Optimising fermentation through simulation

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What if winemakers had advance warning of sluggish fermentation? What if winemakers could predict when a wayward ferment might arise and take steps to prevent it, before it happened? The AWRI Ferment Simulator is a powerful new weapon in the winemaker's arsenal. It can be used to predict ferment behaviour, test and evaluate alternative ferment management strategies, and monitor refrigeration and electricity demand so that corrective action can be taken on time and on target.

FERMENTATION: A CRITICAL STEP

Demanding, resource-intensive and sometimes unreliable: fermentation is, arguably, the most important and critical step in the winemaking process.

Optimal fermentation performance requires significant resources, typically involving daily sample collection, laboratory analysis and winemaker tastings. It also significantly affects equipment availability, energy and water use, and refrigeration capacity. The efficiency and productivity of an entire winery can be affected by stuck and sluggish fermentation.

Australian winemakers can reduce such demands on their resources through process automation control strategies. These are commonly used in other industries such as beer, pharmaceuticals and dairy, where quality can be assessed and controlled through online monitoring in real-time. In the wine industry, problem fermentation behaviour could be predicted through computer simulation, giving producers advance warning of pending issues before they happen.

AT A GLANCE

The AWRI's Ferment Simulator is now available for download from the AWRI website:

- Two versions are available – a lite version that provides basic simulation functionality, and a full version that models up to 100 concurrent ferments together with refrigeration demand profiles
- Problem fermentation behaviour can be predicted earlier (with both versions) and controlled more effectively through computer simulation, giving winemakers advanced warning of pending issues before they occur
- 'What if?' analysis provides winemakers with the ability to simulate, evaluate and fine-tune alternative ferment management strategies
- The full version also calculates refrigeration load profiles and peak electricity so that wine producers are better informed to manage site electricity use more effectively and minimise electricity demand tariffs
- The AWRI Ferment Simulator is a unique and powerful resource for real-time ferment management and maintaining product consistency. It helps winemakers achieve greater productivity and profitability.

SIMULATION: A NEW WEAPON

The AWRI Ferment Simulator is the new weapon in the winemaker's arsenal. This novel tool gives winemakers the ability to predict fermentation performance and behaviour, test and evaluate alternative management strategies, monitor refrigeration and

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The research and selection were conducted by the Institute for wine biotechnology, University of Stellenbosch (Republic of South Africa) and Lallemand.

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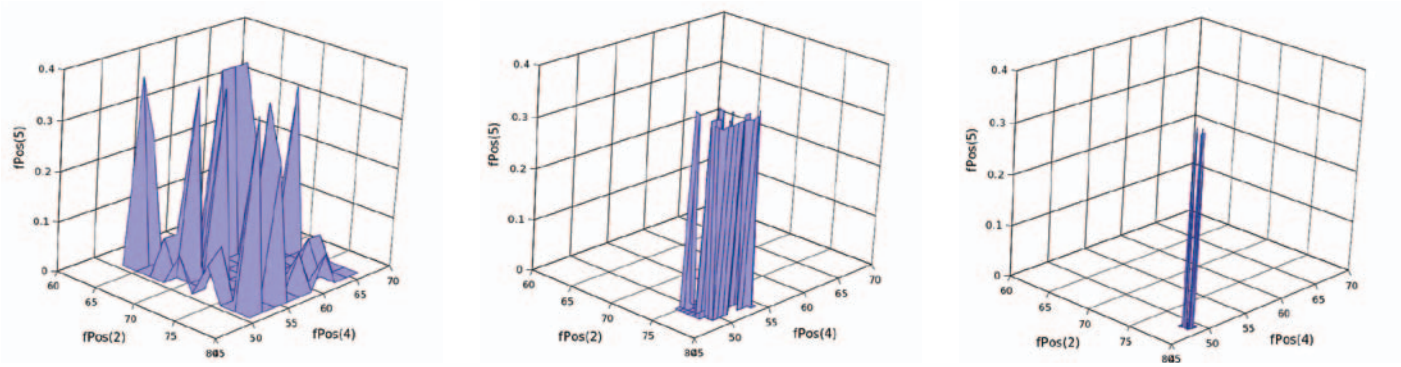

Figure 1. Particle Swarm Analysis allows the simulator to rapidly converge on the optimal parameters, as shown here after one, 10 and 20 calculation steps, respectively, to enable rapid and accurate prediction of ferment status.

electricity demand, and flag potential problems so that corrective action can be taken early, exactly when needed.

Two versions of the tool are now available for download from the AWRI website: a lite version that provides basic simulation functionality and 'what-if?' capability, and a full version. The full version offers all the features of the lite version and also allows modelling of up to 100 concurrent ferments together with the ability to generate refrigeration demand profiles across the entire tank farm.

HOW DOES IT WORK?

The tool applies scientific principles relating to classic engineering process control theory. In order to make correct decisions on how to control a process (in this case, a wine fermentation), information on process conditions must be combined with knowledge of how a process behaves under different circumstances. From an engineering perspective, this knowledge comes not only from human experience, but from process modelling and simulation.

Developing a model can help to promote better understanding and visualisation of the system that users would like to control. The AWRI Ferment Simulator puts this theory into practice by using biochemical equations to model fermentation performance. In this regard, it is similar to other models that have been presented in scientific literature: see Boulton (1980), Caro *et al.* (1991), Cramer *et al.* (2002), Sainz *et al.* (2003), Malherbe *et al.* (2004) and Coleman *et al.* (2007).

There are drawbacks to these other models, however. They require users to estimate a large number of parameters, which can make them difficult to apply in a commercial situation. Some use artificial intelligence models to generate relationships between variables; others use mathematical models without taking physical processes fully into account. Above all, their fundamental limitation is that, generally, they assume perfect mixing and uniform conditions throughout the fermentation vessel. Such assumptions may be valid under laboratory conditions in a fermentation shake-flask or micro-fermentor, but they will rarely apply in a large-scale commercial ferment. Although these models can offer general insights into the conditions affecting fermentation, their ability to predict fermentation performance in a commercial environment can be limited.

The AWRI Ferment Simulator incorporates new elements to address heat transfer and hydro-dynamics – factors that are important in commercial winemaking. One such innovation is particle swarm analysis (PSA), which is used to adapt the simulation to changing commercial ferment conditions such as temperature, yeast, wine type, nutrient levels, agitation regime and tank size.

PSA is a type of artificial intelligence algorithm that has been used for a range of problems across a number of industry sectors including mining, finance, mapping, aerospace and defence. It is designed for modelling complex, non-linear problems and is well suited to commercial wine fermentation. It allows the simulator to quickly and efficiently determine the optimal parameters that match the real-world ferment being modelled. It generates this key information with minimal computation, as shown in Figure 1.

WHAT CAN IT DO?

The AWRI Ferment Simulator was developed over several vintages, incorporating input from industry collaborators to determine its performance requirements and features. To test and evaluate the model, a wide variety of

commercial fermentation data – across multiple production sites and vintages – was used to assess its performance under different operating conditions. Its performance has been evaluated on two fronts: the ability to consistently fit a full fermentation profile and its capability to reliably predict fermentation performance from initial conditions.

There has been a deliberate effort to minimise the information required to run a simulation. The result is a model that simply requires the user to supply tank volume together with initial temperature and Baume data. Users can also supply additional information: initial cell mass and nitrogen levels, information on DAP additions, any external agitation applied, the addition of nutrients, and the inoculation date. Information on wine or yeast type is not required. During industry evaluation, the ferment completion times predicted by the simulator were found to be accurate. Using only two to three days of input data, the difference between actual and simulated ferment times was one to 1.5 days or less, in most cases.

The full version of the simulator allows wine producers to follow multiple concurrent ferments across a tank farm, with a visual 'traffic-light' display indicating the fermentation status of each active ferment. Winemakers can also follow refrigeration load profiles (see Figure 2, see page 42) by tank or across all active ferments based on fermentation progress and expected weather patterns. Warnings are given when total refrigeration capacity is expected to be exceeded.

Both the lite and full versions include a 'what if?' analysis capability. This allows winemakers to assess the impact of management strategies such as temperature adjustment, yeast nutrient addition and tank agitation. For example:

"What if I increase the temperature by 2°C on day 3?" or "What if I add DAP on day 4?"

This capability means that changes to processing can be simulated before they are implemented, to ensure that the optimal strategy is chosen (Figure 3, see page 43).

WHAT ARE THE BENEFITS?

The primary benefit of computer simulation is that problem fermentation behaviour can be predicted earlier and controlled more effectively than would otherwise be possible. Early warning gives winemakers the opportunity to take action and prevent problems before they occur. The risk of a wayward ferment is reduced as a result.

If a potential issue is identified, 'what if?' analysis provides winemakers with the ability to simulate, evaluate and fine-tune alternative ferment management strategies. When using the full version, users can calculate refrigeration load profiles and develop appropriate plans to mitigate the risk of exceeding peak electricity demand. This information can make a significant difference to wine producers' operating costs and profitability: it offers early warning so that wineries can manage electricity usage effectively (particularly on hot days) and take steps to schedule winery operations appropriately to avoid punitive electricity costs.

The tool provides a unique and powerful resource for continuous quality improvement and product consistency from ferment to ferment.

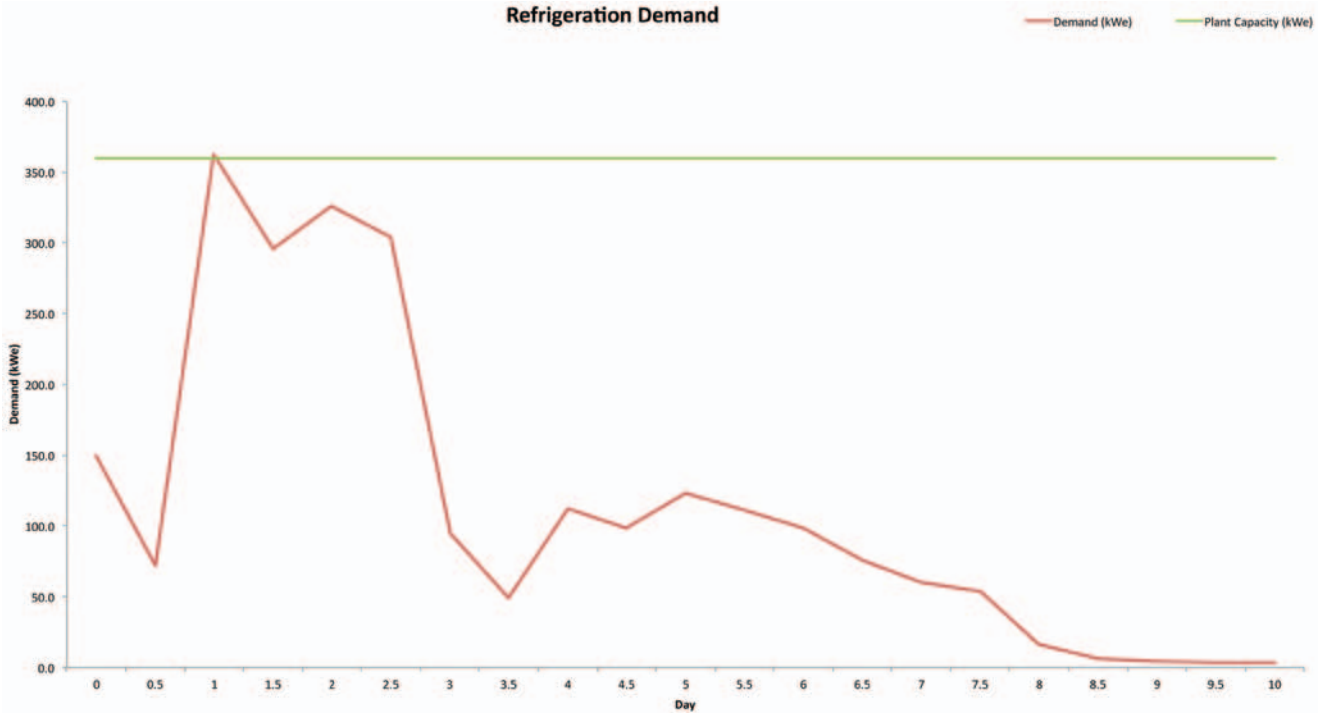

Figure 2. Predicted refrigeration demand in relation to plant capacity over the coming 10 days.

WHERE CAN I ACCESS THE AWRI FERMENT SIMULATOR?

The two versions of the AWRI Ferment Simulator are now available from the AWRI website.

Both versions can be downloaded as Excel files. The lite version (compatible with Office 2003 onwards) provides basic simulation functionality; the full version (compatible with Office 2007 onwards) offers more advanced features.

A LibreOffice version (compatible with v3.5 onwards) of the AWRI Ferment Simulator – full version is also available for Linux operating systems. The source code has been unlocked, allowing wine producers to adapt the simulator

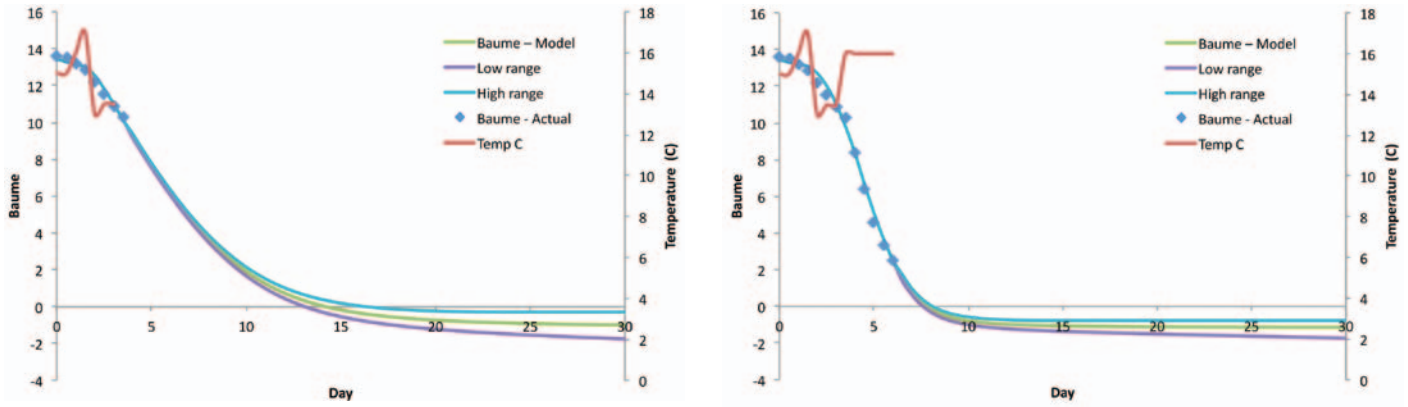

Figure 3. After 3.5 days a sluggish ferment (of 14.5 days duration) is predicted (left). An increase in ferment temperature together with a DAP addition and a pump-over is shown to bring the ferment back 'on-course', with ferment now complete after eight days (right).

functionality to interface directly with their onsite LIMS/PLC/SCADA systems for automatic data acquisition if desired.

To access and download the simulator and obtain further details, visit www.awri.com.au

ACKNOWLEDGEMENTS

This work is funded by Australian winemakers and grapegrowers through their investment body, the Grape and Wine Research and Development Corporation, with matching funding from the Australian Government. The AWRI is a member of the Wine Innovation Cluster. The authors thank Sharon Mascall-Dare and Ella Robinson for their editorial assistance.

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