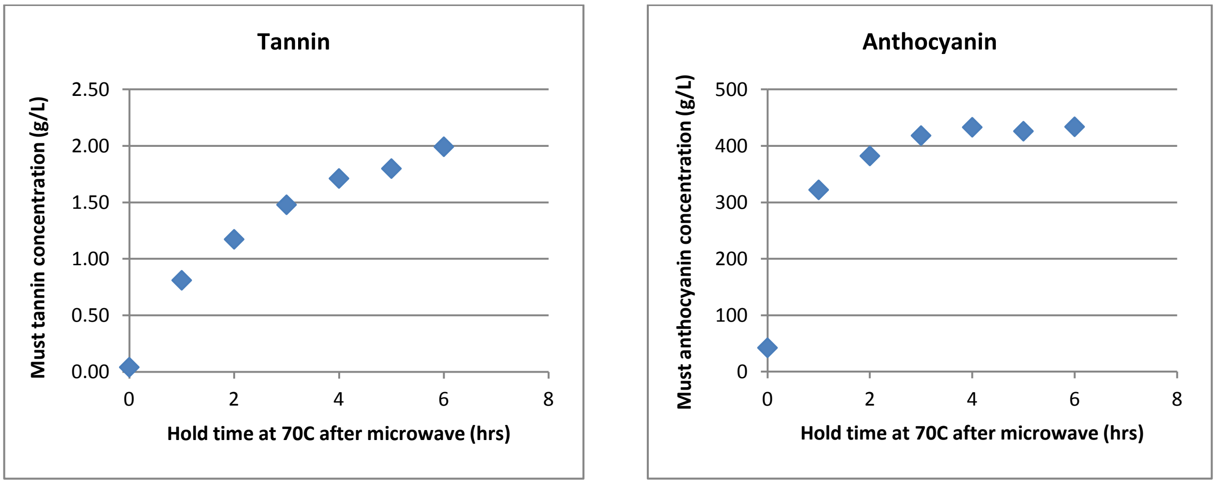

Figure 6. Post-microwave maceration extraction of anthocyanins and tannins.

7. Outcome and Conclusion:

The key outcomes for the Australian wine industry delivered through this stream are:

The development of tools to improve process measurement and control

Application of rapid spectral technologies to the rapid analysis of sugar and colour maturity levels in grape homogenates, and of yeast assimilable nitrogen (YAN) and other compositional variables in white juice and fermentations

A range of technologies have been developed which allow producers to measure a range of important compositional variables of grapes and wines simultaneously, quickly, accurately and in real-time. It has previously not been feasible to conduct such analysis so readily, or to collect such a large volume of data. The implications of this capability are that important relationships between grape and wine composition will be elucidated allowing the full-value of grapes to be realised, and for more objective targets of wine style to be set and achieved during winemaking.

The AWRI Ferment Simulator - a tool which models fermentation kinetics to predict fermentation performance

The Ferment Simulator is one of a number of tools developed by this stream, which producers can access to improve processing efficiency. The 'Simulator' enables winemakers to optimise fermentation performance to maximise wine quality, while also providing early prediction of where problems will arise. It also allows better management of refrigeration, which is the major use of power in a winery, thus reducing electricity use, and the price paid for electricity if punitive tariffs are avoided.

The WineCloud, a web-based tool to measure tannin, colour, and other phenolic parameters in red grapes, fermentations and wine

The WineCloud gives the Australian wine sector the ability to access and generate high-value compositional data related to tannin and phenolic profiles, using their own laboratory equipment. By combining sophisticated calculation algorithms and a user-friendly web-interface, grape and wine producers are able to measure and control variables which, for many winemakers, govern the intrinsic value of red wines.

This innovative web-based system is a major advancement in both processing control, and grape and wine science. The tool allows for better prediction and targeting of grape composition at harvest, and more objective targeting of wine styles in real-time during fermentation, blending, and ageing, in accordance with consumer preferences. It is also a high-value tool for supporting research trials, allowing data for a large range of variables to be generated quickly and cheaply. Additionally, the platform provides a powerful benchmarking function, allowing comparison of the phenolic composition of grapes and wines, by vintage, variety, and region.

Evaluate the potential of renewable energy technologies to reduce carbon liability and offset grid supplied electricity for wine producers

Rising energy costs are increasingly impacting on the bottom-line profitability of wine producers. Opportunities exist for the wine industry to mitigate increasing costs through energy efficiency and renewable energy technology.

The assessment of the viability of biomass power generation using grape marc was carried out. The potential savings in grid-supplied energy and emissions on offer are significant; perhaps as much as 75% depending on the technology employed. The capital payback period, coupled with the transformation of a waste stream into a valuable resource, are attractive.

The development of methods to increase processing efficiency and reduce processing costs

Proctase - a viable alternative to bentonite

Proctase provides an effective enzymatic protein stabilisation method which is a viable alternative to bentonite. The traditional bentonite batch-fining step is cumbersome, tends to tie up tank time, causes volume and quality loss, and presents waste disposal challenges. Bentonite is also very abrasive, causing accelerated wear to winery equipment such as pumps and centrifuges. Proctase significantly reduces both process costs in comparison with batch dosing of bentonite, and environmental impact, and its widespread introduction would represent the most fundamental change in white wine processing, for several decades.

Microwave treatment of red must prior to fermentation

The microwave treatment of Pinot Noir must allowed full phenolic extraction pre-fermentation, meaning that red wines could be fermented off-skins. In all probability this technique is equally applicable to other grape varieties and has profound implications for the way red wines are produced. As well as allowing full phenolic extraction pre-fermentation, the level of phenolic extraction in the wine can potentially be more accurately controlled using this method. Such microwave treatment would dramatically increase winery efficiency and reduce costs, and also potentially allow a new degree of control of red wine fermentation which might enable the development of novel wine styles.

8. Recommendations:

This stream has successfully generated an extensive suite of outcomes which have been made available to the grape and wine sector as knowledge, tools, or methods. A number of outcomes have been adopted by grapegrowers and wine producers; mainly by medium and large wine producers. These producers have the internal capability and resources to utilise the outcomes effectively, and also potentially the greatest need to reduce the costs and complexity of their processing.

Adoption has been facilitated through all of the AWRI nodes, through close interaction with the regional organisations and through commitment from individual producers to focused, collaborative projects. Increased adoption rates can be effectively achieved through continuing communications with each regional group; facilitating involvement and application of outcomes with additional producers through targeted trials; and by offering subsidised access to available tools and technologies to demonstrate the benefits of adoption.

In order to increase adoption by industry and maximise the return on the investment made to date, the following steps are recommended:

- That outcomes are made available to industry for further evaluation and adaption.

- Facilitation of access to technology outcomes such as the WineCloud, the Ferment Simulator, and rapid YAN method, should be made through regional associations, (to be addressed in Project 4.3.1 of the AWRI's R,D&E plan 2013-2018) specifically:
  - The WineCloud should be applied to better understand the impact of alternative maceration techniques with Pinot Noir and other grape varieties.
  - The Ferment Simulator should be utilised for producers who have capacity constraints and performance issues with their current fermentation process.
  - Spectral fingerprinting should be applied to fruit destined for sparkling wine production, in order to modify viticultural practices to achieve targeted phenolic profiles.

- That investment is made to further develop the outcomes of this stream into web-based tools where appropriate:
  - Many of the outputs are suited to web-based application, the efficacy of which has been demonstrated with the phenolic analyses made available to industry via the WineCloud. It is recommended that the WineCloud be extended to incorporate the fermentation simulation model described here, as well as a module which allows users to conduct

advanced statistical benchmarking of their own data, against the vast library of data which would be held in the WineCloud, (to be addressed in Project 4.1.5 of the AWRI's R,D&E plan 2013-2018).
    - Potential also exists to extend the concept of modelling beyond fermentation simulation, to other parts of the grape and wine production process, and to incorporate such models into the WineCloud, (to be addressed in Project 4.1.5 of the AWRI's R,D&E plan 2013-2018).

- That investment is made in complementary technologies which would add greater value to the outcomes of this stream:
    - To be of maximum value, models such as the fermentation simulator requires real-time data to be available on which to base predictions and assessments of the conditions of a wine, compared to known standards or specifications. An obvious opportunity therefore exists to invest in the development and adoption of process analytical technologies which have been tailored to the requirements of the grape and wine sector, in order to gather such data in an automated way, and feed it into models in real time, (to be addressed in Project 3.3.5 of the AWRI's R,D&E plan 2013-2018).

- That further investment is made in the regional nodes network, particularly in their development and adoption functions

- That the nature and value of the stream outcomes are extended to industry via:
    - continued communication on the benefits of adoption through AWRI roadshows and targeted workshops, (to be addressed in Project portfolio 4.1 in the AWRI's R,D&E plan 2013-2018);
    - continued development of focused case studies which showcase the practical use and benefits of adoption, in collaboration with industry partners, (to be addressed in Project 4.3.1 of the AWRI's R,D&E plan 2013-2018); and
    - the provision of support for industry partners in the generation of additional process knowledge through the application of these outcomes, so that the value of the benefits derived can be quantified and communicated to other potential users, (to be addressed in Projects 4.1.2 and 4.3.1 in AWRI's R,D&E plan 2013-2018).

Stream outputs that have unrealised potential and/or could ultimately provide significant benefits to industry are:

- The viability of energy generation from grape stalks and marc, which needs to be demonstrated on a pilot-scale (to be addressed in Project 1.1.4 of the AWRI's R,D&E plan 2013-2018).
- Preliminary studies carried out in the Hunter Valley have indicated that sub-regional differences, specifically soil types, might play an important role in defining phenolic profiles in Semillon juices and wines, and hence their sensory characteristics. It is important for this study to be extended to test this hypothesis, because it could provide winemakers with objective information for use in marketing Hunter Valley Semillon wines, and the ability to create target phenolic profiles in their wines to match market and consumer demands, (to be addressed in Project 3.1.4 of the AWRI's R,D&E plan 2013-2018).
- Preliminary studies in Tasmania have demonstrated the potential of microwave maceration of red must to dramatically increase the rate of colour and tannin extraction, but also to sterilise the must, and deactivate the enzyme laccase. The potential impact of this technology needs to be proven through field trials with industry partners, (to be addressed in Project 4.2.1 of the AWRI's R,D&E plan 2013-2018).

9. Budget reconciliation:

Financial Year	Receipts / Income ❶	Outgoings / Expenditure ❷
Year 1: 2006/2007	$-	$-
Year 2: 2007/2008	$-	$-
Year 3: 2008/2009	$-	$-
Year 4: 2009/2010	$-	$-
Year 5: 2010/2011	$154,964	$154,964
Year 6: 2011/2012	$264,861	$264,861
Year 7: 2012/2013	$415,024	$415,024
TOTAL	$834,849	$834,849

❶ Note that the GWRDC – AWRI Investment Agreement budget was established and approved at an aggregate level, with variances to budget (i.e. annual overspends and underspends) reported and considered at that same aggregate (i.e. whole of agreement) level. The receipts / income relating to a Stream for any year therefore equate to the outgoings / expenditure within that Stream for that year, as any variances between total Investment Agreement funding received and total funds expended were considered at the whole of Agreement rather than individual Stream level.

❷ Includes a pro-rated share of Theme 5 *Executive management and administration*.

I hereby certify that this statement is true and accurate.

Signature of duly authorised representative..

Chris Day	Group Manager – Corporate Services	29/11/2013
Name:	*Title:*	*Date:*

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