AWRI Ferment Simulator

The AWRI Ferment Simulator is a spreadsheet-based tool designed to provide wine producers with the capability to monitor and predict wine fermentation performance, as well the ability to track important winery metrics such as refrigeration load, energy costs and fermentation throughput.

The AWRI Ferment Simulator has been developed based on field testing conducted through the AWRI Riverina Node during vintages 2011-13. The Simulator was 'trained' on commercial-scale fermentation data sourced from multiple sites across several vintages, and during development was found to reliably predict commercial fermentation performance under various different operating conditions including temperature, yeast strain, wine type, nutrient levels, and fermenter size.

The Simulator allows for multiple concurrent ferments (up to 100 concurrent ferments) and staggered fruit intake, together with additional engineering metrics including refrigeration requirements for must-chilling, cold-settling/cold-soak and fermentation temperature maintenance, as well as energy demand and cost, and impacts from ambient weather conditions. The Simulator also incorporates additional parameters such as variable tank mixing and fermentation/must-chilling/cold-soak heat loads, as well as capability for 'what-if?' analysis that allows winemakers to assess the impact of alternative fermentation management strategies such as temperature adjustment, yeast nutrient addition, and tank agitation regime. The following documentation details these operating procedures, from entering fermentation data, running and updating simulations, what-if analysis, and archiving fermentation records.

The AWRI Ferment Simulator is now provided as an unlocked Excel file (compatible with Office 2007 onwards). A LibreOffice version (compatible with v3.5 onwards) is also available for Linux operating systems. The source code is also unlocked, allowing wine producers to adapt the simulator functionality to interface directly with LIMS/PLC/SCADA systems for automatic data acquisition is desired.

Please feel free to contact the AWRI with any queries, comments, and suggestions regarding the Simulator, or for assistance in use of the package.

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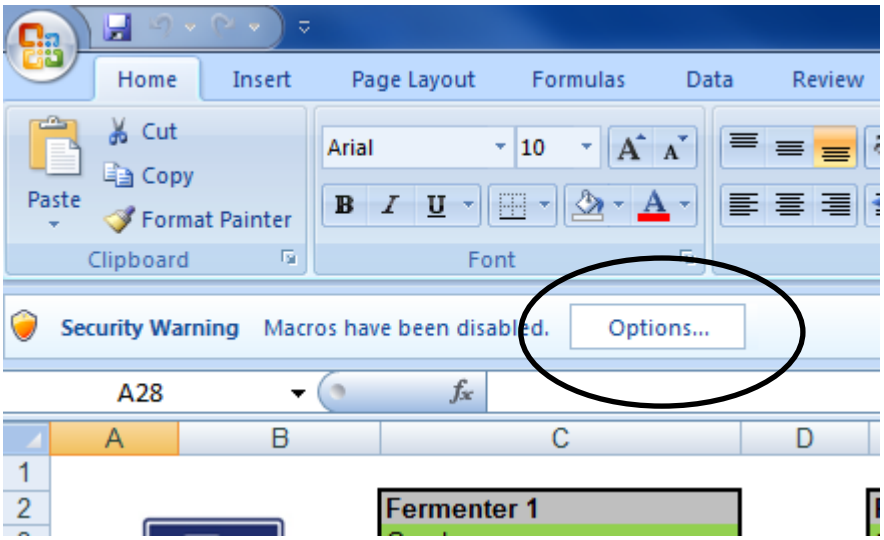
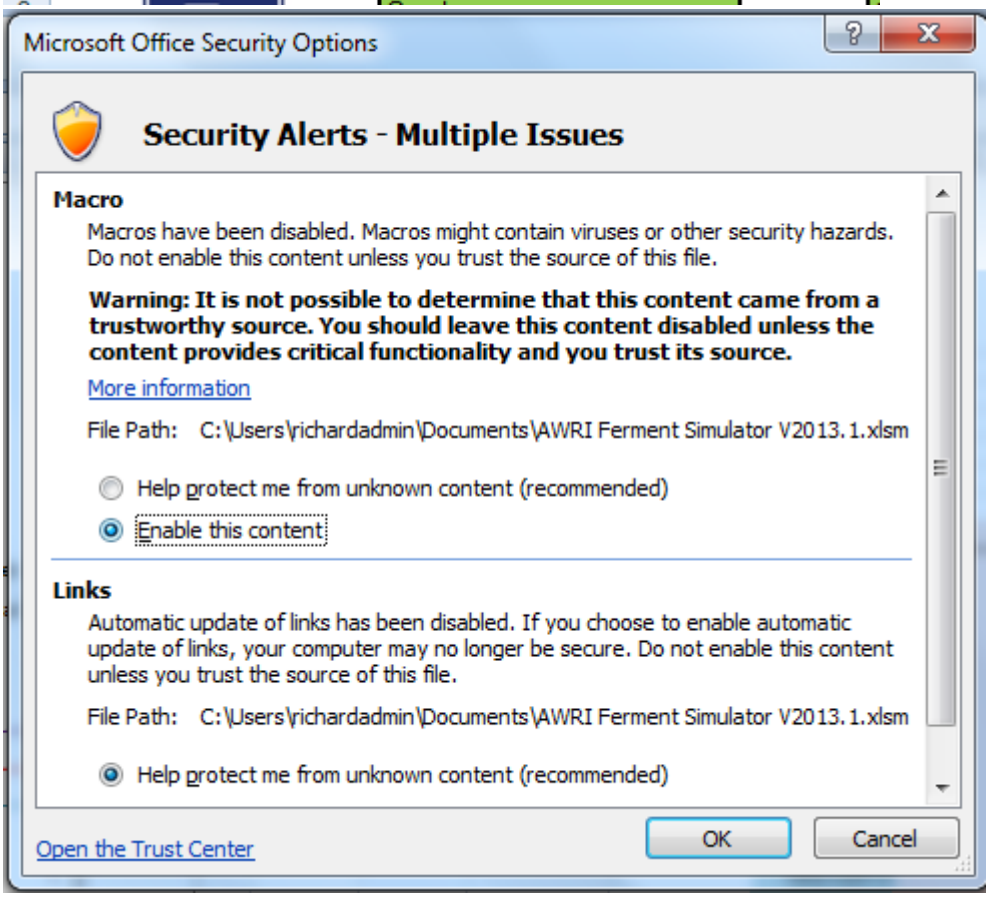
AWRI Ferment Simulator

Operating Procedure

1. Enable Macros

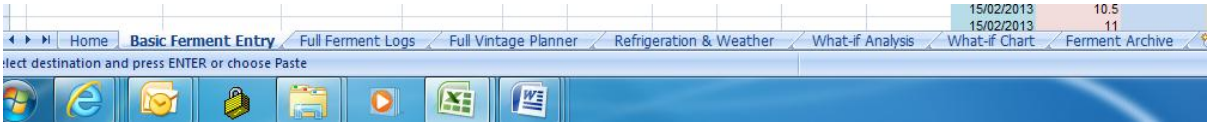
Upon opening the Simulator, please ensure that macros are enabled.





Click OK

2. Worksheets – Overview



Home – this worksheet displays the current status of all tanks in the Ferment Simulator. From here you can see a summary of each fermenter, including fermenter status, current baume and estimated ferment duration.

Basic Ferment Entry The 'Basic Ferment Entry' screen sheet is a simple screen that allows the user to enter in basic ferment data such as the fermenter start date and time, fill volume and nitrogen, as well as regular baume and temperature values collected throughout fermentation. A baume and temperature chart of the current ferment is also shown, together with the ferment prediction.

Full Ferment Logs – this worksheet tab contains the full details of each active fermenter, and is similar in layout to the paper ferment record sheets used by many commercial wineries. In addition to the baume and temperature fields shown on the basic ferment entry screen, this worksheet provides fields to enter data such as initial yeast cell mass, tank insulation, must chilling and cold settling conditions, tank additions and operations such as pump-overs and agitation – all of which will impact on the model predictions. Additional fields are also provided for users to enter comments, or additional analysis results conducted during fermentation.

Full Vintage Planner – this worksheet displays fermentation and refrigeration data across all 100 fermenters for the entire vintage, in 3 hour increments. This screen is used by the simulator to determine overall refrigeration demand, however some producers have commented that this screen would also be a helpful guide to assess tank availability and to plan tank movements.

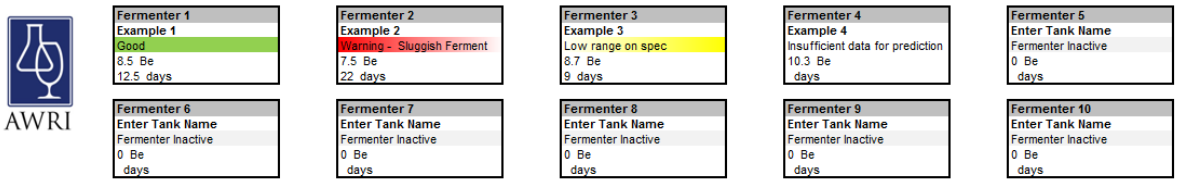
Refrigeration & Weather – this worksheet gives both a tabular and graphical display of predicted refrigeration demand over the coming 10 days, based on the fermentation data that has been entered into the Simulator. A table is also provided for users to enter the max/min weather forecast (up to 10 days) for the winery. This worksheet is also where the user provides details on their refrigeration plant, such as brine temperature and overall refrigeration capacity.

What-if Analysis – this worksheet is used for 'what-if?' analysis.

What-if Chart – this tab displays the detailed view of most recent fermentation simulation run. It is also used to show the results of 'what-if?' analysis.

Ferment Archive – this worksheet is used to store completed ferments that have been archived.

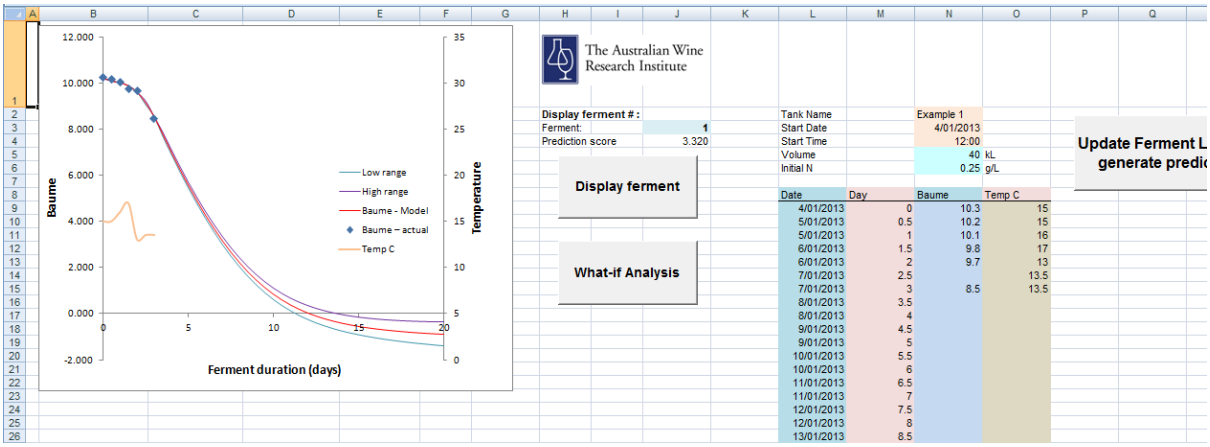
3. Getting Started- Home



This worksheet displays the current status of all tanks in the Ferment Simulator. From here you can see a summary of each fermenter, including fermenter status (Green – Good, Yellow – trending away from specified ferment duration but still within low/high limits, Red- Warning out of spec), current baume and estimated ferment duration.

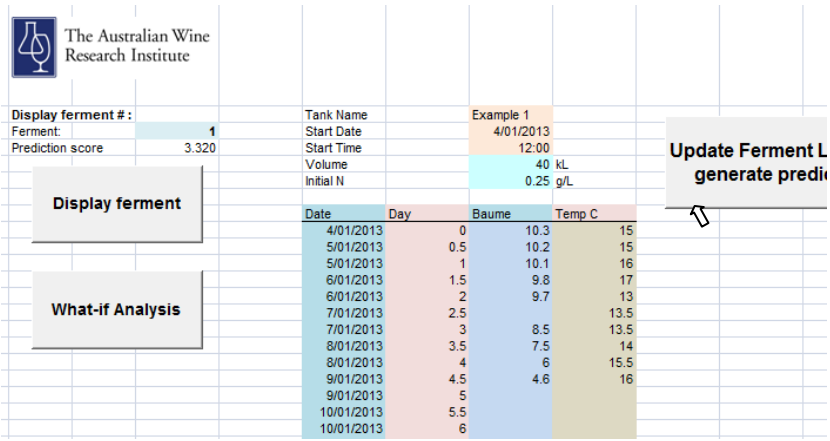
Any ferment which requires attention can then be displayed either by double clicking on that fermenter's grey "Fermenter #"label box, or using the display ferment button on the Basic Ferment Entry worksheet.

4. Getting Started – Basic Ferment Entry



Go to the Basic Ferment Entry worksheet

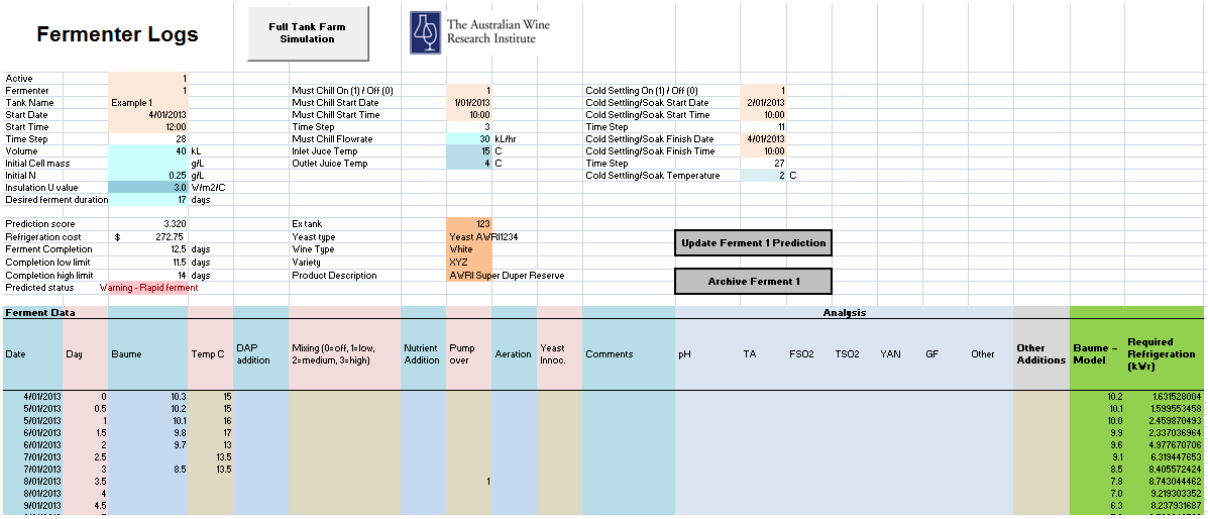
1. Go to the Basic Ferment Entry worksheet. Three example ferments are provided, with Ferment 1 being displayed the first time the simulator is used.
2. New baume and temperature data for a ferment can be added using this screen. Try adding some new values (hit enter after each value is entered), and then click on the "Update Ferment Log and generate prediction" button on the worksheet. E.g.



3. This will update the full ferment log (which can be seen on the Full Ferment Log worksheet) with these new values. If the ferment log for that fermenter contains more than 5 data points, the prediction will also be updated, with the updated prediction shown on the chart to the left of screen. (A minimum of 5 data points is required to calculate a prediction.)
4. To display a different ferment, type the ferment number into the blue "Display ferment #" cell (Cell J3), and press enter. Then click on the "Display ferment" button on the worksheet. Three example ferments have been provided. To display example ferment 2, type 2 into "Display ferment #" cell (Cell J3), and press enter. Then click on the "Display ferment" button. The data for Ferment 2 will now be displayed.
5. The Basic Ferment Entry worksheet can also be used to enter data for a new ferment. To enter new data for a newly inoculated ferment, first display the fermenter. For example, type 4 into the blue "Display ferment #" cell (Cell J3), and press enter. Then click on the "Display ferment" button on the worksheet.

6. Enter the tank name, the start date (in the format: day/month/year) and the start time (in 24 hour time).
7. Enter the ferment volume (in kL) and the initial YAN value if known. If the YAN value is unknown, this cell can be left blank.
8. Enter in the first baume and temperature values. Click on the “Update Ferment Log and generate prediction” button on the worksheet. This new information will now have been entered into the full ferment log.
9. You will notice another button on this worksheet – “What-if Analysis”. This feature is used to troubleshoot a potential problem ferment by allowing the user to try different ferment conditions to help establish what action can be taken to rectify the problem. For more detail on this feature, refer to **Section 8 - What-if analysis**

5. Getting Started – Full Ferment Log



Fermenter Logs

Full Tank Farm Simulation

The Australian Wine Research Institute

Active	1								
Fermenter	1		Must Chill On (1) / Off (0)	1		Cold Settling On (1) / Off (0)	1		
Tank Name	Example 1		Must Chill Start Date	1/01/2013		Cold Settling/Soak Start Date	2/01/2013		
Start Date	4/01/2013		Must Chill Start Time	10:00		Cold Settling/Soak Start Time	10:00		
Start Time	12:00		Time Step	3		Time Step	11		
Time Step	28		Must Chill Flowrate	30	kL/hr	Cold Settling/Soak Finish Date	4/01/2013		
Volume	40	kL	Inlet Juce Temp	15	C	Cold Settling/Soak Finish Time	10:00		
Initial Cell mass		g/L	Outlet Juice Temp	4	C	Time Step	27		
Initial N	0.25	g/L				Cold Settling/Soak Temperature	2	C	
Insulation U value	3.0	W/m2/C							
Desired ferment duration	17	days							
Prediction score	3.320		Ex tank	123					
Refrigeration cost	$ 272.75		Yeast type	Yeast AWRI1234					
Ferment Completion	12.5	days	Wine Type	White					
Completion low limit	11.5	days	Variety	XYZ					
Completion high limit	14	days	Product Description	AWRI Super Duper Reserve					
Predicted status	Warning - Rapid ferment								

Update Ferment 1 Prediction

Archive Ferment 1

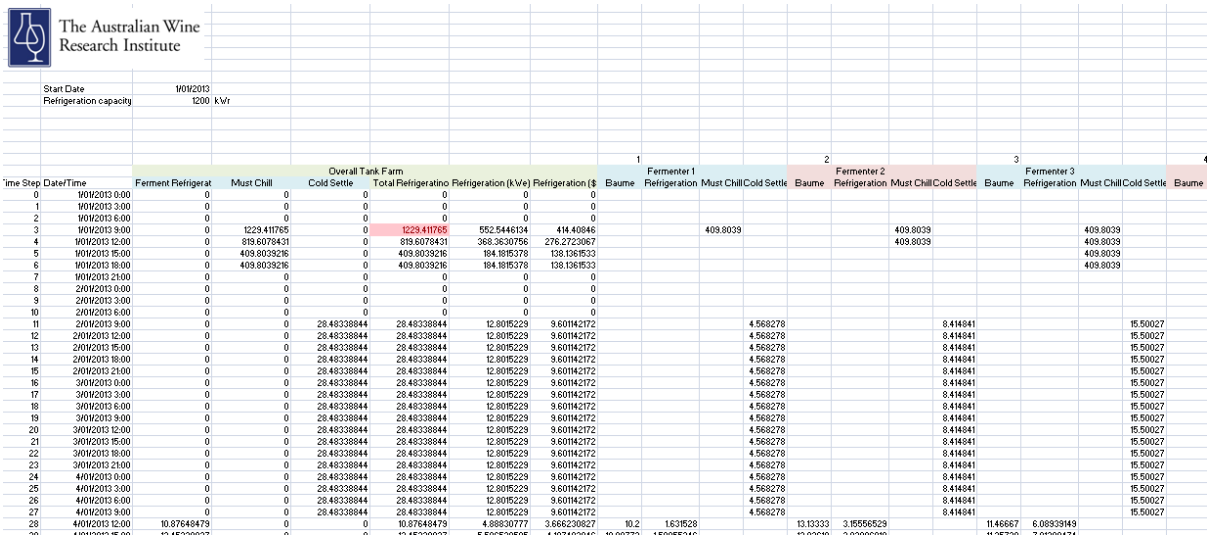
Ferment Data										Analysis								
Date	Day	Baume	Temp C	DAP addition	Mixing (0=off, 1=low, 2=medium, 3=high)	Nutrient Addition	Pump over	Aeration	Yeast Innoc.	Comments	pH	TA	FSO2	TSO2	YAN	GF	Other	Other Additions	Baume - Model	Required Refrigeration (kWr)
4/01/2013	0	10.3	15																10.2	1.631528004
5/01/2013	0.5	10.2	15																10.1	1.599553458
5/01/2013	1	10.1	16																10.0	2.459870493
6/01/2013	1.5	9.8	17																9.9	2.337036964
6/01/2013	2	9.7	13																9.6	4.977670706
7/01/2013	2.5		13.5																9.1	6.319447653
7/01/2013	3	8.5	13.5																8.5	8.405572424
8/01/2013	3.5						1												7.8	8.743044462
8/01/2013	4																		7.0	9.219303352
9/01/2013	4.5																		6.3	8.237931687

1. As described in **Section 2 – Worksheet Overview**, the Full Ferment Log worksheet contains the full details of each active fermenter. This worksheet is designed to be similar in layout to the paper ferment record sheets used by many commercial wineries.
2. In addition to the baume and temperature fields shown on the Basic Ferment Entry screen, this worksheet provides additional data fields for the ferment, to enter information such as initial yeast cell mass, must chilling and cold settling conditions, tank additions and operations such as pump-overs and agitation. All of these parameters if used will impact on the model predictions, however this information is optional and is not required for a prediction to be made (obviously the prediction will be more robust as more information about the ferment is supplied).
3. Additional fields are also provided for users to enter comments, or additional analysis results conducted during fermentation, as well as text fields for yeast and wine type, variety and product description. This information is also optional as it is not used by the simulator for calculating the prediction.
4. Throughout the ferment, DAP additions can be recorded in the appropriate column (in g/L) on the fermenter log as they occur.
5. Mixing and agitation is also recorded on the fermenter log, with a numerical value used to simulate agitation and mixing operations. Suggested values are:
   - 0 = no mixing
   - 1 = low mixing (eg in-tank agitator)
   - 2 = moderate mixing
   - 3 = high mixing
6. When a mixing value is entered, that value is used in the simulation until another non-blank value is encountered on the fermenter log. A blank cell will not reset the mixing value back to zero; a zero value must be physically entered into the log.

   To simulate an in-tank agitator which is switched on and then left on for a period of time, enter a mixing value of 1 or 2 at the time the agitator is switched on, and then a 0 (zero) value when it is again switched off. Mixing due to CO_2 production by the ferment is already accounted for in the model and so does not need to be entered here by the user.

7. To simulate a one-off mixing event (such as a pump-over or gas sparging), simply enter a 1 into the appropriate column at the time the mixing event is to occur.
8. To simulate a nutrient addition, enter a 1 into the appropriate column at the time the addition is to occur.
9. After new data are entered on a ferment log, the ferment should be updated by double clicking in the grey "Update Ferment # Prediction" box (where # is fermenter in question)
10. If data are recorded on the ferment log before inoculation actually occurs, the time of inoculation should be indicated by entering a 1 into the appropriate column at the time inoculation is to occur. If the ferment is an uninoculated wild ferment, then this column can be left blank.
11. The user can enter the desired ferment duration (in row 12 of the ferment log). This value is used to determine if the ferment is trending on or off course. When a prediction is made, the simulator predicts the ferment duration (given in row 16 of the ferment log), as well as a predicted completion low limit and high limit. If the user's desired ferment duration is within 2 days of the predicted ferment duration, the predicted status will be "Good" (indicated with a green colour bar). If the user's desired ferment duration is within 2 days of the predicted high or low limit, the predicted status will be "High/Low range on spec" (indicated with a yellow colour bar). If the user's desired ferment duration is not within 2 days of the predicted high or low limit, the predicted status will be "Warning – Rapid/Sluggish ferment" (indicated with a red colour bar).
12. The Refrigeration cost (shown in row 15) is the predicted refrigeration energy cost for fermentation cooling for that ferment. This is calculated based on the refrigeration data provided on the "Refrigeration & Weather" worksheet. See **Section 7- Refrigeration & Weather**
13. The refrigeration calculations will also take into account the weather forecast data entered on the "Refrigeration & Weather" worksheet. Again, see **Section 7- Refrigeration & Weather**
14. The refrigeration calculations will further take into account the insulation used on the tank. This is indicated with the "Insulation U value" which is given in row 11. Suggested values are 0.8 for a completely insulated tank, 3.0- 5.0 for a partially insulated tank, and 10.0 – 12.0 for an uninsulated tank.
15. If the user wishes to record additional comments or notes (or other additions not already provided for on the ferment log), these can be entered into the "comments" and "analysis" columns.
16. Once the ferment has concluded, double click on the grey "Archive Ferment #" box to copy the fermenter record to the ferment archive worksheet. The fermenter log is then automatically reset, ready for the next ferment to be entered.
17. It is possible to update the ferment predictions of all active ferments (as indicated by the "Active" flag on the fermenter log) at once by clicking on the "Full Tank Farm Simulation" button. Note that if there are a large number of active ferments, this operation could take several minutes to calculate and update.
18. Note: The "Time step" values that are shown on this worksheet are internal calculation values that are used to determine where on the Full Vintage Planner those results should recorded.

6. Full Vintage Planner



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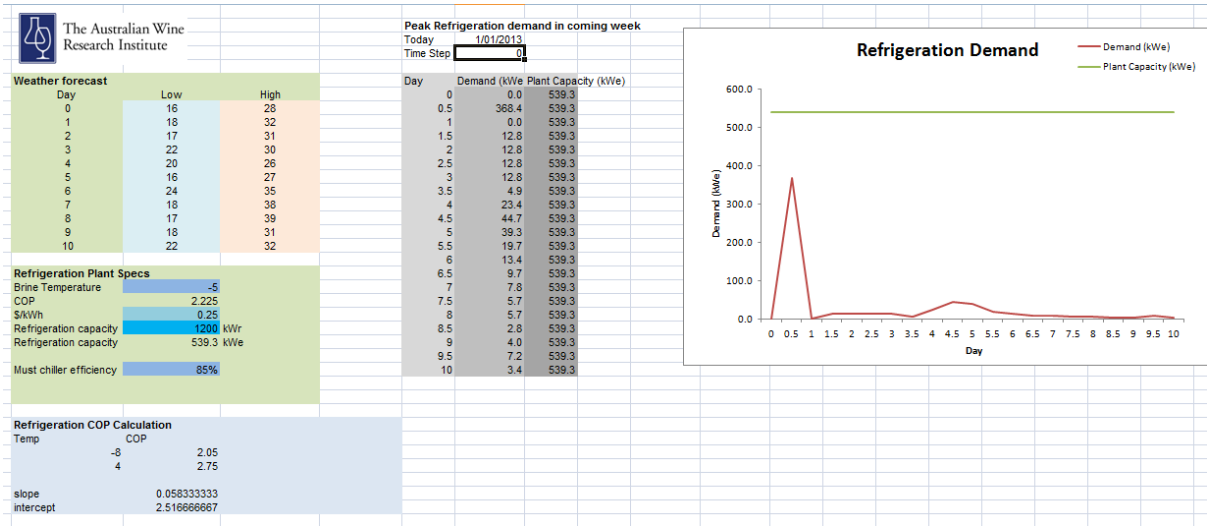
Start Date	1/01/2013	
Refrigeration capacity	1200	kWr

			Overall Tank Farm					1	Fermenter 1			2	Fermenter 2			3	Fermenter 3			4
Time Step	Date/Time	Ferment Refrigerat	Must Chill	Cold Settle	Total Refrigeratino	Refrigeration (kWe)	Refrigeration ($	Baume	Refrigeration	Must Chill	Cold Settle	Baume	Refrigeration	Must Chill	Cold Settle	Baume	Refrigeration	Must Chill	Cold Settle	Baume
0	1/01/2013 0:00	0	0	0	0	0	0													
1	1/01/2013 3:00	0	0	0	0	0	0													
2	1/01/2013 6:00	0	0	0	0	0	0													
3	1/01/2013 9:00	0	1229.411765	0	1229.411765	552.5446134	414.40846			409.8039				409.8039				409.8039		
4	1/01/2013 12:00	0	819.6078431	0	819.6078431	368.3630756	276.2723067							409.8039				409.8039		
5	1/01/2013 15:00	0	409.8039216	0	409.8039216	184.1815378	138.1361533											409.8039		
6	1/01/2013 18:00	0	409.8039216	0	409.8039216	184.1815378	138.1361533											409.8039		
7	1/01/2013 21:00	0	0	0	0	0	0													
8	2/01/2013 0:00	0	0	0	0	0	0													
9	2/01/2013 3:00	0	0	0	0	0	0													
10	2/01/2013 6:00	0	0	0	0	0	0													
11	2/01/2013 9:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
12	2/01/2013 12:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
13	2/01/2013 15:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
14	2/01/2013 18:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
15	2/01/2013 21:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
16	3/01/2013 0:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
17	3/01/2013 3:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
18	3/01/2013 6:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
19	3/01/2013 9:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
20	3/01/2013 12:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
21	3/01/2013 15:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
22	3/01/2013 18:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
23	3/01/2013 21:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
24	4/01/2013 0:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
25	4/01/2013 3:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
26	4/01/2013 6:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
27	4/01/2013 9:00	0	0	28.48338844	28.48338844	12.8015229	9.601142172				4.568278				8.414841				15.50027	
28	4/01/2013 12:00	10.87648479	0	0	10.87648479	4.88830777	3.666230827	10.2	1.631528			13.13333	3.15556529			11.46667	6.08939149			

This worksheet displays fermentation and refrigeration data across all 100 fermenters for the entire vintage, in 3 hour increments. This screen is used by the simulator to determine overall refrigeration demand. Time intervals where the Total Plant Refrigeration Demand is predicted to exceed capacity are highlighted in Red.

Some producers have commented that this screen may also be helpful to assess tank availability and to plan tank movements. As the user scrolls across the worksheet, the time that different parcels are predicted to be must chilled and then occupy a fermenter are shown on the table. This could be used as a visual cue to assess when tanks will become available, or when scheduling issues with access to the must chiller may arise. This is a new feature, and so any feedback that users can provide to the AWRI for improvement would be very helpful.

7. Refrigeration & Weather



This worksheet gives both a tabular and graphical display of predicted refrigeration demand over the coming 10 days, based on the fermentation data that has been entered into the Simulator. As ferment predictions are made and the results recorded on the Full Vintage Planner, the Refrigeration Demand graph will be updated.

A table is provided for users to enter the max/min weather forecast (up to 10 days) for the winery. In future versions it is planned for these data to be automatically retrieved from www.bom.gov.au based on the user's location within Australia. However for this version, weather data must be entered manually.

This worksheet is also where the user provides details on their refrigeration plant, such as brine temperature and overall refrigeration capacity in kW (refrigeration). These values are entered into the appropriate cells as indicated above. [Note: to convert Refrigeration Tons to kW (refrigeration) multiply the Refrigeration Tons value by 3.52.]

Refrigeration Plant COP (Coefficient of Performance) is estimated using the brine temperature.

8. ‘What-if?’ Analysis

= user adjustable field

What-if ??

Ferment start time	12:00
Volume	250 kL
Initial Cell mass	g/L
Initial N	0.3 g/L
Desired ferment time	8 days
Prediction score	9.067
Refrigeration cost	$ 1,437.04

Refrigeration COP	2.225
Electricity Cost ($/kWe)	0.25
Overall Tank U value (W/m2/C)	3.0

Commercial Ferment									Simulation model								
Day	Baume – actua	Temp C	DAP additi	Mixing (0 t	Nutrient A	Pump ovei	Aeration	Yeast Innoc.	dBe/dt	Baume – li	Required r	Active Cel	Ethanol	Nitrogen	Corrected	Low range	High range
0	11.5	14							7.19655	11.5	6.08939	0.33974	0	0.3	14	11.4667	11.4667
0.5	11.5	15							4.59707	11.4	7.79189	0.76679	0.82408	0.27702	14.25	11.3577	11.3577
1	11.4	14							5.8843	11.3	13.2658	1.09894	1.58348	0.2561	14.8	11.2573	11.2573
1.5	11.3	15							3.79387	11.1	17.9397	1.68826	3.01509	0.21749	14.2	11.0681	11.0681
2	10.3	15							6.25709	10.7	36.9552	2.73935	5.95789	0.14281	15	10.6793	10.6793
2.5	9.5	14							4.95817	9.8	77.1662	4.28431	12.9645	0.02023	14.8	9.75483	9.75483
3	8.7	14							6.83319	8.3	97.4679	4.56558	24.2109	0.00012	14	8.27354	8.27354
3.5									8.25308	6.9	86.9964	4.56075	34.9636	6.6E-07	14	6.63606	7.08118
4									15.5331	5.6	82.5104	4.55245	44.8878	3.5E-09	14	5.3117	5.79675
4.5									23.3564	4.4	72.8376	4.54211	53.9252	2E-11	14	4.10324	4.63304
5									33.2232	3.3	66.8592	4.52995	61.9799	1.2E-13	14	3.02385	3.60208
5.5									40.9014	2.4	55.9217	4.51619	68.9723	8.7E-16	14	2.08419	2.71368
6									38.7358	1.6	49.2492	4.50108	74.8598	7.8E-18	14	1.28974	1.9727
6.5									43.154	1.0	38.4819	4.48486	79.6548	9.4E-20	14	0.63844	1.37659
7									39.4582	0.5	32.9884	4.46778	83.4348	1.6E-21	14	0.11959	0.91429
7.5									41.1248	0.1	24.2799	4.45005	86.3328	4.1E-23	14	-0.28472	0.56762
8									42.9535	-0.1	21.3413	4.43184	88.5119	1.5E-24	14	-0.59606	0.31481
8.5									42.8627	-0.4	15.2225	4.41329	90.1352	8.2E-26	14	-0.83577	0.13434
9									42.7494	-0.5	14.5645	4.39453	91.3446	6.2E-27	14	-1.02227	0.00769
9.5									43.7029	-0.6	10.2675	4.37562	92.2521	6.2E-28	14	-1.17004	-0.07973
10									47.0905	-0.7	10.9756	4.35662	92.9413	8E-29	14	-1.28982	-0.07973
10.5									36.5444	-0.8	7.66605	4.33758	93.4723	1.3E-29	14	-1.38933	-0.07973
11									31.4419	-0.8	9.07575	4.31852	93.8875	2.5E-30	14	-1.47404	-0.07973
11.5									28.8883	-0.9	6.26259	4.29947	94.2173	5.5E-31	14	-1.54781	-0.07973
12									26.8303	-0.9	8.02493	4.28044	94.4829	1.4E-31	14	-1.61338	-0.07973
12.5									27.8894	-0.9	5.46458	4.26145	94.6998	4E-32	14	-1.67272	-0.07973
13									25.2897	-1.0	7.41031	4.2425	94.879	1.3E-32	14	-1.72727	-0.07973
13.5									27.815	-1.0	4.98473	4.2236	95.0289	4.3E-33	14	-1.77807	-0.07973
14									29.6405	-1.0	7.03083	4.20476	95.1554	1.6E-33	14	-1.82591	-0.07973
14.5									24.4977	-1.0	4.68099	4.18598	95.2633	6.2E-34	14	-1.87138	-0.07973
15									22.7527	-1.0	6.78499	4.16726	95.3561	2.6E-34	14	-1.91494	-0.07973

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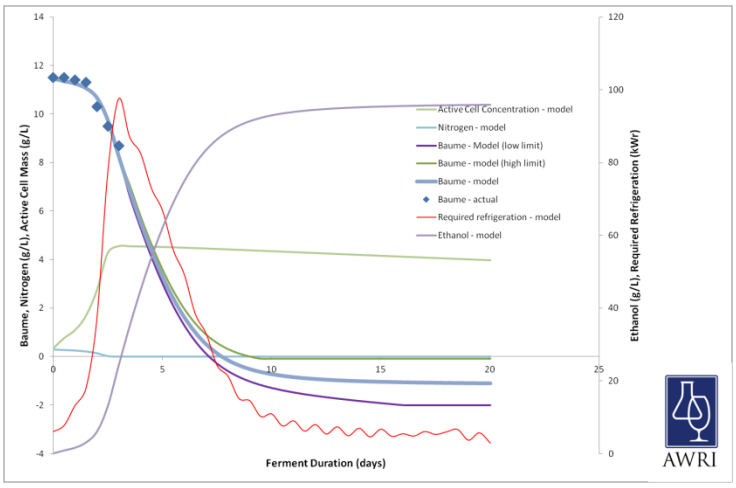
fPos(6)

Estimated Fe
Model
Low range
High range

Ferme

1. To run a ‘what if?’ analysis on a specific ferment, first go to the Basic Ferment Entry woksheet.
2. Then display the ferment by typing the ferment number into the blue “Display ferment #” cell (Cell J3), and press enter. Then click on the “Display ferment” button on the worksheet.
3. Then click on the “What-if Analysis” button on the worksheet.
4. This will take you to the “What-if Analysis” worksheet. The ferment log will be automatically copied to the what-if analysis worksheet, and the prediction recalculated.
5. Once this has completed, the user can make changes as desired to the temperature profile, initial N value, “Refrigeration COP” or “Insulation U value”, weather forecast etc. Click the “What if?” button to see the effect of those changes. Click on the “What-if? Chart” worksheet tab to see a graph of the current “what if?” scenario.



6. Return to the What if Analysis worksheet. To see the impact of different agitation, or nutrient additions, or YAN addition, or pump-over etc, enter those new parameters on the worksheet and click on the “What if?' button. The winemaker can then make their own assessment as to whether those new conditions should then be implemented in the winery

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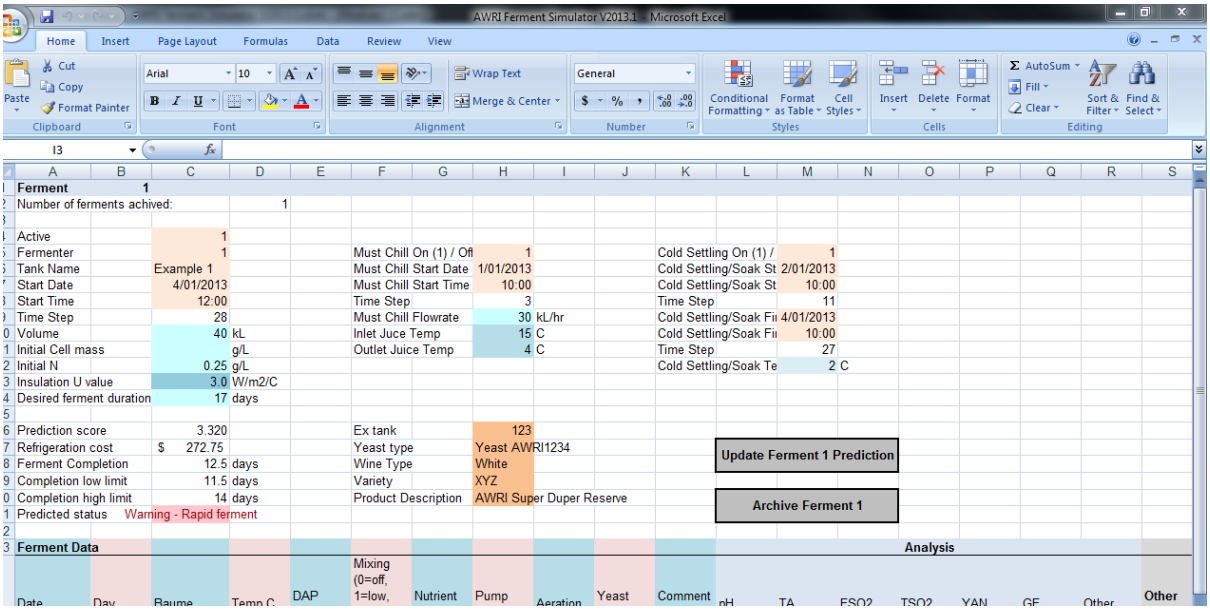
9. Ferment Archive



This worksheet is used to store completed ferments that have been archived. This is a display worksheet only - ferment predictions cannot be updated from this worksheet.