Recovery of valuable products from lees and integrated approach to minimise waste and add value to wine production

FINAL REPORT to
Grape and Wine Research and Development Corporation

Project Number: **UM 01/01**

Principal Investigator: **Professor Tony Bacic**

Research Organisation: **The University of Melbourne**

Date: **July 2003**

Executive Summary

It has been proposed that valuable products could be recovered from wine lees (and other winery solids wastes). Added-value products from yeast lees could include spreads, non-caloric thickeners, flavour enhancers, and functional food additives, such as ß-glucans. However, the economic benefits for the wine industry are difficult to calculate as there were no reliable figures on the solid wastes produced at Australian wineries or information on how these wastes are handled or disposed.

Based on an industry-wide survey we have calculated that wineries create over 300 kg of solid waste for each tonne of fruit crushed, i.e. 30% of the harvest, on average. Our model estimates that from the 1,605,846 tonnes of fruit crushed in the 2001/02 vintage the following wastes were generated:

- 57,000 tonnes of stalks,
- 218,000 tonnes of grape marc,
- 21,000 tonnes of unfermented juice lees solids,
- 10,000 tonnes of fermented yeast lees solids, and approximately
- 8,000 tonnes of bentonite clay was used.

Forty five wineries were selected for the survey, approximately 4% of the total number in Australia, representing the ten winery size categories used in the Australian and New Zealand Wine Directory. A database of wine waste information was created and a model extracted from the survey responses. This model has been validated to ensure that it is both reasonable and useful for predicting waste quantities. Using statistical methods an average figure was calculated for each major waste stream as a percentage of the fresh fruit over a range of tonnages. The quantity of the wastes produced is related to the size of the winery, primarily due to the different technologies used during the winemaking process. For example large wineries often use a rotary drum vacuum filter (RDV) to recover an additional ~2% of fruit from lees as juice/wine.

Grape marc can account for 22% of the fruit processed at small wineries. Stalks are a significant waste for both red and white wines accounting for up to 5.5% of the crush. After wine and juice are recovered from yeast lees, from both red and white ferments, there are still 0.5-0.7 tonnes dry lees per 100 tonnes fruit. Although this seems very low in a 10,000 tonne winery this equates to the production of 50-70 tonne dry yeast waste per year.

The majority of wineries do not process their wastes, and the most common practise is to dispose them on-site, by dumping or settling in ponds. The destinations for winery waste off-site include processing for tartaric acid, low quality wine and ethanol, animal feed and composting. Proximity to an extraction facility and the value of the material are major drivers as to whether these wine wastes get processed.

The costs and revenues from winery waste are varied, with smaller wineries often considering solid wastes as valuable by-products for vine nutrition through mulching. Some wineries had their waste collected, or paid a minimal transport cost, to be processed off-site which generated an income (or rebate on low quality wine for fortification). Animal feed was the destination for one winery's wastes, generating a small return. Some large wineries pay significant amounts (up to $50,000) to have their waste disposed at landfill and composting facilities. However, a lack of local markets was considered a barrier to establishing new large-scale composting operations.

A model has been developed to calculate the solid wastes produced by Australian wineries and can now be used by the wine industry to calculate the quantities of wastes created at both

the winery level and regional level. This information will be valuable in the assessment of the net benefits to the wine industry for alternative uses of these wastes.

Jane Evans
CRC for Bioproducts

Acknowledgements
The CRC wishes to acknowledge the winery owners, winemakers and other winery staff who were extremely helpful and patient in answering the questions and providing technical input upon which this survey was built. The CRC also acknowledges the substantial contribution made by Mr Robert Jordan and Mr Simon Lane in the preparation, conduct and analysis of the survey.

1. Introduction

Cleaner production is a hierachial approach to waste management with the objectives of both minimising waste and recovering products for reuse. These principles have been used to assist the Australian Wine Industry to manage its production waste water. A similar approach is needed for solid waste management and forms the basis of the current study.

Marc and lees are reported to be used in certain wineries as a source of ethanol and tartaric acid, and extracted from these wastes by third parties. Lees not despatched for extraction of by-products are directed to waste, where they contribute significantly to oxygen removal via microbiological metabolism and resulting odour problems. The study reported here aimed to assess the availability and current value of marc and lees and the potential value-added products from solid waste (lees). This report explores the potential for commercial and environmental net benefits to the wine industry from alternative uses of these waste lees.

2 Aims of Survey

To conduct a national survey of the winery industry in order to capture current practices in handling solid winery processing waste.

3 Methodology

A set of survey questions was developed (Appendix A) in collaboration with a small focus group of wine industry contacts to ensure that the relevant questions and wine industry perspectives were addressed. Substantial contributions were made by Mr. Robert Jordan, who had performed a similar but narrower survey on grape marc in Victoria in 2001/2. The survey was performed in early to mid 2003, primarily by telephone, using the standard survey questions as a guide. For larger wineries the survey questions were circulated by email to the survey participants in advance to facilitate discussion and to expedite the telephone interviews.

It was anticipated at the outset that the amount of a waste, such as marc, generated per tonne of incoming fruit would vary across all wineries. The fruit used and the winery technology and practices both influence the proportions of wastes obtained. The berry size and rachis determine the proportion of seeds, skin and stalk that will be removed. This in turn is a result of variety, berry size, cultural practice and climate, all of which tend to be a reflection in turn of the region. Wine quality, winery technology and winery size were also expected to impact on the proportion of fruit that ends up as a particular waste. (see Appendix B 'Overview of wine waste characteristics').

It was also acknowledged at the outset that winery size and region are not entirely independent. Very large wineries tend to be concentrated in the larger fruit production regions. The varieties, berry size and cultural practice are all a reflection of the region and as a result are reflected in the data when viewed by winery size. In addition, technology also tends to change with winery size. So, while winery size is a useful parameter with which to analyse changes in the level of waste streams, it was anticipated that it would vary widely due to a number of other factors. Some statistical analysis was therefore employed to smooth out the resulting "noise" in the data.

3.1 Sample size and spread

According to the 2001 Australian and New Zealand Wine Directory, 1182 wineries produce wine on-site in Australia. Forty-five wineries representing approximately 4% of the total Australian number were selected for the survey. These wineries were selected so as to be representative of various winery sizes, and to allow identification of wine waste practices and typical amounts of waste at each scale. Table 1 below indicates how the wineries sampled were distributed across the ten winery size categories used to classify wineries in the directory. The wineries were selected to allow roughly equal number of interviews for each of

the size categories. Where possible, the sample also took into account geographic spread including all wine producing States (and ACT) on a roughly pro-rata basis.

State	> 20	20 - 49	50-99	100-249	250-499	500-999	1000-2499	2500-4999	5000-9999	10000 -19999	20000 plus	Total
ACT	0	0	0	1	0	0	0	0	0	0	0	**1**
NSW	1	1	1	1	1	0	2	0	1*	1	2	**11**
QLD	0	1	0	0	0	0	0	0	0	0	0	**1**
SA	0	1	1	1	1*	0	1	1	1*	2	1	**10**
TAS	1	0	0	0	1	0	0	0	0	0	0	**2**
VIC	2	1	1	1	2	1	2	1	1	1	1	**14**
WA	1	0	1	1	0	1	1	1	0	0	0	**6**
Total	**5**	**4**	**4**	**5**	**5**	**2**	**6**	**3**	**3**	**4**	**4**	**45**

* Did not respond or responses could not be used.

Table 1: Distribution of the survey participants sample by winery size and state

3.2 Survey execution

The survey consisted of a questionnaire (see Appendix A) that was carried out by telephone. It involved contacting the person or persons at the winery who had the best overview and knowledge of the winemaking process. In most cases this was the winemaker, owner or operations manager, but in some cases environmental co-ordinators completed the survey. For the larger wineries (mostly those that crush 999 tonnes or more) an electronic copy of the survey was forwarded by e-mail to facilitate the gathering of information prior to the telephone survey. Three wineries did not respond or their responses could not be used. In total 42 wineries were successfully surveyed and their responses analysed and included in the results section of this report.

The survey included questions aimed at establishing quantities of wastes created, waste handling practices, disposal logistics and economic, social and environmental factors associated with the wastes. All questions related to the 2001 vintage. The questionnaire covered wastes created from the beginning of the winemaking process (crushing/de-stemming) through to primary wine clarification (see diagram A). It focused on stalks, grape marc, juice, wine lees and filter cake, but information regarding bentonite clay usage was collected in order to provide a further indication of the quantities of waste generated. Wineries were also asked to estimate the quantity of tartrates that precipitated during winemaking.

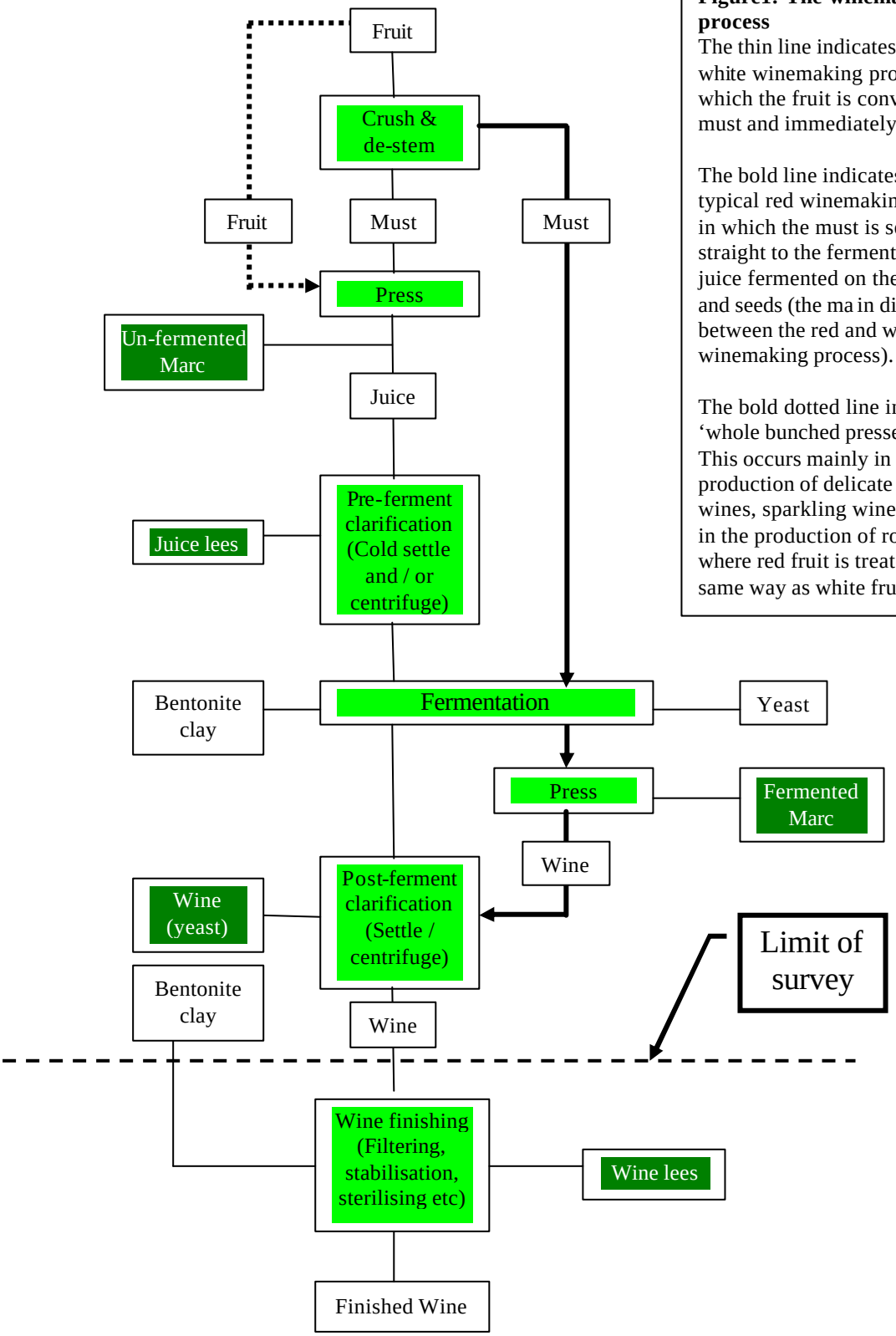


Figure1: The winemaking process
The thin line indicates typical white winemaking process in which the fruit is converted into must and immediately pressed.

The bold line indicates the typical red winemaking process in which the must is sent straight to the fermenter and the juice fermented on the skins and seeds (the ma in difference between the red and white winemaking process).

The bold dotted line indicates 'whole bunched pressed' fruit. This occurs mainly in the production of delicate white wines, sparkling wine bases and in the production of rose wines where red fruit is treated in the same way as white fruit.

3.3 Graphical summary of Survey Results
The responses to the survey questions are summarised in graphical form in Appendices C & D. The data characteristically varied widely from one winery to another even for wineries of similar scale, but it is possible to identify some significant trends by using statistical methods to smooth or "model" the primary data.

3.4 Analysis of data
Quantitative Data
Six categories of waste were identified: Stalks, White Grape Marc, Red Grape Marc, White Juice Lees, White Wine Yeast Lees, Red Wine Yeast Lees. For each waste type the quantity reported in the survey was normalised to the mass of fruit crushed, to provide a basis for comparison. To further facilitate comparison of the effects of scale of production on these figures, the data was then arranged in order of increasing winery size (tonnes of fruit crushed) and plotted.

It is possible to smooth the data by a number of means in order to allow the quantification of trends across the industry as the size of crush increases. A Cusum chart was selected in this report to smooth the data and provided a "model" of the trend, describing the percentage waste per tonne of fruit. When a significant change was observed in the waste streams, the model (the Cusum line) was used to identify the crush range at which the change occurred.

Qualitative
The survey included qualitative questions about the respondent's concerns in relation to wastes and about their views on the potential for minimising waste. The responses to such questions were notably varied and few in number and are summarised in Appendix D.

3.5 Data checks
Data on the mass of initial fruit crushed and the mass of finished wine produced by each winery formed the basis of two validation checks.

The first check was to confirm the credibility of the initial estimates from each winery. Some respondents had only 'Rules of Thumb' to calculate wine yield. These have been combined here with a theoretical estimate of the amount of carbon dioxide produced during fermentation to calculate an expected wine yield. This was then compared to the actual wine production reported to confirm that the figures supplied were reliable.

The second check was to confirm the reliability of the model produced. The (Cusum) "models" for each of the wastes and a calculation for carbon dioxide production were combined to provide a model to estimate the expected yield of wine from a given fruit mass. The actual winery crush data was then fed into this model to generate expected yields of wine for each winery based on their fruit crush. This was done for White and Red wine separately. For each winery the expected yield of wine per mass of fruit was plotted along with the wineries' reported yield figures, providing a means to gauge the overall degree of fit of the model.

4 Survey results
4.1 Nature of Responses
All wineries provided answers to each of the questions on handling and disposal of each waste.

Of the forty two wineries in the survey only six routinely measured and recorded the quantities of each of the various waste streams created, a further six kept records of only one or more of the wastes or had done so in the past. The remaining thirty wineries did not routinely measure or keep records of the quantities of wastes created.

Only twenty six wineries were able to provide estimates for each of the wastes throughout the winemaking process. The remaining sixteen wineries were unable to provide a meaningful estimate of one or more of their wastes. All available responses were used to construct the models, but it was sometimes not possible to validate the estimates of those respondents that gave incomplete records

4.2 Quantitative results

Survey results

Table 2 below indicates the average percentage of a tonne of fruit each waste accounts for as derived from the industry-wide survey. Cusums were used to determine at which crush figure the average waste percentage changed. As the model relies upon data obtained in the survey there are some crush ranges (such as between 1100 tonnes and 10,000 tonnes for white juice lees) that remain unexplored as none of the data fell in this range. In this situation an estimate is necessary and can be made by referring to the individual waste charts in Appendix C.

For each major waste category an average figure was calculated for the percentage of the fresh fruit that the waste constitutes. This figure usually depended on the size of the winery. The cusum curve was used to estimate the average figure over a range of fruit tonnages. Table 2 shows a summary of the sizes of the various waste streams. Grape marc can account for up to 25% of th incoming fruit in small wineries. Stalks are a significant waste for both red and white wines at up to 5.5% of the crush. Yeast lees from red and white ferments are 0.5 – 7% (0.5-0.7 tonnes dry lees / 100 tonnes wet fruit). Although this seems very low, in a 10,000 tonne winery, this equates to 50-70 tonne dry yeast.

Waste	Relevant fruit tonnage range	Waste as percentage of tonne of fruit
Stalks	0-250 tonnes	5.5%
	250 tonnes plus	3.5%
White grape marc	0-600 tonnes	25%
	941 tonnes plus	12%
Red grape marc	0-540 tonnes	22%
	605 – 3200 tonnes	18%
	4454 tonnes plus	11%
White juice lees	0-45 tonnes	3.7% (2%)*
	100 – 1100 tonnes	2%
	10,000 tonnes plus	4%
White wine (yeast) lees	All sizes	(0.5%)*
Red wine (yeast) lees	All sizes	(0.7%)*
Carbon Dioxide from White winemaking	0-250 tonnes	6.4%
	250-941 tonnes	6.9%
	941 tonnes plus	7.7%
Carbon Dioxide from Red winemaking	0-130 tonnes	7.3%
	130-4454 tonnes	7.8%
	4454 tonnes plus	8.9%

* Figures in brackets expressed as solids when juice/wine is recovered.

Table 2: The average percentage of a tonne of fruit for each waste as derived from survey responses

Australian wine waste

This report uses crush data obtained from Australian Bureau of Statistics (ABS) to obtain an estimate of each of the wastes produced across the country. It should be noted that the ABS data fall into two winery crush ranges, 50-400 tonnes and above 400 tonnes (Table 3 below)

Winery crush range (tonnes)	Tonnes crushed
50 – 400	31,806
400 plus	1,574,040
50 plus	1,605,846

Table 3: Australia wine grape crush in tonnes for 2001/02

As the survey's grape crush ranges do not match up exactly with those of the ABS data, an appropriate value has been assigned for each ABS crush range. These are shown in Table 4 below.

Waste type	**Estimated Australian waste (% of crush)**		Tonnes of waste in wineries crushing >50 tonnes (ABS data)
	Winery crush 50 – 400 tonnes	**Winery crush 400 plus tonnes**	**Winery crush 50 plus tonnes**
Free stalks (RED & WHITE)	5.50%	3.50%	56,841
WHITE marc	25%	12%	85,116
RED marc	22%	14.50%	133,373
JUICE lees (as solids)	2%	3%	20,767
Yeast lees (WHITE) as solids	0.50%	0.50%	3,481
Yeast lees (RED) as solids	0.70%	0.70%	6,367
Carbon Dioxide from White winemaking	6.9%	7.7%	53,516
Carbon Dioxide from Red winemaking	7.8%	8.9%	80,736
Bentonite clay (Kg/tonne of WHITE fruit)	0.66*	0.66*	7.7

Table 4: Waste estimates extrapolated across Australia using 2001/02 ABS wine grape crush figures

This data is summarised graphically in Figure 1 below.

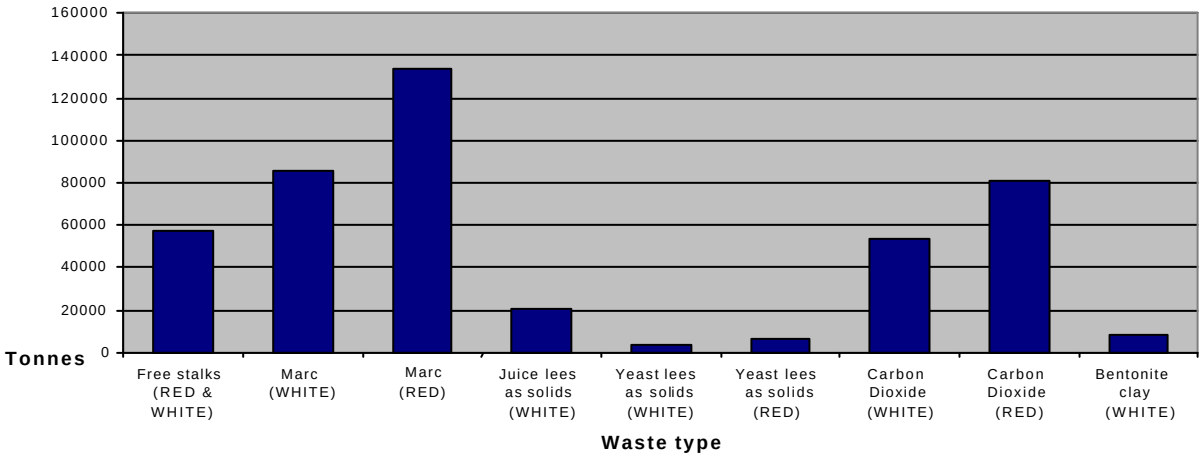


Figure 2 Estimation of wine wastes generated in Australia during vintage 2001/02

4.3 Qualitative results

Handling and disposal
Wineries were asked how they either handled or disposed of their waste streams. The common practices for each stream are summarised in Table 5, which lists the two most common methods for each stream. By far the most common practice is to dump / pile or settle the waste in ponds. (See appendix D for more details). Where value added products can be extracted by external companies, certain streams (red (yeast) lees in filter cake, red and white grape marc) are sent out for extraction.

Waste as percentage of tonne of fruit	Most frequent method of handling / disposal	Second most frequent method of handling / disposal
Stalks	Dumped/piled (30%)	Fed to animals (19%)
White grape marc	Dumped/piled (27%)	Sent for extraction (15%)
Red grape marc	Dumped/piled (27%)	Sent for extraction (15%)
White juice lees	Settled in ponds (24%)	Dumped/piled (19%) & Composted (19%)
White juice lees in filter cake	Dumped/piled (52%)	Sent for extraction (28%)
White (yeast) lees	Dumped/piled (24%)	Settled in ponds (23%)
White (yeast) lees in filter cake	Dumped/piled (50%)	Sent for extraction (40%)
Red (yeast) lees	Settled in ponds (22%)	Dumped/piled (21%)
Red (yeast) lees in filter cake	Sent for extraction (50%)	Dumped/piled (50%)

Table 5: Categories for classifying waste handling methods

This data is classified based on whether it is processed or unprocessed; utilised or not utilised in Tables 6 and 7. Less than 30% fo respondents processed the white or red grape marc, whereas 50-72% processed red and white lees (from either juice or filter cake).

Not Utilised	**Processed**	Burnt
	Unprocessed	Dumped/piled
		Settled (eg in Ponds)
		Slurry tank, Sceptic or Sewer
		Waste water treatment plant / digester
Utilised	**Processed**	Sent for extraction
		Composted
		Feed ingredient
		Sent for-Animal feed Ingredient
		Sent for-Compost Ingredient
	Unprocessed	Fed to animals
		Direct Mulch

Table 6: Categorisation of waste handling practices

Table 7 following indicates that significant numbers of wineries in the sample processed their wastes but also that significant numbers didn't.

	Processed			Unprocessed		
Waste	**utilised**	**not utilised**	**total**	**utilised**	**not utilised**	**total**
Stalks	29%	24%	**53%**	17%	30%	**47%**
White marc	27%	0%	**27%**	31%	42%	**73%**
Red grape marc	27%	0%	**27%**	32%	41%	**73%**
White juice lees 'free'	56%	0%	**56%**	6%	38%	**44%**
White juice lees in filter cake	52%	0%	**52%**	4%	44%	**48%**
White yeast lees 'free'	66%	6%	**72%**	0%	28%	**28%**
White yeast lees in filter cake	50%	0%	**50%**	0%	50%	**50%**
Red yeast lees 'free'	62%	3%	**65%**	0%	35%	**35%**
Red yeast lees in filter cake	50%	0%	**50%**	0%	50%	**50%**
Tartrates	20%	0%	**20%**	0%	80%	**80%**

Table 7: Waste handling - processed/unprocessed utilised/not utilised

On-site disposal was the most common response (Table 8) but any further processing was minimal (composting or animal feed) with little value adding.

Waste	Disposed off-site	Disposed on-site
Stalks	12	30
White marc	15	26
Red grape marc	15	26
White juice lees 'free'	5	12
White juice lees in filter cake	14	8
White yeast lees 'free'	9	20
White yeast lees in filter cake	5	5
Red yeast lees 'free'	12	22
Red yeast lees in filter cake	5	2
Tartrates	11	30

Table 8: Destinations for disposed wastes

Cost and revenue from of waste handling and disposal

Responses on the costs and incomes for handling wine wastes were extremely varied. Some wineries provide quite specific or detailed information, others very brief responses and many no information at all or didn't regard the removal / handling of waste by themselves as a cost. Some wineries, especially smaller ones, did not regard stalks, marc and lees as a waste but rather as a valuable by-product for vine nutrition. Some wineries quoted costs as dollars, time, and quantity of fuel they put in the truck or the number of skips required over a vintage. For a detailed summary of the responses refer to Appendix D.

Other wineries avoid significant costs by dumping on-site with 3 wineries quoting $2 / tonne to truck the waste from the winery to the paddock.

Of the wastes covered in this study stalks had the least economic value, no winery sent stalks for extraction. Lees and filter cake however were more valuable due to the higher concentration of potential extracts such as Tartaric Acid.

Depending on the location of the winery and the agreement with the extraction facility, some wineries paid minimal transport costs, received rebates on tartaric acid & low wine and others had their wastes collected free-of -charge and received an income per tonne for the waste. For further information on wine waste extraction/reprocessing refer to Appendix B.

Environmental and social concerns
Several questions were asked to gain some insight into environmental and social concerns relating to winery wastes and how they could be minimised. Eighteen wineries stated that they had no concerns regarding their wastes. Six wineries stated that odour was a concern, several wineries were concerned with run-off / leachates from wastes and their affect on water quality and soil quality, particularly pH. Other concerns included vinegar fly, vermin and phylloxera. Some wineries stated that they had worked hard over recent years to improve waste handling especially wastewater, others stated that compliance with EPA regulations is hard work and one winery believed that the industry was on 'borrowed time'.

There was quite some concern regarding the use of Diatomaceous Earth (DE) with one winery specifically stating that they were concerned with the occupational health hazard of using DE. A number of larger wineries stated that they were looking to become 'no earth' wineries and some had already achieved this by purchasing centrifuges to remove solids from their juice and wine as opposed to using an RDV. Other wineries suggested that cross-flow filtering technology and agitators on tanks to aid settling could also eliminate the need for earth filtration.

Smaller wineries generally did not perceive that they had a problem. One winery suggested that composting or feeding the wastes to animals was the most appropriate method of disposal for small-scale wineries. A number were willing to co-operate or would be interested in working with local compost contractors to compost their wastes either on-site or off-site depending on the situation. One larger winery that had been proactive in settling up a large composting operation stated that lack of local markets for the compost was a serious inhibitory factor in reducing the economic viability of composting especially as the volumes were far greater than required back by local vineyards.

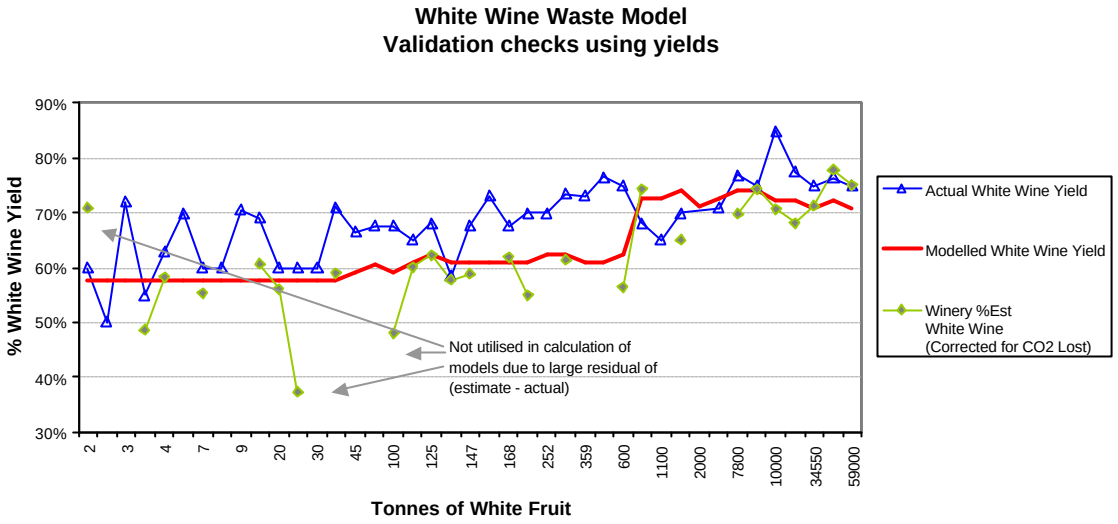
Some wineries did not appear to relate problems to impacts outside of their wineries. For instance one winery that was concerned with vermin saw the answer to be the rapid and regular removal of wastes off-site and another saw waste handling improvement as investing in mechanical tipping gear to reduce labour costs. This suggests, that a number of wineries are primarily concerned reducing problems that directly affect them, rather than with reducing environmental or social impacts. Others however do appear to be concerned about environmental and social impacts and state that they aim to recycle as much as possible, settle their lees for extended periods to reduce waste and implement sophisticated wastewater treatment systems.

4.4 Data checks
In order to provide checks on the quality of the data and the model derived, the following mass balance equations have been used.

Mass of White Wine =Mass of White Fruit In - Mass [Stalks, Marc, Juice lees, & Wine lees]- Mass CO_2
Mass of Red wine =Mass of Red Fruit In - Mass [Stalks, Marc and Wine lees]- Mass CO_2

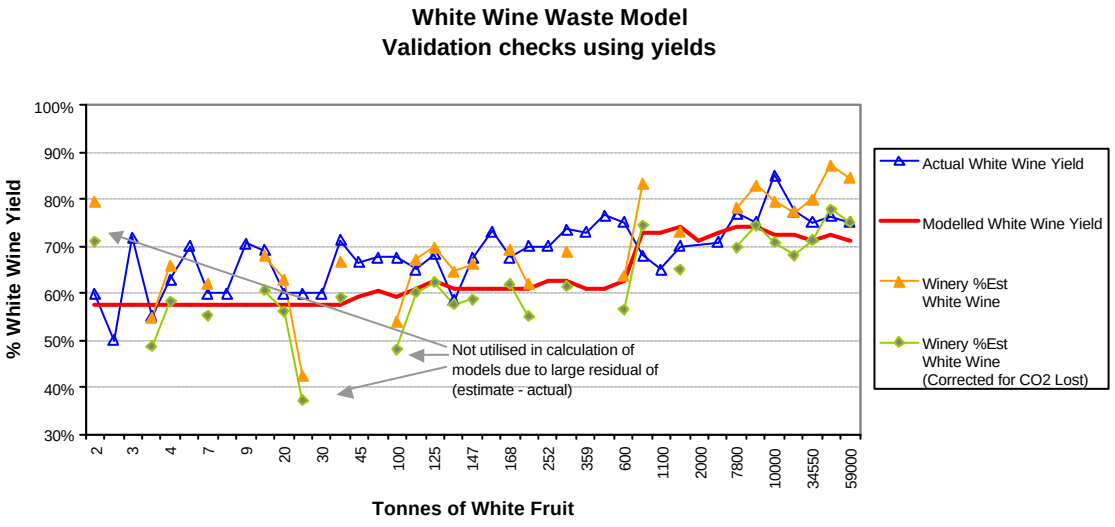
Although there are other losses, such as evaporation and lees removed at wine finishing, these equations were considered sufficient for the purpose validation.

Checks on white wine data and model
Three of the wineries provided wastes estimates that, when taken together, provided expected wine yields that were very different (by more than 10%) from their actual yields (see chart below). Those points identified in the charts were not used in determining the models.



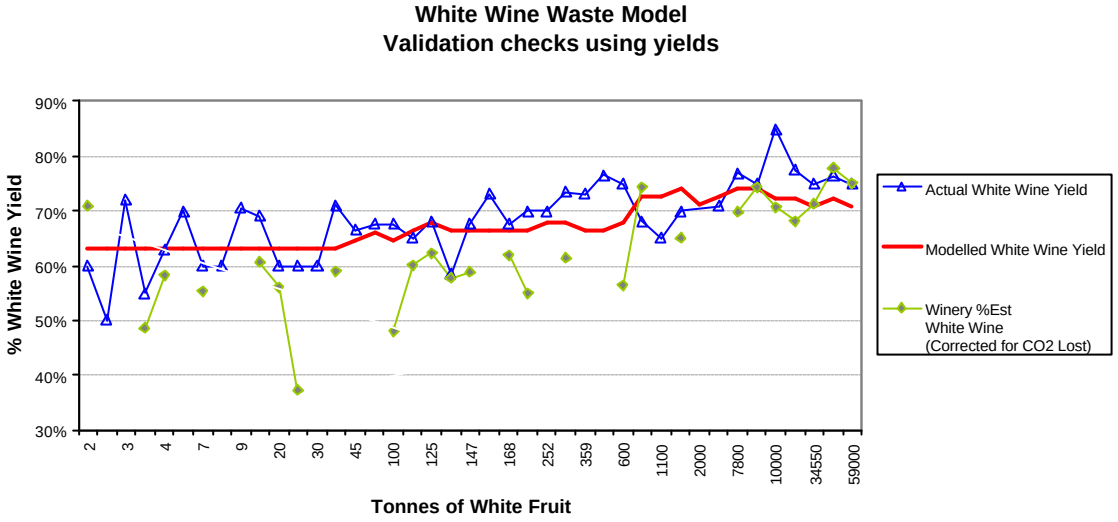
As illustrated by the chart above, the actual white wine yields for each of the wineries is on average about 5-6% higher than the yield expected using individual wineries' estimates corrected for Carbon Dioxide lost during fermentation. This 5% difference is reasonably consistent across the crush range up to about 600 tonnes, and is then much less. Although evaporation and wine finishing may account for some of this discrepancy it seems unlikely that it would account for it all.

It is interesting to note that the estimates prior to correction for CO_2 are much closer to the actual wine yield for wineries up to 600 tonnes (See chart below). This might be explained by understanding how some wineries that do not measure their waste went about providing data. In general Wine makers have a good understanding of their juice extraction rates in terms of litres per tonne for red and whites varieties, as they know the mass of the grapes received and the volumes produced.



It seems that smaller wineries, less than 600 tonnes, where wastes have been more commonly estimated than measured, the extraction rate may have been used by the wine maker as a mass out of the press and by difference used this to estimate both the marc and stalks masses. As juice is significantly denser than water, approximately 1.09 g/mL, many of the wineries have probably overestimated the proportion of the fruit that ends up as marc and stalks.

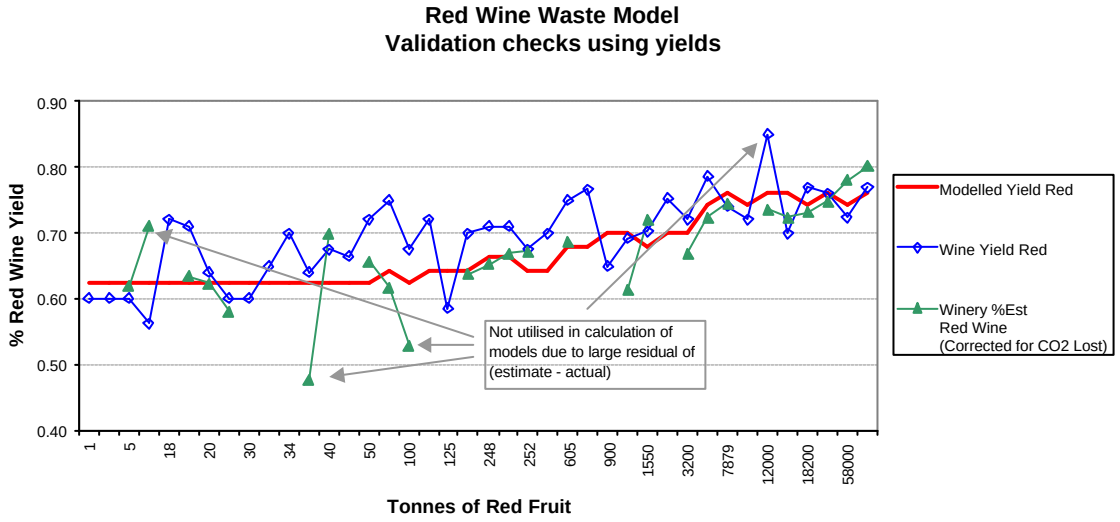
The chart below shows an alternative model where the percentage marc waste figure has been adjusted down from 25% to 19% of initial fruit for those wineries from 0-600 tonnes of crush. As can be seen from the chart this provides a much better fit with the final wine data.



Although only a hypothesis that white marc and stalks may be lower than indicated by the model, it is worthy of note that one or more of the wastes has definitely been over estimated to a total of 5% of fruit.

Checks on red wine data and model

Four of the wineries provided wastes estimates that, when taken together, provided expected wine yields that were very different (by more than 10%) from their actual yields (see chart below). These have been highlighted in the charts and were not used in determining the models.



The chart (on the previous page) indicates that in general the actual red wine yield for each of the wineries is tracked reasonably well by the model. A more detailed analysis reveals that in

the crush range from about 30 tonne to 700 tonnes of fruit the actual wine yield is again higher than that predicted by the model by an average of about 5%. This 5% difference is reasonably consistent across the crush range up to about 700 tonne. Past that point the model fits the data extremely well.

The best explanation for this is probably the same as for the white wine, marc and stalks have probably been over estimated by using the extraction rate volume as a mass.

Taking into account the difficulties in providing a rigorous mass balance check, the models still fit the data reasonably well. This provides some assurance that the information is valid. It is also clear that the data below 1,000 tonnes generally fit less well and in both white and red over estimate total wastes by approximately 5%. As outlined earlier it is probably a combination of stalks and marc that have been overestimated.

5 Industry wide conclusions

It was beyond the scope of this report to capture all the information from all wineries, but by sampling across a large number of regions the results obtained do reflect the industry as a whole.

Wineries generally unaware of the quantity of wastes that they are creating with very few are actually recording any wastes.

Winemakers and other winery staff that responded to the questionnaire generally had much better knowledge of how their wastes were handled than how much they created. Winemakers were aware of the extraction rates they achieved but generally had little idea of how much waste was created during each of the major winemaking steps. This was reinforced by the fact that only 6 wineries recorded all of the wastes surveyed.

However some wineries, especially very large ones, had a better idea of wastes created as many send their wastes for re-processing and need to record masses for transportation or rebate purposes. As a consequence of this general lack of hard data, the model extracted from the survey responses is largely based on the perceptions/'rules of thumb' of winemakers rather than on actual waste figures. Despite this the validation checks indicate that the model is both reasonable and useful for predicting waste quantities.

Wineries tend to be overestimating their wastes, especially marc and stalks
On average large wineries produce approximately 20-25% waste and small wineries approximately 35%

The accuracy validation checks indicate that on average wineries appear to be over estimating their wastes by approximately 5% for both white and red wine. It is postulated that smaller wineries, less than 1000 tonnes are probably over estimating the amount of marc and stalks that they generate.

It is also noted that wineries can create as much as 50% waste from a tonne of fruit to as little as 15%. On average large wineries produce approximately 20-25% waste and smaller wineries approximately 35%.

Future surveys should capture and utilise standard data collected by winemakers to improve accuracy of estimates and models.

It is recommended that to improve accuracy and precision of future wine wastes surveys accurate records of the extraction rate, fruit-in and wine-out figures (taking into account the movement of juice and must between wineries) be obtained and the technologies used by the winery recorded. This would increase the robustness of the survey / model.

It is also recommended that that a review of standard winemaking measurements is carried-out to assess what data is readily available that could further improve the accuracy of the waste estimations. Information that could be beneficial in future surveys includes turbidity and baume measurements.

Quantification of wine wastes

The model provides average percentage waste figures per tonne of fruit for stalks (red and white combined), red grape marc, white grape marc, white juice lees and both red and white wine yeast lees, carbon dioxide and bentonite clay for the wineries in the sample. In most cases the model changes along the winery crush range resulting in several average percentage figures for a particular waste being applicable.

For most wastes different average percentage waste figure are applicable depending on crush size. Grape marc for example can be as high as 25% and as low as 11% of fruit depending on crush size.

The percentage marc and stalks created of fruit seems to be dependent on winery size. Stalks decrease from 5.5% of fruit to 3.5% when the fruit crush of a winery goes above 250 tonnes. White marc decreases from an average of 25% for wineries that crush up to 600 tonnes to 12% for wineries above 941 tonnes. Red marc however has three average percentage figures depending on red fruit crush size. Wineries crushing up to 540 tonnes of red fruit had an average of 22%, those crushing 605-3200 tonnes 18% and those with a red fruit intake of 4454 tonnes plus only 11%. The data did not produce a model/average percentage figure for the crush ranges that represent the gaps in the figures above due to the lack of wineries in these particular ranges. Mass loss as Carbon dioxide was calculated based on juice figures for red and white fruit. Wineries crushing up to 250 tonnes of white fruit had an average of 6.4%, those crushing 250-941 tonnes 6.9% and those with a red fruit intake of 941 tonnes plus 7.7%. from white winemaking. Wineries crushing up to 130 tonnes of red fruit had an average of 7.3%, those crushing 130-4454 tonnes 7.8% and those with a red fruit intake of 4454 tonnes plus 8.9%.

Technology, terroir and variety have significant impact on the quantities of waste per tonne of fruit (especially marc) and wine yield.

It therefore appears that the larger the winery the smaller the proportion of fruit that becomes waste. The survey supports the hypothesis that technology, variety and terroir (climatic, topography, soil, cultural practice) factors have significant impact on wine yields and wastes. Larger wineries generally seem to be located in regions where larger berried fruit are produced and the use of high-pressure press equipment is used.

The composition of lees wastes varies significantly by winery size and the type of technology (if any) used to recover juice or wine from the lees

Lees can be in the form of 'free lees' or in the form of filter cake where the juice or wine has been reclaimed using earth filtration such as Rotary Drum Vacuum Filters (RDVs). Free lees can vary significantly in the amount of juice or wine in the lees depending whether they were obtained through settling or via centrifuges. The survey revealed that wineries over 100 tonnes in crush size have devices such as RDVs or centrifuges (or both) and are also therefore more likely to produce filter cake.

Lees solids range from 2-4% per tonne of fruit for pre-ferment clarification of white juice and 0.5 for white and 0.7% for red per tonne of fruit for post ferment clarification of wine.

The survey provides an estimate and a model of the amount of lees solids (lees with juice or wine removed) as a percentage of fruit either as 'free lees' or in filter cake. The survey and model therefore do not provide an estimation of the amount of filter cake produced. For juice lees created during pre-ferment clarification of white juice the amount of solids generated is estimated at 2% of fruit for wineries up to 1100 tonnes and 4% for wineries over 10,000 tonnes. It is not clear why the very large wineries appear to have more juice lees solids. It should be kept in mind however that there might be no real difference and what we see is a result of the larger wineries more accurately measuring waste. Yeast lees solids generated during post ferment clarification of the wine accounts for 0.5% of fruit for white wine and 0.7% of fruit for red wine.

Bentonite clay usage accounts for on average 0.66kg per tonne of white fruit

Bentonite clay is used universally in the white wine making process and according to the responses an average of 0.66Kg is used per tonne of white fruit.

Waste handling & disposal

For the ten wastes studied (including lees in filter cake etc) dumped/piled was the most frequent method used by wineries for 7 out of the 10 waste types

All wineries in the sample were able to provide information on how they handled each of their wastes. For the ten wastes studied (including lees in filter cake etc) dumped/piled was the most frequent method used by wineries for 7 out of the 10 waste types. It should be noted that this is frequency of practice, which is heavily influenced by smaller wineries in the sample whereas disposal by tonnage is almost totally dominated by the practices used by the few very large wineries.

The value of the material and the proximity of a winery to an extraction facility are major drivers to whether wine wastes get processed

Of the wineries that did send waste to a major extraction facility all were located in the same region as the extraction facility – except one which shipped waste from Victoria to South Australia for processing. It can therefore be determined that the value of the material and the proximity of a winery to an extraction facility are major drivers to whether wine wastes get processed. Stalks were generally not sent for extraction due to their absence of alcohol and low levels of tartartic acid.

Some wineries seem to have high transport and disposal costs for their marc while others seem to have very little cost or even obtain significant incomes from their marc. This can be partly explained by the fact that many large wineries are located close to extraction facilities so transport costs are low. Also extraction facilities sometimes pay for the raw material or provide a rebate on the purchase of recovered extracts for re-use in winemaking. However some wineries have found markets for their marc and receive an income of up to $10 / tonne as animal feed instead of paying significant costs to often just dump or landfill their waste. In some regions compost facilities exist but the market for compost is limited.

Forty-eight percent of responses to waste handling questions fell into the unprocessed category, with the majority handling wastes on-site

Categorising waste handling methods employed by wineries into processed/unprocessed provides a very rudimentary indication of potential environmental impacts of winery practice. Forty-eight percent of responses to waste handling questions for the ten wastes covered in the survey (including tartrates) fell into the unprocessed category. This suggests that a significant proportion of wineries are disposing of their wastes in an unprocessed form by using methods such as dumping in piles, sending to landfill, feeding to animals or using as mulch.

The survey data also revealed that the majority of wineries were disposing of wastes on-site. There is perhaps greater potential for pollution or contamination of on-site disposal than off-site where one would expect that in most cases the operators would be implementing best practice, meeting regulatory requirements and minimising risks.

Some wineries have environmental concerns related to the handling of winery wastes but many are not concerned about it.

Responses to environmental and social concerns relating to winery wastes provided a very mixed picture with many wineries, especially smaller ones not perceiving that they had any problems. A significant number of wineries however had concerns regarding the use of Diatomaceous Earth (DE) with a number of larger wineries stated that they were looking to become 'no earth' wineries - others had concerns with leachates. One large winery that had been proactive in setting up a large composting operation stated that lack of local markets for the compost was a serious inhibitory factor to economic viability as the volumes were far greater than required by local vineyards. A number of wineries believed waste management was a significant issue and one winery believed the industry was on 'borrowed time'. A significant number stated that they aim to recycle as much as possible, settle their lees for extended periods, and implement sophisticated wastewater treatment systems as well as replacing earth filtration with centrifuges, tank agitators and cross-flow filter technology.

Some wineries didn't know what happened to their wastes or how the wastes were treated once collected by disposal companies suggesting that a significant number of wineries are not concerned with the impact of their wastes once they are removed. Other wineries however do appear to be concerned about environmental and social impacts.

Eight wineries expressed great interest in receiving a copy of the report and a number stated that they would be willing to cooperate in projects or initiatives that may follow this study. Some wineries said that they would make a point of taking more measurements of wastes in the future.

6 References

Australian & New Zealand Wine Industry Directory Database of Australian & New Zealand Wine Producers (2001). Winetitles, Adelaide

Australian Wine and Grape Industry 1329.0 (2000 and 2002). Australian Bureau of Statistics, Canberra

Appendix A

Simplified paper transcript of questionnaire

The document below was provided as an overview of the questions that the wineries could expect to be asked during the telephone survey. It enabled larger wineries in particular the opportunity to obtain figures prior to the phone survey and therefore improved the quality of the responses.

Vintage 2001/2 - Solid winery waste – overview of questions
This national project is funded by the GWRDC in order to provide industry wide info regarding the status (masses and practices) of solid winery wastes in Australia. The information will be used to determine the need for funding for waste initiatives in the wine industry. No raw data or information that could link individual wineries to specific answers will be given to the GWRDC. Only consolidated figures and a list of wineries contacted will be provided to GWRDC. Thank you for your assistance – it will significantly add to the quality of the outcomes for industry.

Production figures 2002
White fruit in (tonnes)?
Red fruit in (tonnes)?
White wine produced from above fruit (tonnes)?
Red wine produced from above fruit (tonnes)?
How does the above figures compare with an average year (eg. 50% up / down)?

Harvest 2002
Percentage of fruit hand picked (%)?

Stalks 2002
Percentage destemmed (%)?
Tonnes of stalks over vintage and / or estimate of % stalks per tonne of fruit?
How are stalks handled / discharged?
Cost and / or income of handling / discharging stalks ($/T or in hrs)?

Pre-ferment Marc (White) 2002
Type of press(es) (screw, air bag etc)?
Tonnes of pre-ferment marc over vintage and / or estimate of % marc per tonne of fruit?
How is pre-ferment (white) marc handled / discharged?
Cost and / or income of handling / discharging marc ($/T or in hrs)?

Post-ferment Marc (Red) 2002
Type of press(es) (screw, air bag etc)?
Tonnes of post-ferment marc over vintage and / or estimate of % marc per tonne of fruit?
How is post-ferment marc handled / discharged?
Cost and / or income of handling / discharging marc ($/T or in hrs)?

Pre-ferment clarification (white wine) 2002
% lees from must (%)?
Is juice reclaimed if no how handled and discharged?
If yes what percentage goes through RDV (%) and Centrifuge (%)?
If RDV is used how many kg/kL of filter earth is used for RDV (kg/kL)?
If RDV is used what type of filter earth is used (DE?)?
How are centrifuge solids handled and discharged?
If RDV is used how is filter cake handled and discharged?

Continued

Post-ferment clarification (white wine) 2002
Percentage lees from wine (%)?
Is wine reclaimed if no how handled and discharged?
If yes what percentage goes through RDV (%) and Centrifuge (%)?
If RDV is used how many kg/kL of filter earth is used for RDV?
If RDV is used what type of filter earth is used (DE?)?
How are centrifuge solids handled and discharged?
If RDV is used how is filter cake handled and discharged?
Cost and / or income of handling / discharging pre-ferment lees & cake ($/T or in hrs)?

Post-ferment clarification (red wine) 2002
Percentage lees from wine (%)?
Is wine reclaimed if no how handled and discharged?
If yes what percentage goes through RDV (%) and Centrifuge (%)?
If RDV is used how many kg/kL of filter earth is used for RDV?
If RDV is used what type of filter earth is used (DE?)?
How are centrifuge solids handled and discharged?
If RDV is used how is filter cake handled and discharged?
Cost and / or income of handling / discharging pre-ferment lees & cake ($/T or in hrs)?

Tartrates that precipitate out during winemaking 2002
Tonnes of tartrates over vintage and/or estimate of Percentage tartrates per tonne/fruit or litre of wine?
How are the tartrates handled / discharged?
Cost and / or income of handling / discharging tartrates ($/T or in hrs)?

Bentonite clay - White winemaking 2002
How many g/L of Bentonite clay is used for YEAST settling (g/L)?
How many g/L of Bentonite clay is used for PROTEIN STABILISATION (g/L)?

Bentonite clay - Red winemaking 2002
How many g/L of Bentonite clay is used for YEAST settling (g/L)?
How many g/L of Bentonite clay is used for PROTEIN STABILISATION (g/L)?

General questions
Are you aware of any complaints or concerns (internal or external) regarding the above wastes such as, run-off, odour, transport, vermin etc?
What potential is there for minimising wastes or improving handling and discharge of wastes?

Appendix B

Overview of wine waste characteristics

Stalks

The quantity of stalks generated at the winery per tonne of fruit received varies significantly. It primarily depends on whether the fruit was machine harvested or handpicked. Secondary factors are how efficiently the machine removed the berries from the rachis as well as the varietal, climatic, soil, and viticultural practice (e.g. irrigation) otherwise known as *terroir* affect the proportion of fruit to rachis. If the fruit was effectively machine harvested the effect of *terroir* is minimal as almost no stalk material is present in a tonne of fruit received at the winery. If however the fruit is handpicked the fruit is still attached to the rachis and is therefore transported to the winery and becomes a winery waste rather than a vineyard waste. In this case, stalks (rachis) become a significant waste in the form of 'free stalks' or if the fruit is not destemmed prior to crushing and/or pressing the stalks become a significant part of the marc (skins and seed).

Grape marc

Grape marc is the material that is discarded after the juice or wine is extracted through pressing. This material consists of grape skins/pulp, seeds and either juice or wine depending on whether pressing occurred before or after fermentation. If pressing occurred before fermentation as with white, rose and sparkling wine styles then the marc will contain unfermented grape juice and the marc itself will therefore be unfermented and is often referred to as 'sweet marc'. If however pressing occurred post fermentation, as is normal with red wine styles, then the marc will be fermented and will contain wine rather than juice. Diagram A provides an illustration of the differences between the red and the white winemaking process and indicates at which stage unfermented and fermented marc becomes a waste or by-product.

As with the stalks the key factors determining the quantity of marc generated per tonne of fruit depends on *terroir* and technology use or choice. In addition the desire to remove more juice or wine from the pressings (ultimately grape marc) is dependent not only on having the equipment or time to do so but also on having a market for the lower quality juice or wine recovered by pressing harder or longer. The harder or the more times the pressings are pressed the greater the recovery of juice or wine and therefore the mass of the pressings are significantly reduced. Once the pressings are removed from the press it is generally known as marc.

Therefore the type of press used is a significant factor in determining the quantity of marc produced per tonne of fruit. At one extreme, small wineries may use a basket press while others an air bag press, which is more efficient. Larger wineries may have air bag presses, which depending on the pressure utilised, can obtain very high extraction rates. Smaller wineries using smaller versions of such presses are unlikely to apply higher pressure, as they are unlikely to have a market for the lower quality juice or wine. Most smaller wineries aim for higher quality and niche markets for their product. Larger wineries especially the very large ones often have continuous screw presses which extract nearly all available juice or wine from the marc. All though the free-flow juice and wine are used for higher quality wines the juice and wine extracts from the screw press are usually used in the production of bulk wines.

The other key factor determining the percentage of marc produced from a tonne of fruit is *terroir* and the variety of the grape. In Australia in the hotter grape producing regions such as Sunraysia, Riverina and the Riverland produce grapes that are in many cases quite different to other grapes used for winemaking in cooler regions. For example they may use 'dual purpose' grapes such as Sultana and larger non-premium wine grapes such as Gordo. In addition the higher temperatures and cultural practices such as higher rates of irrigation commonly result in much larger berries than those grown in milder climates. Large juicy berries result in a

much higher juice to skin and seed ratio and therefore the amount of marc will be significantly less for a variety grape grown under these 'favourable' conditions as opposed to those grown under a different regime and climate.

The percentage of marc per tonne of fruit is at its lowest extreme where large berries are fed into a winemaking process that applies high pressure during pressing or uses a screw press.

Lees

Lees are generally defined as sediment that is removed from juice or wine. These sediments most often contain grape solids however they can also contain other materials added to juice or wine during the winemaking process such as yeast and bentonite clay.

Juice lees

Juice lees specifically refer to the mixture of solids (with a varying amount of juice) removed from the juice post pressing but prior to fermentation. Juice lees (or pre-ferment clarification lees) therefore only occur during the white winemaking process as no grape solids are removed from the must prior to fermentation in the production of red wine. Depending on the processes used, juice lees will contain varying proportions of solids and juice.

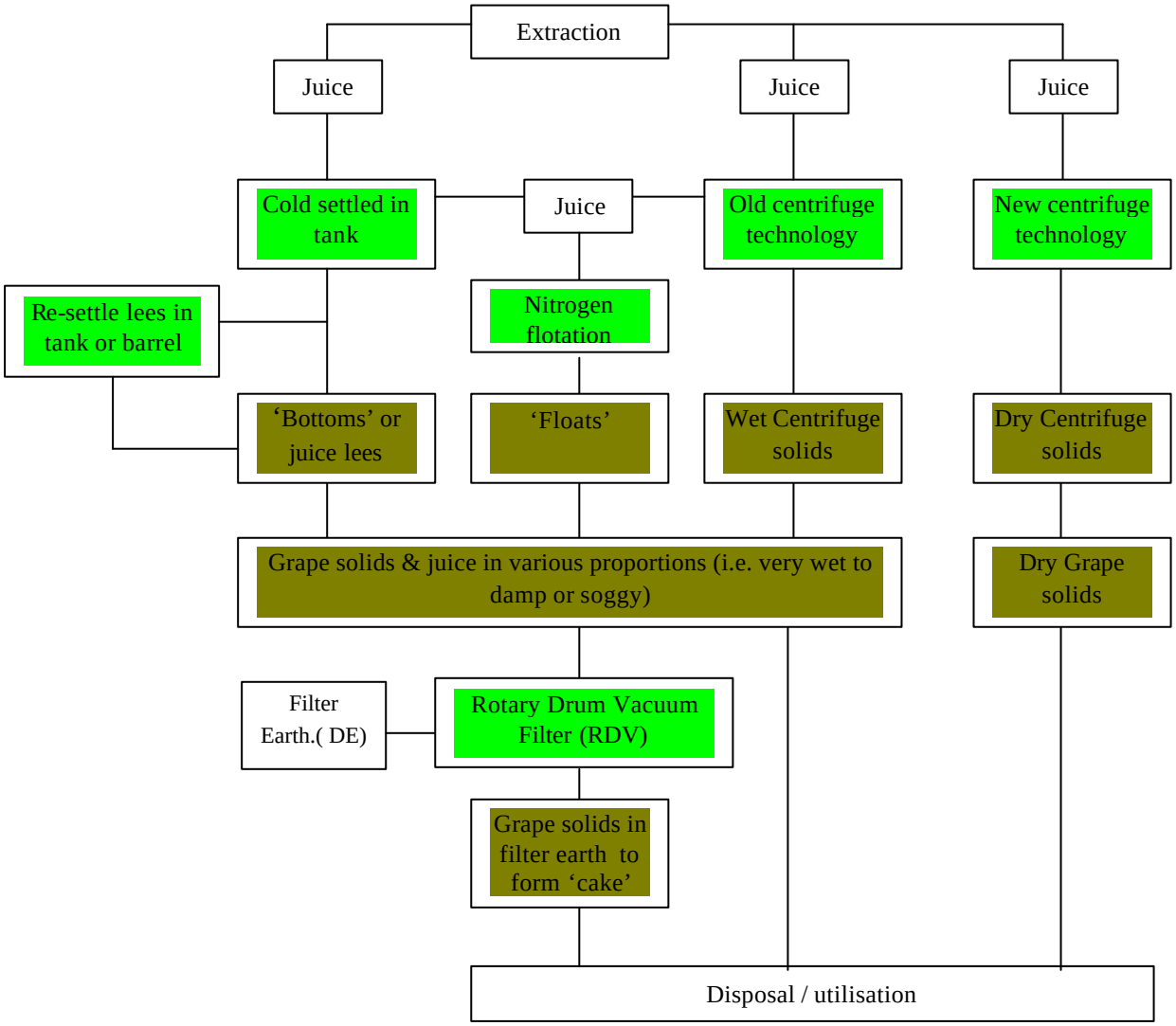


Figure 3: Methods in which juice lees are generated (removed from juice) and treated

The quantity of juice lees depends on the quantity of solids in the juice post crushing. Crushing is primarily aimed at breaking the skin of the grape to facilitate the release of the juice from the berry. However some crushers break-up the skins more than others causing a

'blending' effect which results in a greater proportion of the grape solids being partitioned into the juice rather than remaining with the pressings (marc) in the press.

Figure 3 illustrates the various methods in which juice lees can be generated (removed from the juice) and how these juice lees, once removed from the bulk of the juice are treated. Generally the aim, as with grape marc, is to lose as little of the juice as possible from the winemaking process. However the recovery of juice from the lees depends on the type of equipment available to the winery. The type of equipment a winery may employ is also dependent on the cost benefit of the purchase of capital equipment. The cost of equipment varies greatly. A new top of the range centrifuge which removes almost all solids from bulk juice with very little juice lost in the solids may cost in the region of $500,000, other centrifuges which are less efficient leave more juice in the solids (desludge) cost around $100,000. Some wineries utilise nitrogen gas in the settling process to float the solids to the surface – these lees are in this case often referred to as 'floats'. The use of centrifuges and nitrogen in particular accelerate the winemaking process as it reduces the need to remove sediment through natural settling.

Wineries that cannot afford, or where it is not viable or necessary, to invest in such high capital cost equipment normally cold settle the juice and then 'rack-off' (decant) the juice from the top to leave the wet juice lees (or 'bottoms') at the bottom of the tank. These lees contain significant amounts of juice. If left longer to settle more juice can be racked-off or recovered – this is often carried-out in a separate vessel and involves several 'rackings'.

Some wineries utilise Rotary Drum Vacuum Filters (RDV) in which filter earth, such as perlite or diatomaceous earth, is used is used as a filter media to recover juice. RDVs maybe used to recover juice from the juice lees generated during cold settling and also from centrifuge desludge. Centrifuge solids from the top of the range machines contain so little juice it is not necessary or viable to recover any remaining juice with a RDV. The disadvantage of an RDV is that it introduces another waste into the winemaking process – many wineries are moving away from earth filtration toward centrifugation to avoid the use of filter earth. A winery may employ a combination of techniques and equipment and it should be noted that it is not always possible to employ the most efficient system as at peak processing periods the load may exceed that of the capacity of a top of the range centrifuge for instance. In such situations other equipment is utilised.

The final juice lees waste created from the pre-clarification of juice therefore varies greatly depending on the processes employed by the winery. Basically the waste will contain significant quantities of grape solids – the difference between the wastes is however how much juice or filter earth is with the grape solids. At one extreme a top of the range centrifuge will produce a material which is very dry with very little juice, at the other extreme the settled lees could be very wet and in the form of a slurry. If an RDV is used then the waste could be in a completely different form where the solids are mixed with a filter earth in the form of a fairly dry filter cake.

Yeast lees

Wine or yeast lees specifically refer to the mixture of solids (with a varying amount of wine) removed from the wine post fermentation. Wine lees (or post ferment clarification lees) therefore occur during both the red and the white winemaking process. The quantity of wine lees depends on the quantity of solids left in the juice prior to fermentation for white winemaking and for red the quantity depends on the solids that remain in the wine post pressing. The amount of yeast added and generated during fermentation also contributes to the amount of solids present in the yeast lees.

As with juice lees in the pre-ferment clarification of juice in the white winemaking process the quantity and type of lees waste produced will also depend on the combination of processes used to recover wine from the solids (including whether filter earth is used). Figure 4

illustrates some of the main methods used by wineries to recover wine from yeast lees. As the process relies on the same equipment as used for juice lees the process are similar and the wastes are also similar apart from that the solids and liquid contained in the lees are fermented and contain yeast.

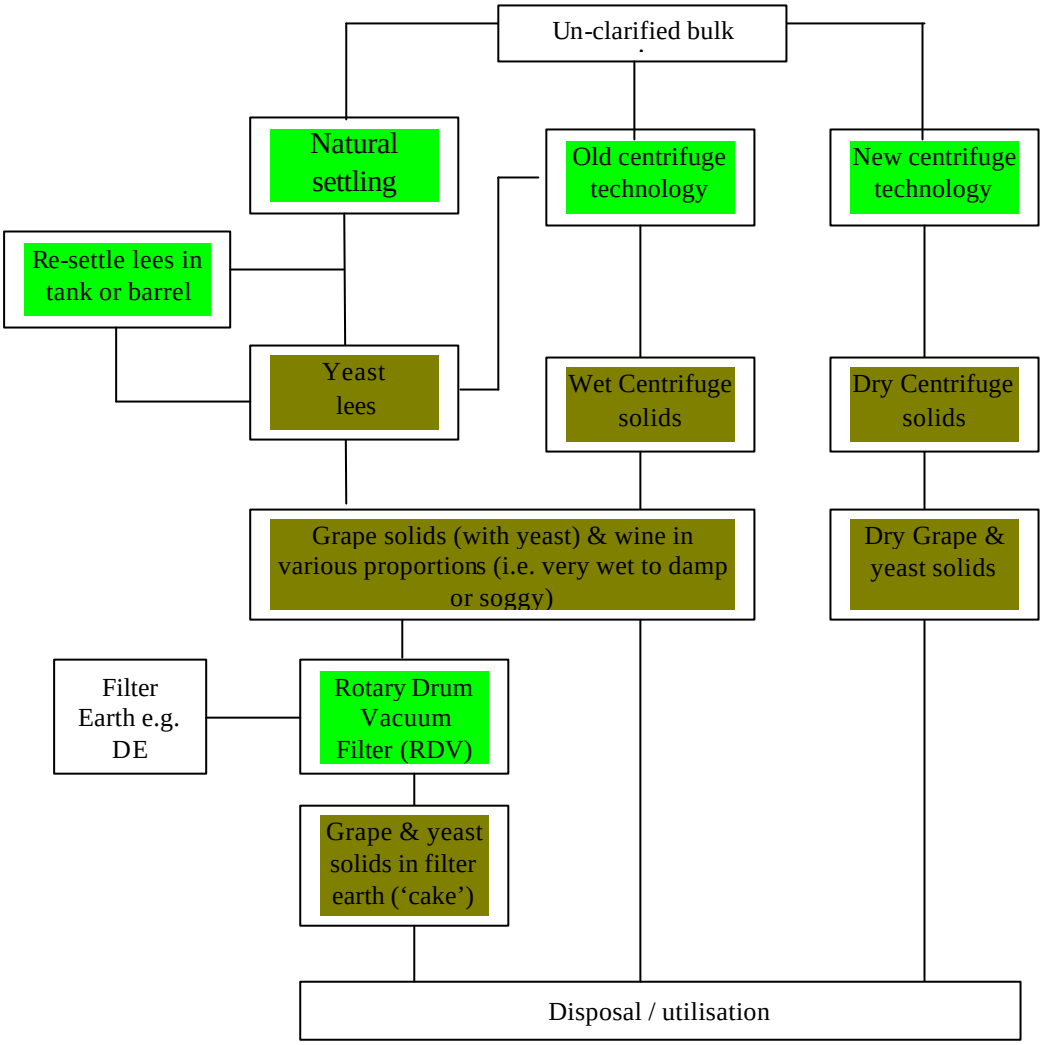


Figure 4: Some of the main methods used by wineries to recover wine from yeast lees.

Tartrates

Tartrates are found in the developing grape as Tartaric Acid but as the berry ripens the acid content decreases and is replaced by tartrate salts of potassium and calcium. These salts precipitate out during winemaking at various stages. Significant quantities precipitate during cold settling and stabilisation. Significant quantities are also deposited on the marc.

Bentonite clay

Bentonite clay (BC) is primarily used in the white winemaking process for protein stability. The addition of BC binds with unstable proteins, which are subsequently removed from the wine by settling and racking or filtered out during wine finishing. However some winemakers add some BC during fermentation to aid the settling out of yeast. However some winemakers add sufficient BC at the fermentation stage to both aid settling and protein stability and therefore do not add any further BC during wine finishing.

Therefore BC waste can exit the winemaking process at various stages including post ferment clarification and wine finishing. The actual waste may end up as part of the yeast lees in a

sludge form, or as dry centrifuge solids, in filter cake or in wine filter cartridges or filter pads. In some cases wine is racked off the bentonite to create 'bentonite lees'.

Large re-processors of wine wastes

Australia has a long established history of collecting grape marc, lees, centrifuge solids and filter cake for the recovery of alcohol and tartaric acid. More recently higher value extracts have been developed by the domestic grape marc processing industry including the production of colour and tannin additives from grape marc derived from premium red grape varieties. These natural additives are used by the wine industry to adjust colour, texture and mouth-feel of the wines. Other extracts such as antioxidants and grape seed oil are also being developed in an attempt to derive further value from waste grape marc. Other established commercial uses of grape marc include as a stockfeed ingredient and as a compost ingredient. Distillation and tartrate recovery facilities are located in four of Australia's largest wine producing regions namely Sunraysia in Victoria, The Riverina in New South Wales, and the Riverland and Barossa in South Australia. The higher value extraction operations including colour, tannin and antioxidant extracts are also located in the Barossa region.

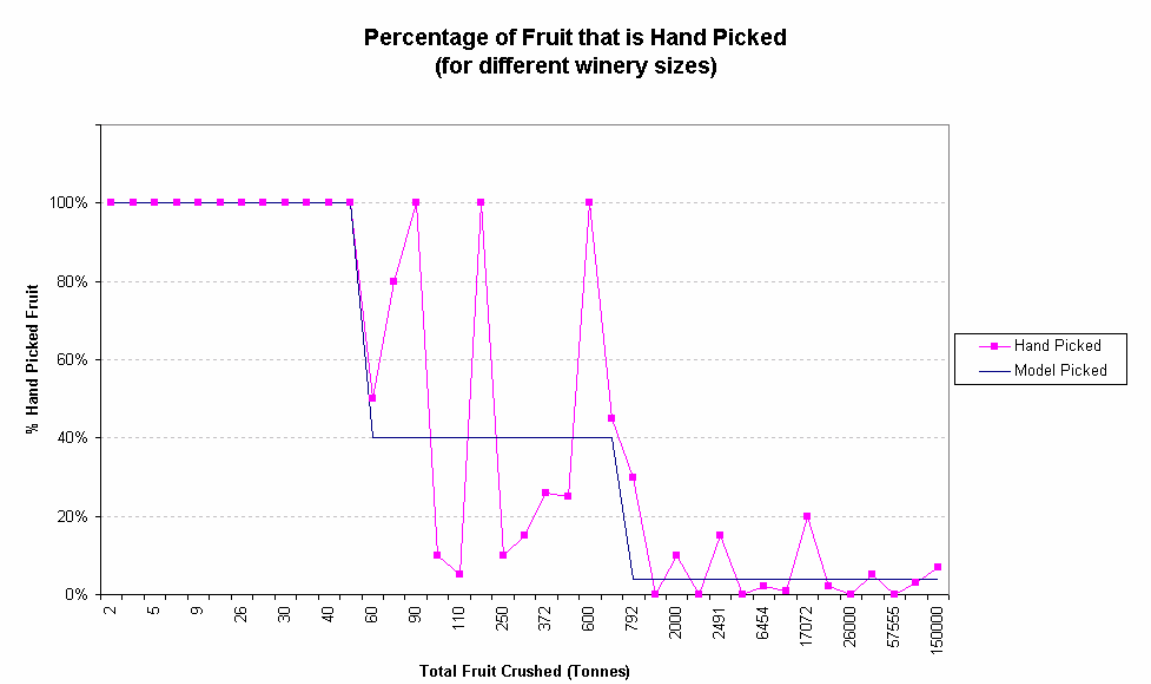
The large-scale commercial use of grape marc for stockfeed in particular is most developed in the Riverina region. Although various composting operations utilise grape marc around the country South Australia especially in regions far from the major wine making centres have developed significant scale compost operations that utilise grape marc and other wastes.

Appendix C

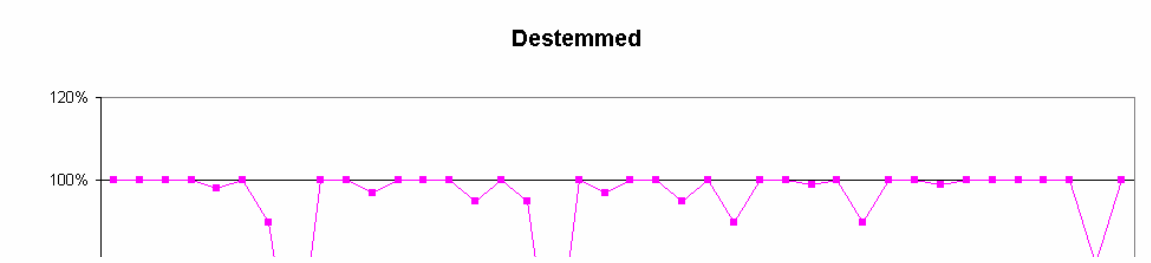
Quantitative Survey results

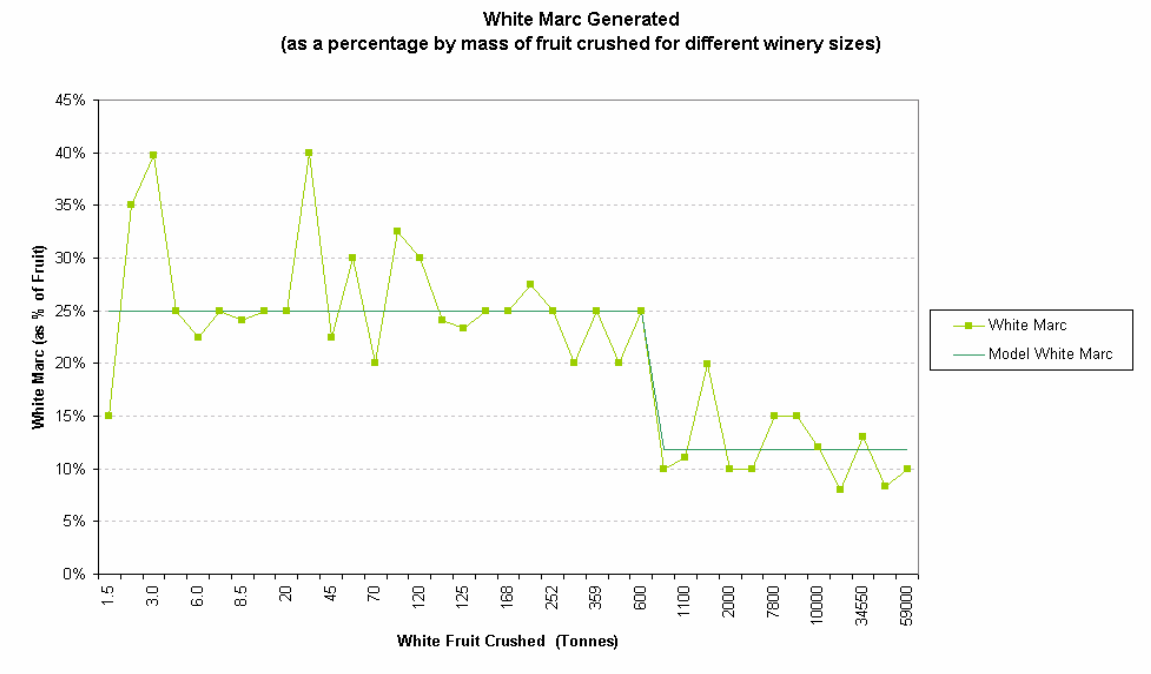
Stalks

The chart below indicates that the wineries in the sample that crush up to 40 tonnes do not have any machine harvested fruit – all (100%) is hand picked. Wineries in the sample above 1900 tonnes have approximately 96% of their fruit machine harvested. Wineries between 60 tonnes and 792 tonnes have approximately 60% machine harvested.



The chart below indicates that nearly all the wineries destemmed 100% of their fruit.





fruit (red and / or white) on average generate approximately 5.5% stalks per tonne of fruit. Wineries above 260 tonnes on average generate approximately 3.5% stalks per tonne. Importantly, as can be seen from the chart the actual percentages of stalks produced by individual wineries vary greatly, particularly below 2000 tonnes of fruit crushed.

White Marc

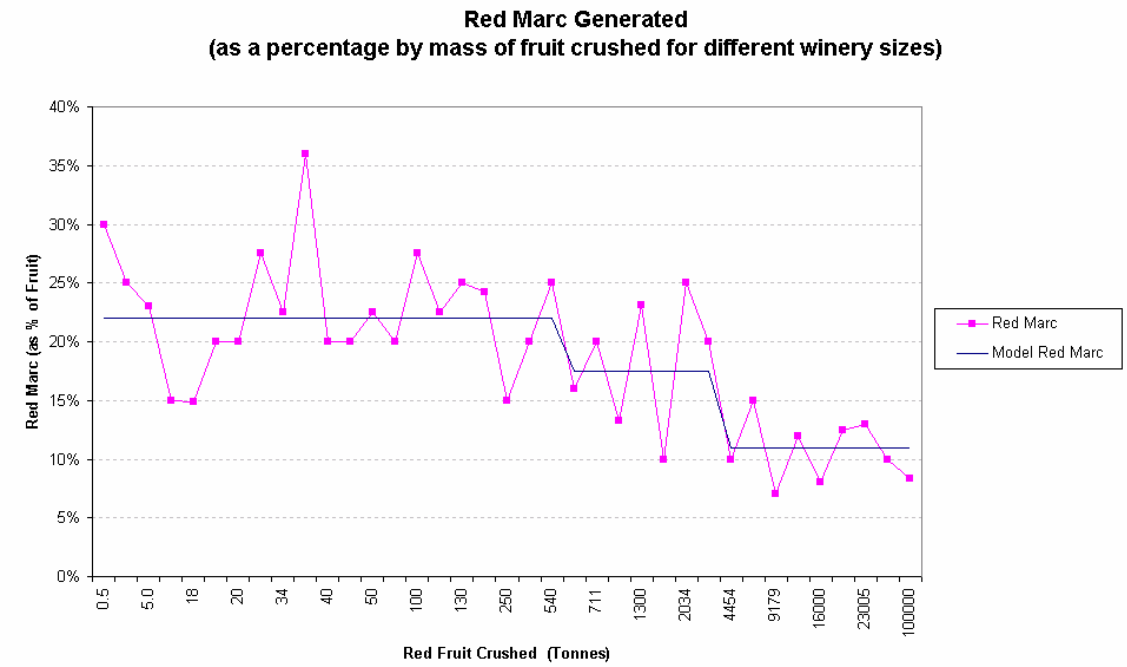
Model-white marc

The chart shows white grape marc figures for each winery in the sample and the model as determined using the 'Cusum' method. The model indicates that wineries that crush less than 600 tonnes of white fruit on average generate approximately 25% white marc per tonne of fruit. And wineries above 941 tonnes on average generate approximately 12% white marc per tonne.

Red Marc

Model – Red marc

The chart shows red grape marc figures for each winery in the sample and the model as determined using the 'Cusum' method. The model indicates that wineries that crush less than 540 tonnes of red fruit on average generate approximately 22% red marc per tonne of fruit. Wineries between 605 tonnes and 3200 tonnes on average generate 18% and wineries above 4454 tonnes approximately 11% red marc per tonne of fruit.



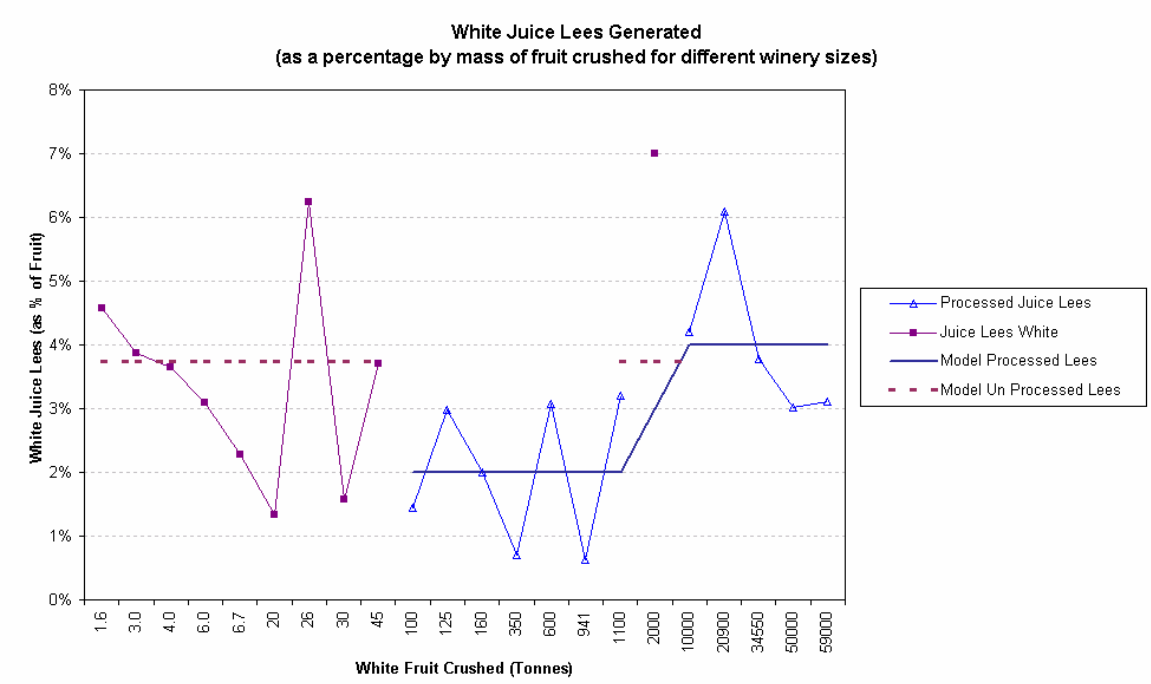
White juice lees

Model – white juice lees

The chart below shows white juice lees figures for each winery in the sample and the model as determined using the 'Cusum' method. The chart indicates that 9 wineries do not reclaim juice from their lees while 12 wineries provided useable information relating to the recovery of juice from their juice lees. Of the nine wineries that do not reclaim juice all but one falls into the white fruit crush range of 0 – 45 tonnes; on average these have 3.7% juice lees per tonne of fruit. The wineries that do reclaim juice seem to fall into two white fruit crush ranges; those that crush between 100 tonnes and 1100 tonnes have on average 2% lees solids and those above 10,000 tonnes have on average 4% juice lees solids per tonne of fruit. The

regions between 1100 tonnes and 10,000 tonnes remains unexplored as none of the data fell in this range.

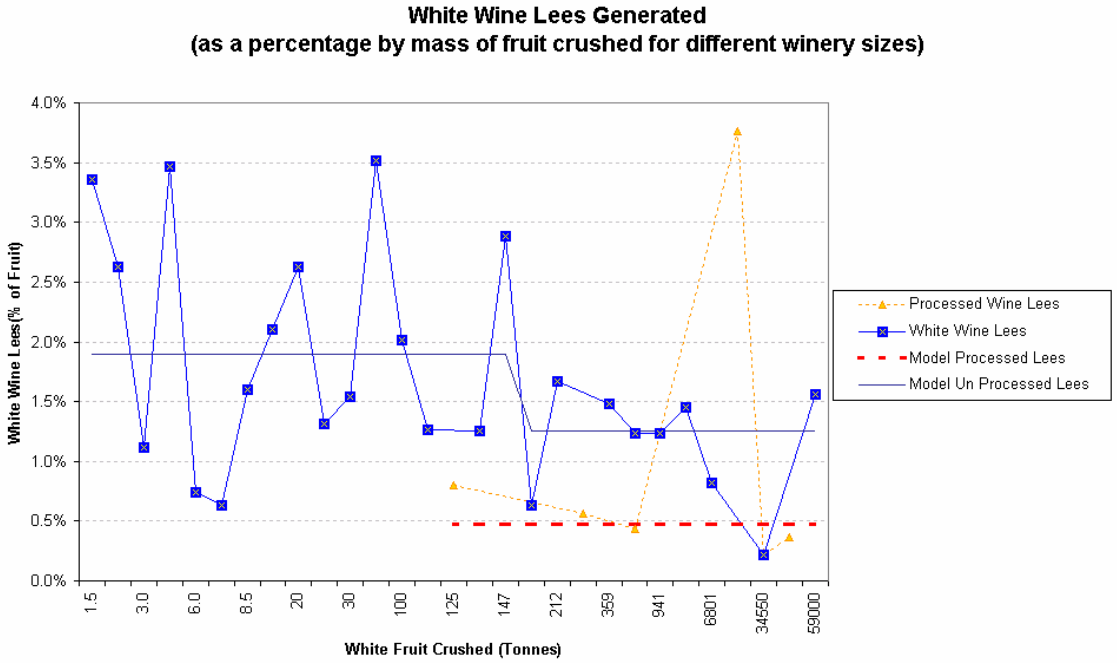
The chart also indicates that the difference between the average percentage waste figures for wineries that do process lees and those that don't, 2% and 3.7% respectively, is probably accounted for as un-recovered juice or juice lost in the lees. If those wineries did process their waste it might be expected that their solid juice lees figure would be close to 2%. As for those wineries over 10,000 tonnes who despite processing still had 4% juice lees as solids it maybe possible that their initial juice solids was much higher.



White Yeast lees

Model – white wine (yeast) lees

The chart below shows white wine (yeast) lees figures for each winery in the sample and the model as determined using the 'Cusum' method.



The model indicates that 25 wineries do not reclaim wine from their yeast lees while 6 wineries provided useable information relating to the recovery of wine from their yeast lees. The 25 wineries that do not reclaim wine had average yeast lees percentage figures that fell into two main white grape crush size ranges.

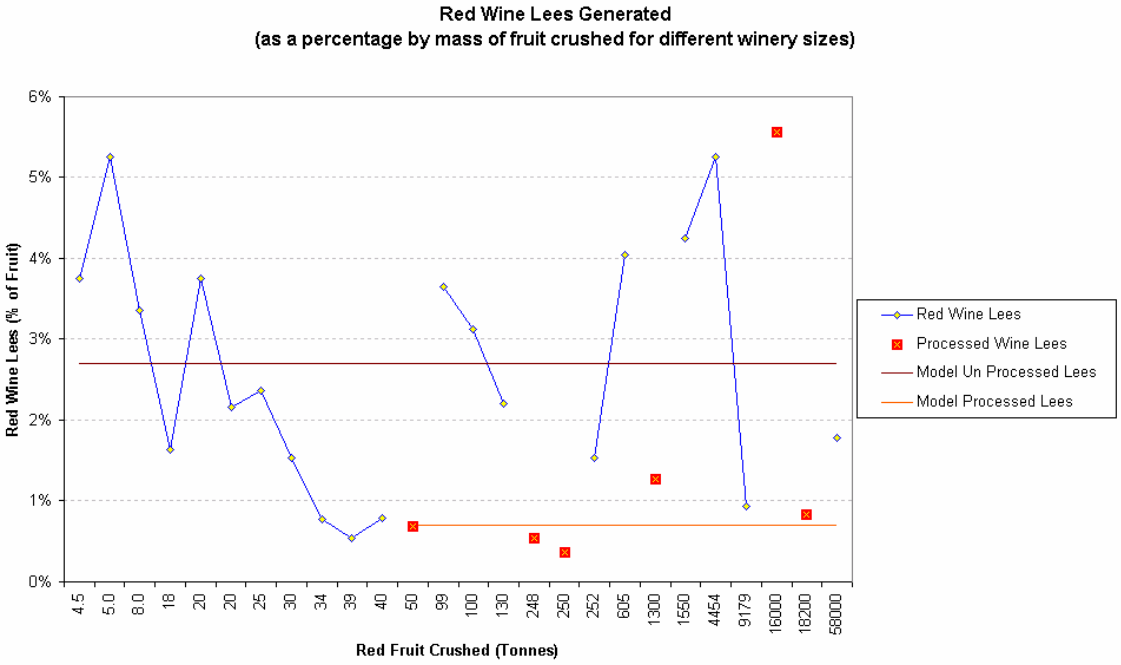
Wineries that crush between 0 –147 tonnes of white fruit had on average 1.9% white wine (yeast) lees by mass of fruit. Wineries above 168 tonnes had on average a white wine (yeast) lees figure of 1.25% by mass of fruit. The wineries that provided useable information regarding the recovery of wine from white wine (yeast) lees were all above 125 tonnes in size. The 'solids' or waste removed by these wineries averaged 0.5% by mass of fruit crushed.

The chart also indicates that the difference in the model percentages between wineries that do (0.5) and don't (1.9% and 1.25%) process lees can probably be accounted for as un-recovered wine or wine left in the lees. If those wineries did process their waste it might be expected that their average solid juice lees figure would be close to 0.5%.

Red Yeast lees

Model – red wine (yeast) lees

The chart shows red wine (yeast) lees figures for each winery in the sample and the model as determined using the 'Cusum' method. The model indicates that 20 wineries do not reclaim wine from their yeast lees while 6 wineries provided useable information relating to the recovery of wine from their yeast lees. The data from the 20 wineries that do not reclaim wine were so randomly distributed that a single average percentage figure for the unprocessed lees model of 2.7% was considered the most suitable fit across all winery sizes. The wineries that provided useable information regarding the recovery of wine from red wine (yeast) lees all crushed above 50 tonnes of red fruit and produced on average 0.7% 'solids' per tonne of fruit.



The chart also indicates that the difference in the model percentages between wineries that do (0.7) and don't (2.7%) process lees can probably be accounted for as un-recovered wine or wine left in the lees. If those wineries did process their waste it might be expected that their average solid juice lees figure would be close to 0.7%.

Tartrates

Model – tartrates

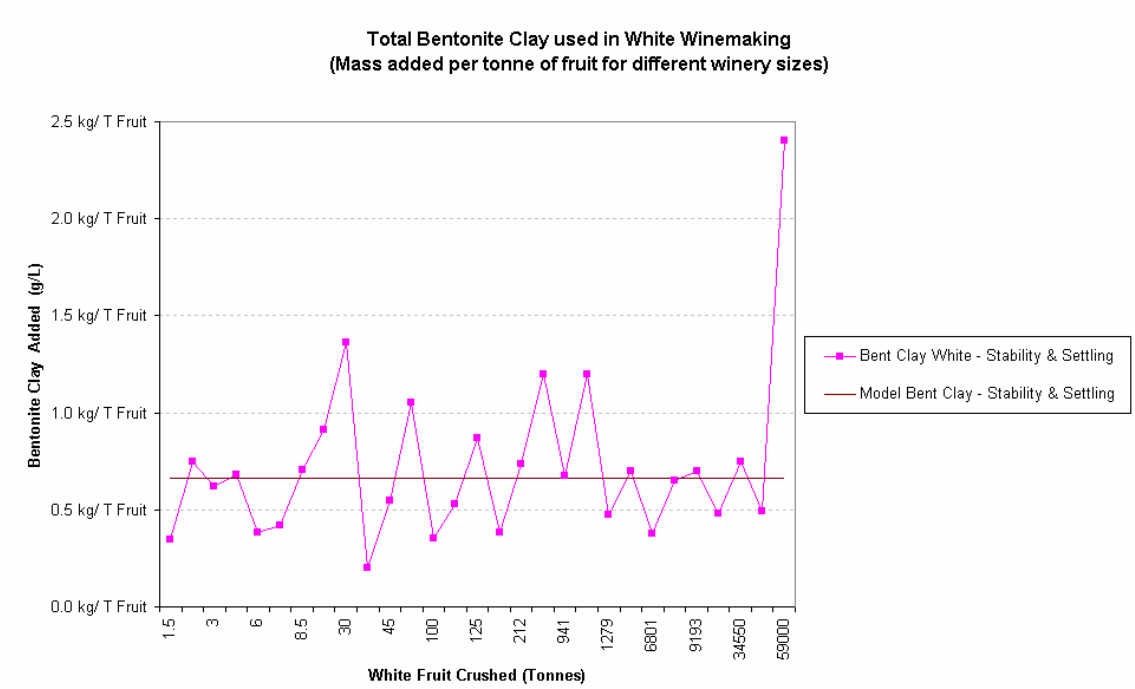
Very few wineries were able to estimate the quantity of tartrates that were generated during the winemaking process. Estimating this was complicated by the fact that Tartaric Acid is

used in the winemaking process. Where figures were obtained they generally related to tartrates that precipitated out in tanks and barrels and not to tartartes that might be present in marc and stalks etc.

Bentonite Clay

Model – bentonite clay

Due to the complexity of where bentonite clay (BC) is added and extracted from the winemaking process it was decided not to ask in the questionnaire the quantity of bentonite waste created. It was decided to ask how much (BC) is added on average by a winery for both settling and stability purposes. Only 6 wineries added BC during red winemaking and it can be taken that in effect the Rule of Thumb or model should be zero. For white winemaking though BC usage was universal and showed no particular trend between wineries of different sizes. Fourteen out of the 41 (34%) wineries that made white wine add BC around the fermentation stage at a rate of 0.74 g per litre. Twenty-four out of the 41 (59%) add BC towards the end of the winemaking process at a rate of 0.82 g / litre for stability reasons.



However neither of these percentage figures are suitable for extrapolation using crush data (as they are in g / l) and some wineries add all their BC at one stage or the other rather than 'half here' and 'half there'. Therefore the total average g/ l figure used by the individual wineries has been converted into a mass of BC per tonne of fruit to aid extrapolation. The chart above indicates that the average amount of BC used per tonne of white grapes is approximately 0.66kg.

Carbon Dioxide

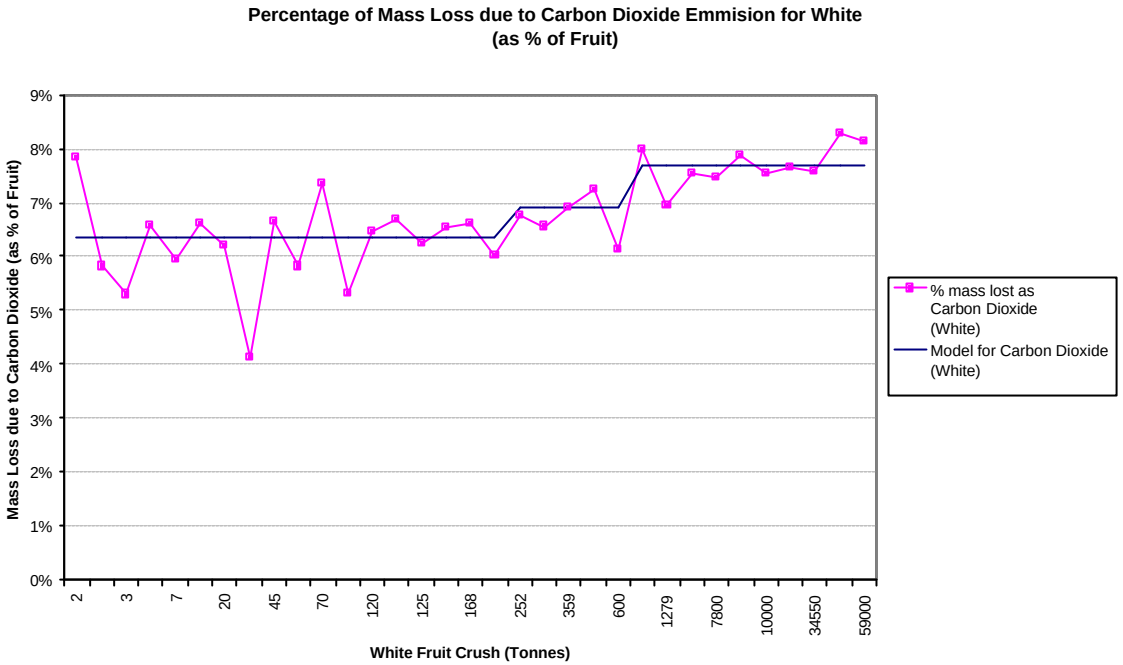
Carbon Dioxide emission during fermentation is a significant proportion of total waste. Although not directly surveyed these losses were calculated from the fermentation reaction as summarised below:

	$C_6H_{12}O_6$	=>	2 CH_3OH	+	2 CO_2
Molecular Mass	180.1584		2 x 46.0694	+	2 x 44.0098

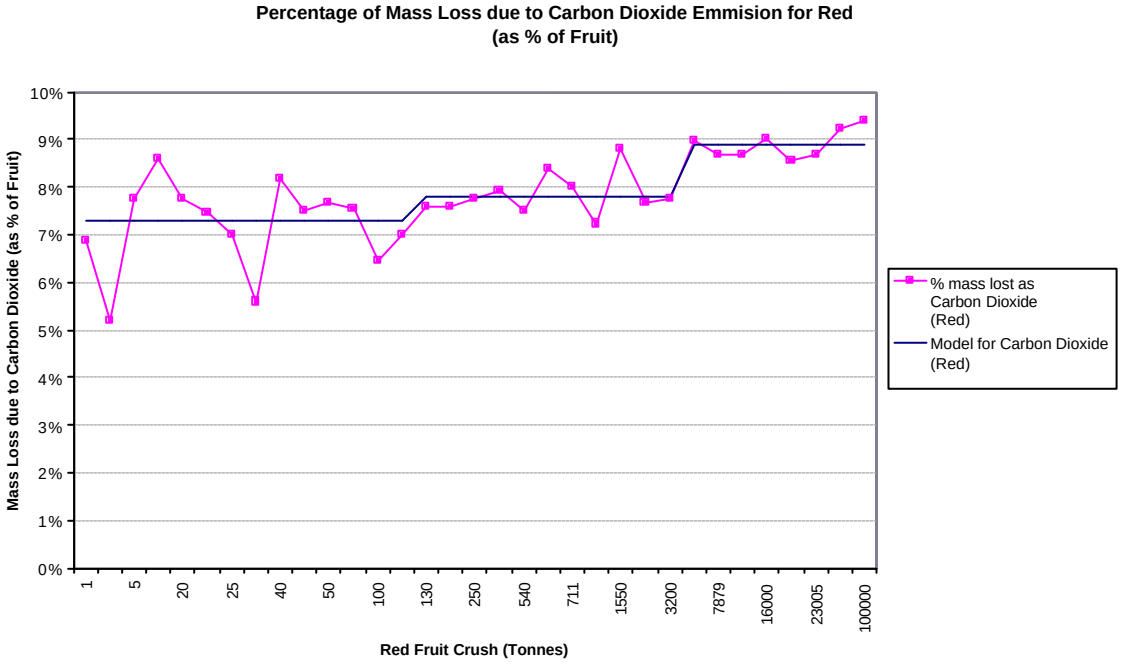
Thus for every 100 unit of mass of sugar converted to alcohol 48.9 units are lost as CO_2.

Therefore the sugar content of the juice was calculated in order to estimate the amount of CO_2 lost due to fermentation. The mass of juice has been calculated using the wineries initial fruit mass and subtracting the estimates of marc and stalks for red wines and also subtracting the

mass of juice lees for white wine. The initial sugar concentration has had to be assumed, for white juice a figure of 210 g of sugar per litre has been used and for red juice a figure of 225 g/litre. The charts below show the percentage of CO_2 lost from white and red winemaking.



The chart above shows CO_2 levels increase in steps from 6.4% to 7.7% across the white crush range, reflecting the greater proportion of juice making it into fermentation at larger wineries.

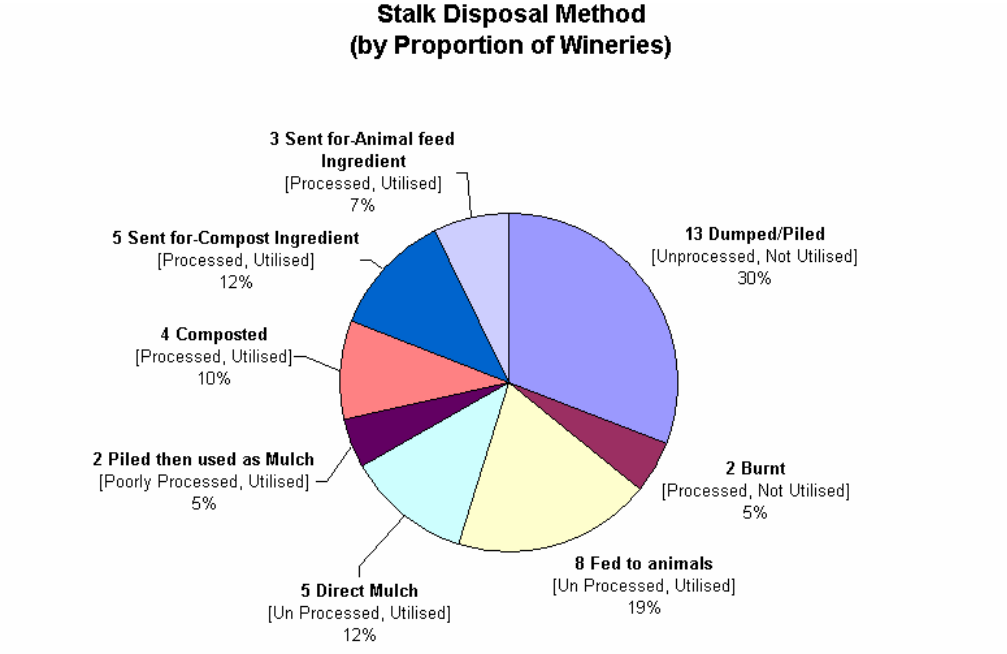


The chart above shows CO_2 levels from red wine making are slightly higher than for white. This is a result of higher extraction rates at pressing for reds, not removing juice lees, and the higher sugar concentration in the juice. Carbon Dioxide increase across the crush range, from 7.3% to 8.9%, again this reflects the greater juice extraction efficiency of larger wineries. Carbon Dioxide is a significant waste from winemaking, second only to grape marc by mass. It is of concern as it is a greenhouse gas. It is also the only waste that increases across the crush range, this being a reflection of the increased efficiencies of wineries at extracting juice from grapes and getting this into the fermenters.

Appendix D

Qualitative survey results

Handling & disposal of stalks



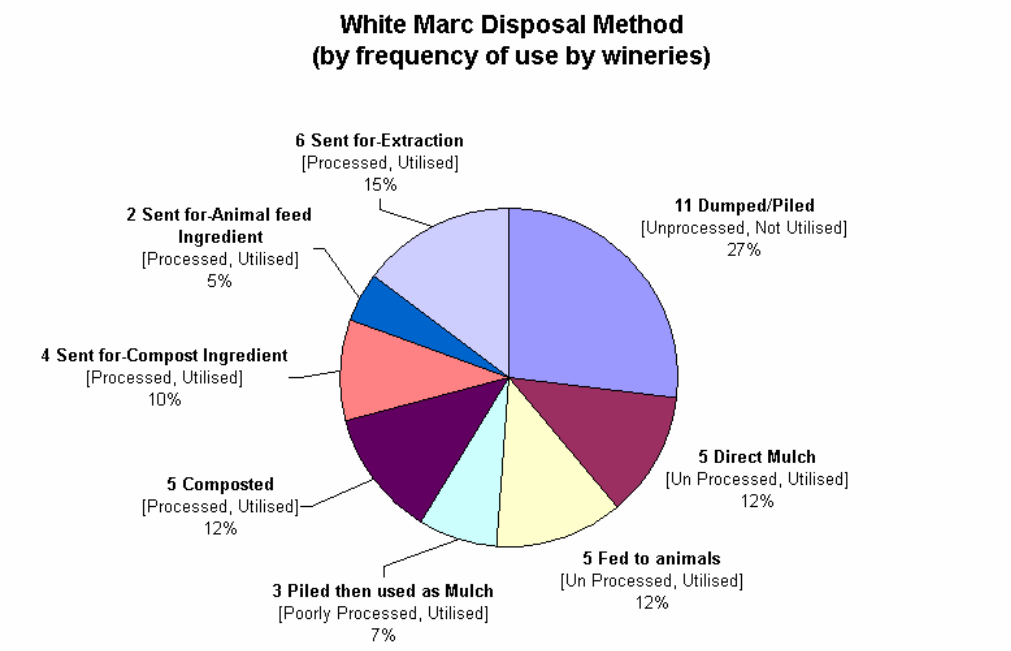
The chart indicates that 42 wineries responded to the question. The following is observed:

- Thirteen wineries or 30% dumped or piled (mostly on-site) their stalks in an unprocessed, unutilised form
- Two wineries or 5% didn't utilise their stalks but processed it on-site by burning.
- Fifteen wineries or 31% utilised their stalks in an unprocessed or poorly processed form (mostly on-site) either by feeding to animals (8), applying as a direct mulch (5) or by piling then using as a mulch (2)
- Eight wineries or 19% sent their stalks off-site for processing and utilisation either as a compost ingredient (5) or animal feed ingredient (3)
- Four wineries or 10% processed and utilised their stalks on-site by composting

Cost or income associated with stalks

Twelve wineries provided some kind of a useful response. Three wineries quoted $2 / tonne to truck stalks to on-site compost or dump area. One winery estimated the cost of dumping marc on-site with a 5 tonne tipping trailers as $50 / hour for 2 hours per day over vintage. Others especially small to medium sized wineries regarded such effort as zero cost as they were utilising their own truck and staff. Some wineries calculated the effort in time or in how much gas they put in the truck over the vintage. One large winery quoted $16 / tonne as the cost for applying the stalks as a direct mulch. One winery used a $20m^3$ skip that cost $137 per month to rent and $170 for each of the 6 empties over the vintage to transport marc to a farm for composting. Several wineries pay significant amounts to have their stalks removed off site. One pays almost $50,000 per vintage to remove stalks and marc to a licensed composting facility and another $7,000 for the solids to be removed by Cleanaway to a landfill site. One winery pays a composting contractor to remove their stalks and in return receives a rebate on the compost produced.

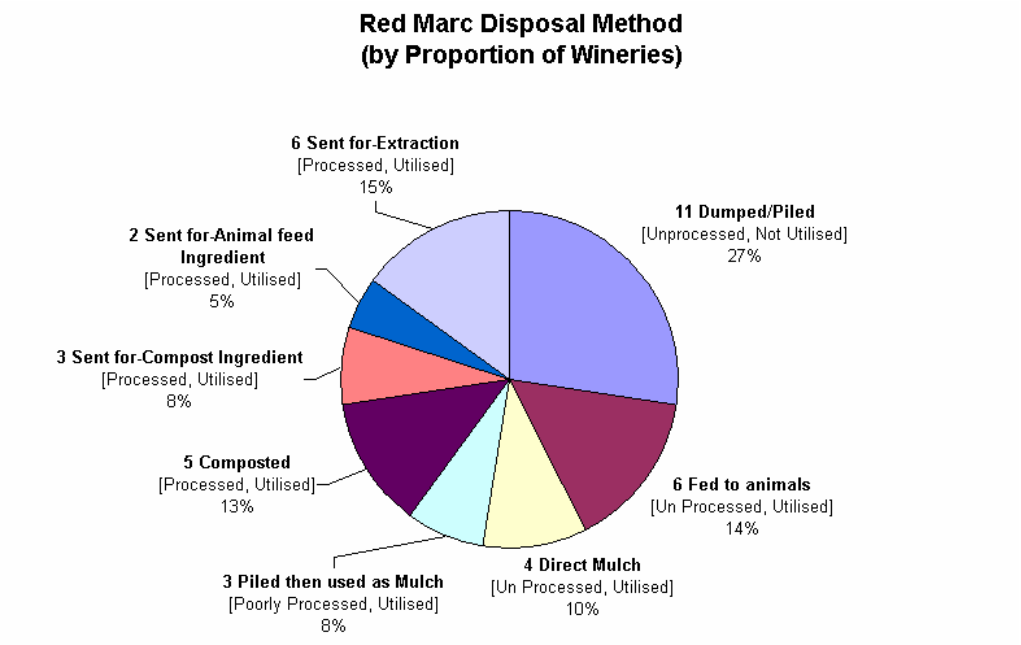
Handling & disposal of white marc



The chart indicates that 41 wineries responded to the question. The following is observed:

- 11 wineries or 27% dumped or piled (mostly on-site) their white marc in an unprocessed, unutilised form
- 13 wineries or 31% utilised their white marc in either an unprocessed or poorly processed form (mostly on-site) for animal feed (5), direct mulch (5) or plied then applied as a mulch (3)
- 5 wineries or 12% processed and utilised their white marc (mostly on-site) as compost
- 12 wineries or 30% sent their white marc off-site for processing and utilisation either as a compost ingredient (4), animal feed ingredient (2) or for extraction (6)

Handling & disposal of red marc



The chart indicates that 40 wineries responded to the question. The following is observed:

- 11 wineries or 27% dumped or piled (mostly on-site) their marc in an unprocessed, unutilised form

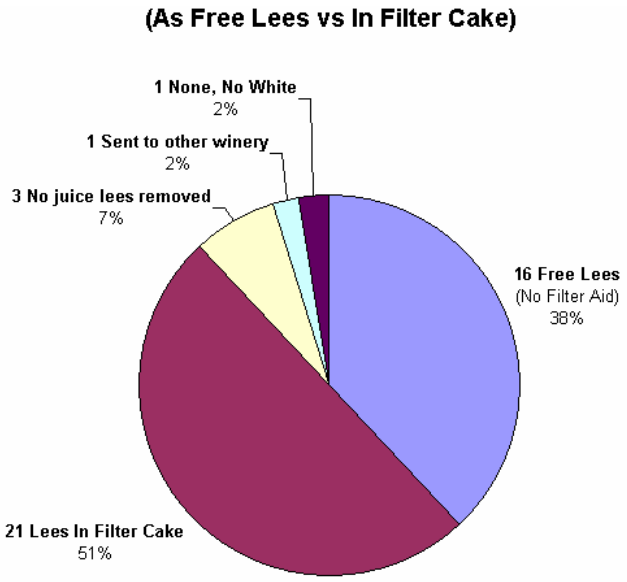
- 13 wineries or 32% utilised their marc in either an unprocessed or poorly processed form (mostly on-site) for animal feed (6), direct mulch (4) or plied then applied as a mulch (3)
- 5 wineries or 13% processed and utilised their (mostly on-site) as compost
- 11 wineries or 28% sent their marc off-site for processing and utilisation either as a compost ingredient (3), animal feed ingredient (2) or for extraction (6)

Cost or income associated with marc

17 wineries gave responses that were useful. Two large wineries sold all their marc for animal feed at $10 per tonne (including loading) and one medium sized winery received $80m / m3 for their marc. One winery pays a composting contractor to remove their marc and in return receives a rebate on the compost produced. Some large wineries close to extraction facilities such as distilleries and Tartaric Acid recovery plants had minimal transport costs of $2 - $4.5 per tonne plus a rebate on low wine for fortification. Other large wineries either received an income from the reprocessor or the marc was collected free of charge by the extraction facility operators. One winery's marc was collected in 15m3 bins at a reduced rate of $350 per load and was utilised by a feedlot.

One winery noted that the handling of red marc was much more expensive than that for white quoting $22 per tonne as opposed to $2 per tonne. This is because red marc has to be removed from the fermenter as well as the press. As noted with stalks some large wineries pay significant amounts to have their solid wastes transported and disposed of at licenses landfill and composting facilities ($7,000 and $50,000 per vintage respectively). Many smaller wineries who did not provide an indication of cost were generally unable to put a cost on the disposal of relatively small amounts of grape marc reported no cost or negligible cost.

Handling & disposal of white juice lees

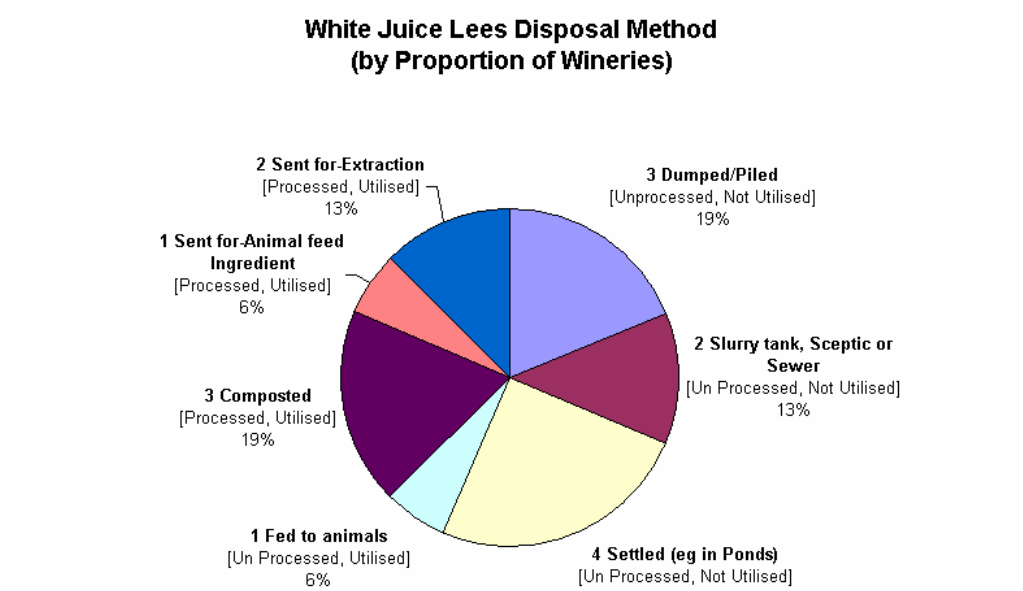


The above chart indicates the final form of the juice lees produced at the 42 wineries that responded to the question. Juice lees end up in filter cake in fifty-one percent of wineries. Thirty-eight percent of the wineries however did not utilise earth filtration and their lees were in the form of 'free lees' consisting of grape solids with various proportions of juice. These lees ranged from a very wet sludge, where no secondary recovery was used, to relatively dry where an efficient secondary recovery process was used, such as top of the range centrifuge was used.

The chart also indicates that 5 wineries didn't produce any juice lees. Of these, three fermented on all lees so the juice lees for these wineries would come out with the yeast lees,

one winery didn't produce any because they didn't process any white fruit and one winery sent the lees off-site to another winery with the clarified juice for finishing.

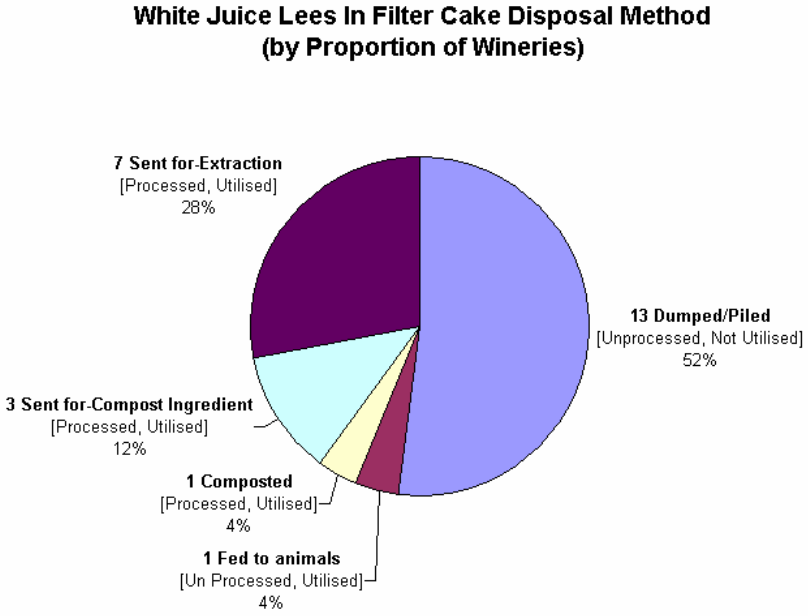
The two charts below indicate respectively how the 'free juice lees' and the 'lees in filter cake' are handled / disposed.



The chart indicates the handling methods for the 16 wineries that did not use filter earth to recover juice from their pre-ferment clarification lees. The following is observed:

- Nine wineries or 56% disposed of their 'free juice lees' (mostly on-site) in an unprocessed, unutilised form either dumped/piled (3), settled in ponds (4) or in slurry/sceptic/sewer (2)
- One winery or 6% utilised their 'free juice lees' in an unprocessed form (on-site) as animal feed
- Three or 19% wineries utilised their 'free juice lees' in a processed form (mostly on-site) as compost
- Three or 19% sent their 'free juice lees' off-site for processing and utilisation either as an animal feed ingredient (1) or for extraction (2)

The chart below indicates the handling methods for the 25 wineries that use filter earth to



recover juice from their pre-ferment clarification lees. The following is observed:

- Thirteen wineries or 52% disposed of their 'juice lees filter cake' (mostly on-site) in an unprocessed, unutilised form by dumping or piling
- One winery or 4% utilised their 'juice lees filter cake' in an unprocessed form (on-site) as animal feed
- One winery or 4% utilised their 'juice lees filter cake' in a processed form (on-site) as compost
- Ten wineries or 40% sent their 'juice lees filter cake' off-site for processing and utilisation either as a compost ingredient (3) or for extraction (7)

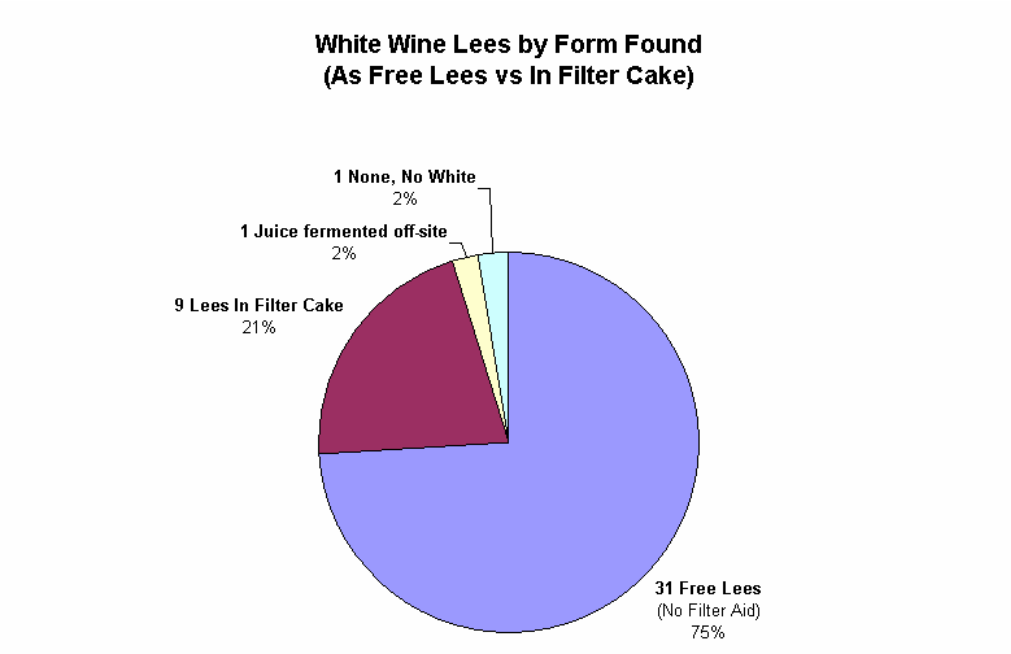
Cost or income associated with lees (juice and yeast lees)

Eleven wineries provided an indication of the financial aspects of handling and disposing of lees in general (juice lees and post ferment lees). Two large wineries received significant incomes for each tonne for their lees, while others received free freight and discounts on recovered extracts. Other wineries who are presumably too far from extraction facilities or too small have quite significant costs. One winery pays $78 per tonne of lees for transportation and tipping at a licensed facility. Another puts the cost of spreading the lees on the paddock at $8 per tonne. One medium sized winery who requires low wine for fortification pay to send their yeast lees a significant distance for distillation and receive a credit or discount against the alcohol they purchase back from the extraction company. Most small wineries attach very little or no cost to the on-site disposal of lees.

Cost or income – filter cake

Wineries that utilise Rotary Drum Vacuum Filters (RDV) have the means to reclaim juice and wine from lees, which contains a significant amount of liquids. In such cases the lees therefore becomes a component of a filter cake. Ten wineries provided some indication of cost for the handling and disposal of their filter cake whether generated from pre or post ferment clarification (juice or wine lees). Two large wineries received a significant income from re-processing whether for distillation or Tartaric Acid recovery. Others were in cost neutral situations where reprocessors collected the waste free of charge – some wineries received a rebate on the cost of subsequent purchases of extracts. Other wineries paid transport costs to reprocessing facilities and others paid up to $55 per bin or skip to have their filter cake removed and disposed of off-site. Smaller wineries generally do not have a RDV for the recovery of juice or wine form lees – however they may create small volumes of cake from the earth filtering of wine prior to bottling.

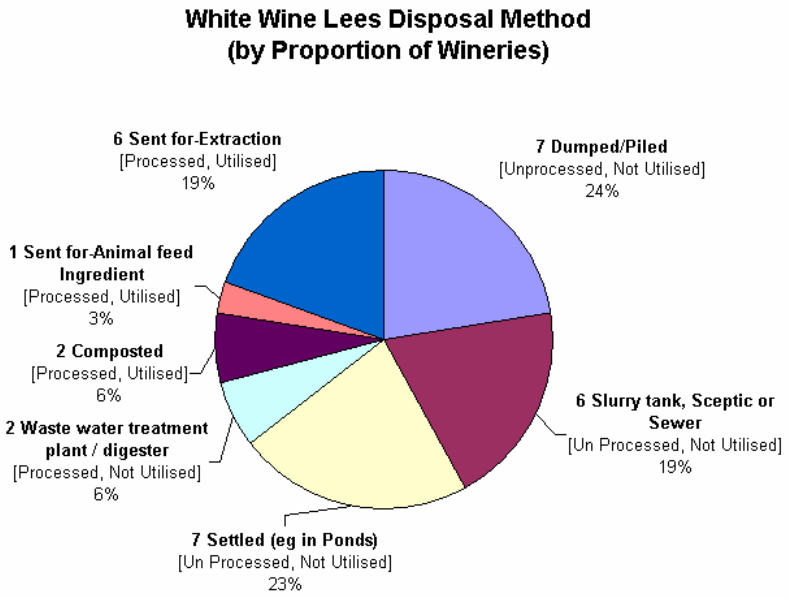
Handling & disposal of white wine (yeast) lees



The above chart indicates the final form of the white wine (yeast) lees produced at the 42 wineries that responded to the question. Twenty-one percent of the wineries utilised a Rotary Drum Vacuum Filter to recover wine resulting in the solid lees being in a filter cake form. Seventy-five percent of the wineries however did not utilise earth filtration and their lees were in the form of 'free lees' consisting of yeast and grape solids with various proportions of wine. Therefore some of the free lees would be in a very wet sludge – especially if no secondary recovery process was used or relatively dry if a top of the range centrifuge was used.

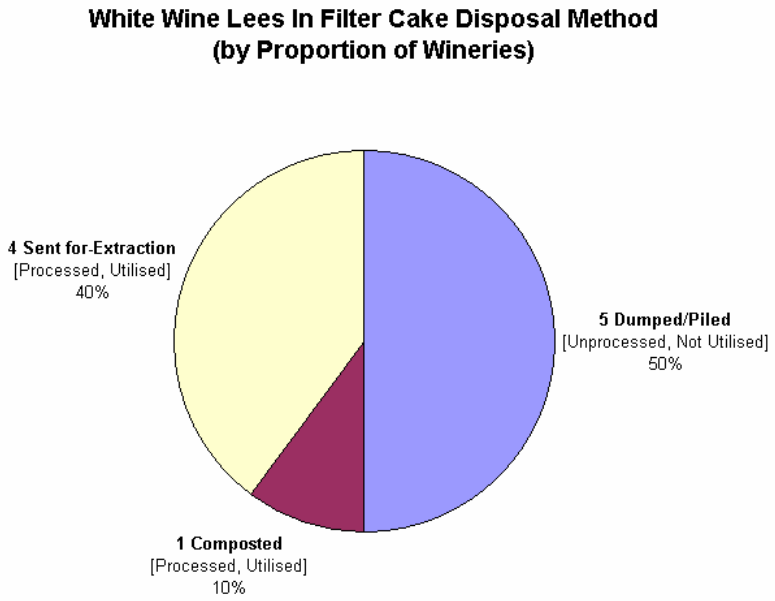
The chart also indicates that 2 wineries didn't produce any white wine (yeast) lees. Of these one winery didn't process any white fruit and the other sent the clarified juice for finishing off-site and so didn't produce any yeast lees on-site.

The two charts below indicate respectively how the free white wine (yeast) lees and the white wine (yeast) lees in filter cake form are handled/disposed.



The chart above indicates the handling methods for the 31 wineries that did not use filter earth to recover juice from their post-ferment clarification lees. The following is observed:

- Twenty wineries or 66% disposed of their 'free white wine (yeast) lees' (mostly on-site) in an unprocessed, unutilised form either dumped/piled (7), settled in ponds (7) or in slurry/sceptic/sewer (6)
- Two wineries or 6% utilised their 'free white wine (yeast) lees' in a processed form (mostly on-site) as compost
- Two wineries or 6% processed their free white wine (yeast) lees' on site via wastewater digester system but did not utilise the solids
- Seven wineries or 22% sent their 'free white wine (yeast) lees' off-site for processing and utilisation either as an animal feed ingredient (1) or for extraction (6)



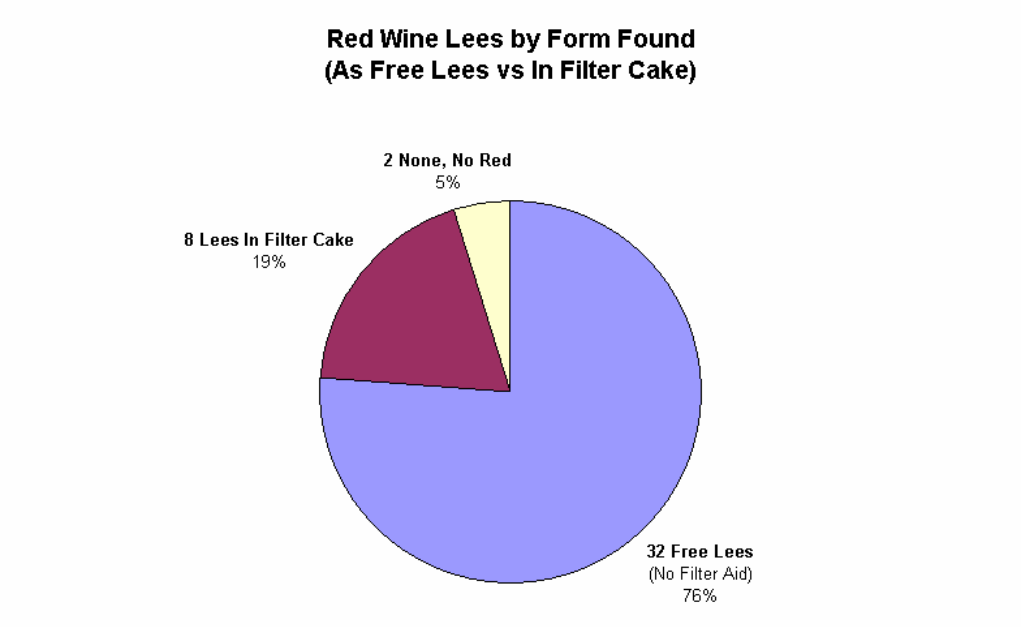
The chart above indicates the handling methods for the 10 wineries that use filter earth to recover wine from their post-ferment clarification lees. The following is observed:

- Five wineries or 50% disposed of their 'white wine (yeast) lees filter cake' (mostly on-site) in an unprocessed, unutilised form by dumping or piling

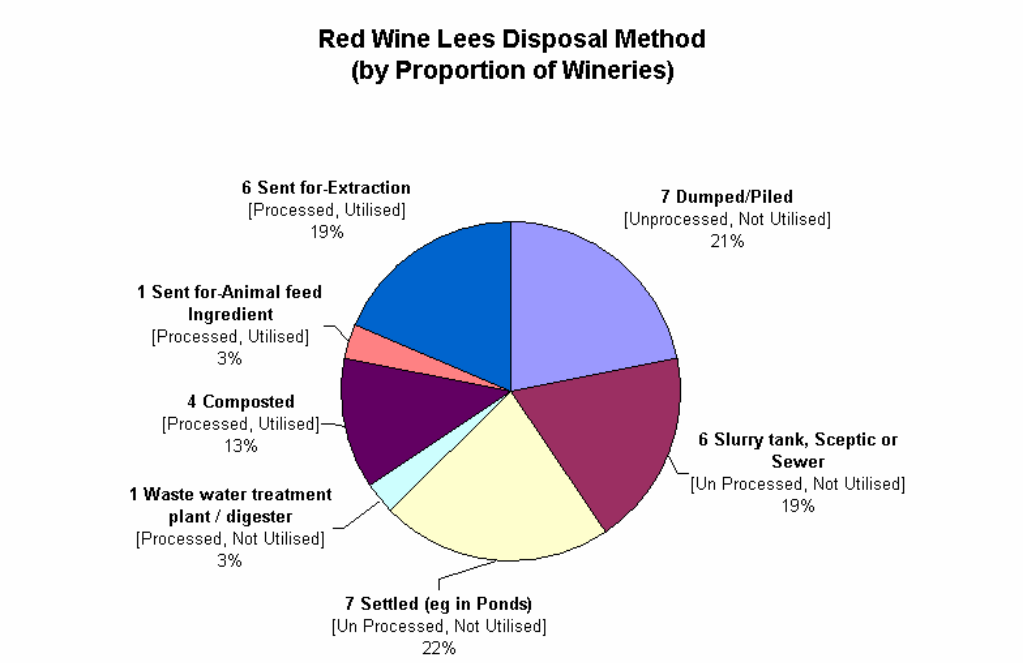
- One winery or 10% utilised their ‘white wine (yeast) lees filter cake’ in a processed form (on-site) as compost
- Four wineries or 40% sent their ‘white wine (yeast) lees filter cake’ off-site for processing and utilisation for extraction (7)

Cost or income – lees and filter cake
See juice lees

Handling & disposal of red wine (yeast) lees

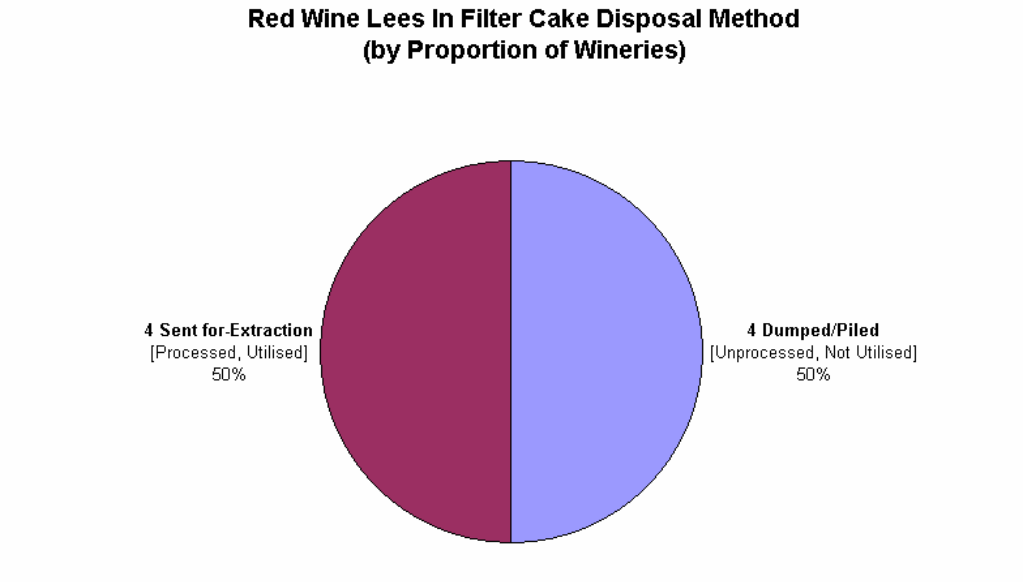


The above chart indicates the final form of the red wine (yeast) lees produced at the 42 wineries that responded to the question. Nineteen percent of the wineries utilised a Rotary Drum Vacuum Filter to recover wine resulting in the solid lees being in a filter cake form. Seventy-six percent of the wineries however did not utilise earth filtration and their lees were in the form of ‘free lees’ consisting of yeast and grape solids with various proportions of wine. Therefore some of the free lees would be in a very wet sludge – especia lly if no secondary recovery process was used or relatively dry if a top of the range centrifuge was used. The chart also indicates that 2 wineries didn’t produce any red wine (yeast) lees. The two charts below indicate respectively how the ‘free red wine (yeast)’ and the ‘red wine (yeast) lees in filter cake’ are handled / disposed.



The chart indicates the handling methods for the 32 wineries that did not use filter earth to recover wine from their post-ferment clarification lees. The following is observed:

- Twenty wineries or 62% disposed of their 'free red wine (yeast) lees' (mostly on-site) in an unprocessed, unutilised form either dumped/piled (7), settled in ponds (7) or in slurry/sceptic/sewer (6)
- Four wineries or 13% utilised their 'free red wine (yeast) lees' in a processed form (mostly on-site) as compost
- One winery or 3% processed their 'free red wine (yeast) lees' on site via wastewater digester system but did not utilise the solids
- Seven wineries or 22% sent their 'free red wine (yeast) lees' off-site for processing and utilisation either as an animal feed ingredient (1) or for extraction (6)



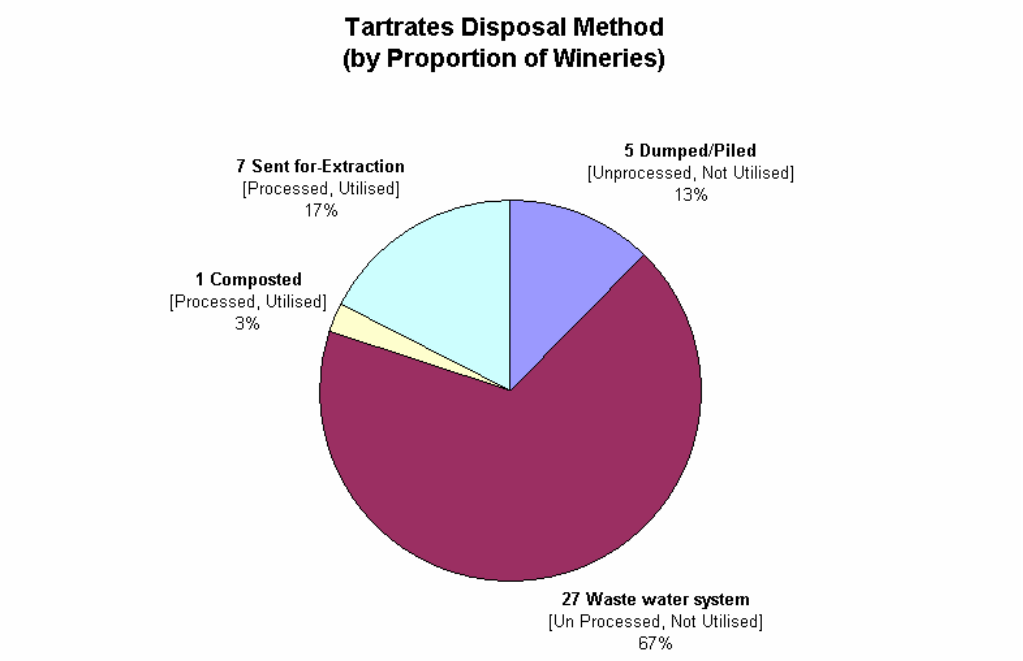
The chart indicates the handling methods for the 8 wineries that use filter earth to recover red wine from their post-ferment clarification lees. The following is observed:

- Four wineries or 50% disposed of their 'red wine (yeast) lees filter cake' (mostly on-site) in an unprocessed, unutilised form by dumping or piling

- Four wineries or 50% sent their 'red wine (yeast) lees filter cake' off-site for processing and utilisation via extraction

Cost or income – red wine yeast lees and filter cake
See juice lees

Handling & Disposal - tartrates



The chart indicates the handling methods for the 40 wineries that responded. The following is observed:

- Thirty-two wineries or 80% disposed of their tartrates (mostly on-site) in an unprocessed, unutilised form by dumping /piling (5) or disposing to waste water system (27)
- One winery or 3% utilised their tartrates in a processed form (on-site) as compost
- Seven wineries or 17% sent their tartrates off-site for processing and utilisation via extraction

Cost or income - tartrates
Tartrate deposits were generally removed from tanks and barrels and neutralised with caustic before entering the wineries wastewater system. A few larger wineries collected tartrates and drummed them before sending them for reprocessing into Tartaric Acid. Only five wineries however provided some indication of costs and incomes. Several large wineries received significant incomes for their tartrates. One winery supplied the tartrates mixed in with filter cake to one re-processor for Tartaric Acid (TA) recovery and received a rebate on the purchase of TA.

Handling & Disposal – bentonite clay
An estimation of total bentonite clay was made as this additive exits the winemaking process in many different places depending on the process employed. No questions were asked relating to how these wastes were handled and disposed.