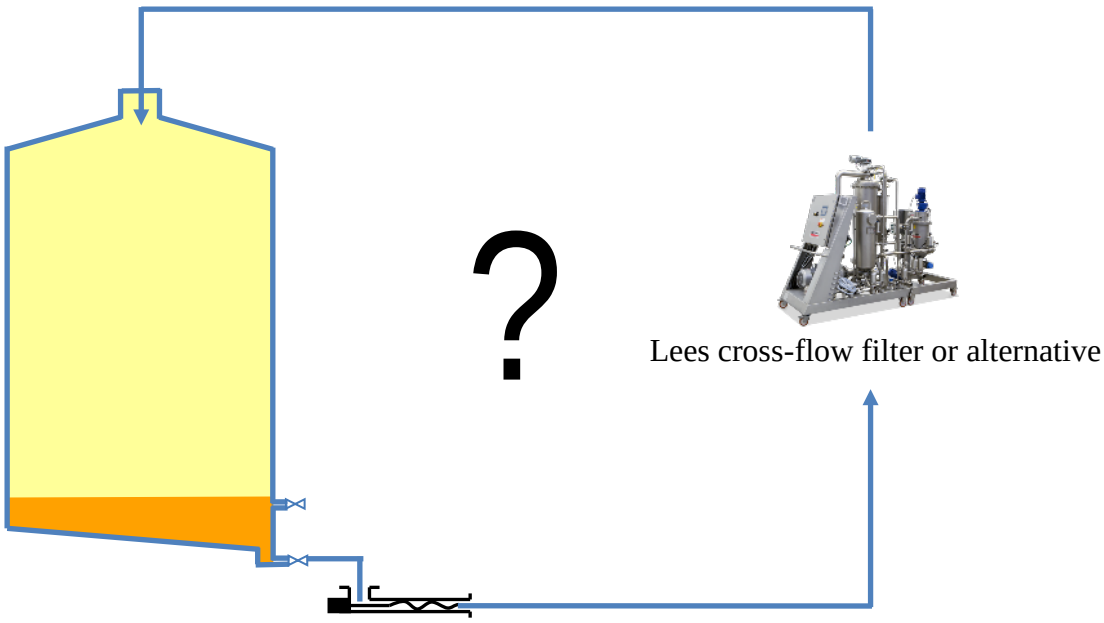
Australian Government

Australian Grape and Wine Authority

The Australian Wine Research Institute

Removal of lees from underneath wine to reduce wine movements and tank cleaning



FINAL REPORT to

AUSTRALIAN GRAPE & WINE AUTHORITY

Project Number: **AWR 1307**

Principal Investigator: **Simon Nordestgaard**

Research Organisation: **Australian Wine Research Institute**

Date: **January 2017**

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Disclaimer:

Readers should undertake their own specific investigations before purchasing equipment or making major process changes. AWRI does not endorse or dis-endorse any of the products described.

Version: 1.0, January 2017

Abstract

Studies were performed to understand the sources and properties of winery lees. Grape solids were the largest source of lees and apart from red ferment lees, all settled lees flowed readily. Laboratory experiments were performed to study the possibility of removing settled lees out from underneath juice or wine. Experiments with 55° sloped cylindroconical tanks were somewhat successful, but experiments with a typical winery tank shape (5° sloped bottom from back to front) were unsuccessful even with the thinnest lees and with tank modifications. A workshop on lees and new lees reprocessing equipment was also convened at the 16th Australian Wine Industry Technical Conference.

Executive summary

Clarification is a major reason for moving juice and wine between tanks at wineries. After each movement, the source tank needs to be cleaned. Tank cleaning and the movement of juice/wine consumes labour, water and cleaning chemicals and generates wastewater. This project aimed to learn more about the sources and properties of winery lees. It also aimed to study the possibility of removing settled lees out from underneath juice or wine, such that the bulk of the juice or wine could remain in the same tank.

Samples of lees and information on lees volumes were collected from collaborating wineries and supplemented by laboratory experiments. Grape solids were the largest source of lees. In white wine production, these are removed prior to fermentation, while in red wine production they are removed after fermentation in combination with yeast. The other major source of lees was bentonite.

Most lees separated by settling were quite thin. The exception was gross red ferment lees. Gross red ferment lees samples exhibited high yield stresses (the minimum stress needed to initiate flow). This difference was not purely related to their relative solids content, as white ferment lees samples with similar solids contents exhibited low yield stresses. The difference likely relates to the inclusion in red ferment lees of grape solids and/or soluble materials extracted during fermentation on skins that are not present in white ferment lees. High yield stresses in red ferment lees were exacerbated by the inclusion of oak chips in samples from one winery. At that winery, oak chips were added to red ferments and were not all removed by their draining and pressing processes. These high yield stresses make these lees particularly difficult to manage in the winery. Alternatives to oak chips for colour stabilisation is an area that may benefit from further research.

A laboratory apparatus with changeable transparent tanks was constructed to study the possibility of removing settled lees out from underneath juice or wine. The use of 55° sloped cylindroconical tanks was somewhat successful in facilitating the removal of lees from underneath the clear phase, but this was not considered a practical option for large wineries as it would require the installation of new more expensive tanks. The use of winery-style tanks with a 5° slope from back to front with or without some simple modification was the experimental focus. With unmodified winery-style tanks, the clear phase quickly broke through the lees even with the thinnest lees. The use of a baffle above the tank sump just moved the location of breakthrough without materially improving lees removal. The use of a ‘Kreepy Krauly’ style device showed some ability to remove lees but continually moving the device to the location of the remaining lees presents major challenges and hygiene issues. The use of a sweeping arm on the floor of the tank was able to keep the lees moving and prevent the breakthrough of clears such that a portion of lees could be removed from the tank. However, this configuration would also require an expensive tank retrofit and as the lees level drops and the sweeping arm starts to break the lees surface it resuspended the remaining lees. Alternative means of agitating the lees while not resuspending it using devices that could be moved between tanks were explored unsuccessfully. Results from laboratory experiments were not sufficiently successful to justify the development of a prototype winery-scale device to facilitate lees removal from normal winery tanks.

A workshop on lees was also convened at the 16th Australian Wine Industry Technical Conference. This included presentations from wineries on their experiences with new lees reprocessing equipment. Slides from this workshop are included in Appendix A of this report. Several discussions were also held with wineries on the use of new lees reprocessing equipment during the project. A question raised by one wine company that had trialled a range of lees reprocessing equipment was how much of the downgrading that occurs with some lees reprocessing technologies is just a consequence of the juice/wine being occluded in different types of lees as opposed to the technology used to recover it from the lees. Further research to understand lees-occluded juice/wine interactions could be worthwhile.

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1. Introduction

Clarification is a major reason for moving juice and wine between tanks at wineries. After each movement, the source tank needs to be cleaned. Tank cleaning and the movement of juice/wine consume labour, water and cleaning chemicals and generate wastewater.

When racking juice/wine off settled lees, the current practice (Figure 1.1) is to first rack the clear juice/wine to another tank, then pump the lees to a lees tank (where they are often mixed with other similar lees). In large wineries, juice/wine is then recovered from these lees, sometimes by rotary vacuum drum filtration (RVDF) that can result in product oxidation and downgrading.

Settled lees generally occupy less than 10% of the volume of the tank. We were interested in whether it might be possible to rack this relatively small quantity of lees out from underneath the clear juice/wine. This would allow the larger volume of clear/juice wine to remain in the same tank, avoiding the need to move the bulk of the juice/wine and clean the source tank (Figure 1.2a). Ideally, in some cases it might even be possible to immediately recover juice/wine by one of the new generation alternatives to RVDF that are less likely to downgrade the juice/wine and return it to the same tank (Figure 1.2b).

In considering the possibility of removing lees from underneath juice/wine, it became apparent that there were very few data available on the properties of winery lees and even on the relative volume of different lees throughout the winemaking process.

This project endeavoured firstly to collect data from wineries on lees[1] volumes, supplemented by laboratory experiments where required. Secondly, lees samples would be collected from winery and laboratory experiments and analysed to better understand their properties, particularly their flow properties (rheology). Laboratory-scale experiments would then be performed to investigate the possibility of removing lees from underneath juice/wine. If the results from these laboratory experiments were sufficiently promising, a winery prototype device was to be built to facilitate lees removal from winery tanks.

Section 2 of this report contains information on the sources of lees in wineries. Section 3 contains information on the properties of different lees and Section 4 contains results from the laboratory-scale investigations of the underneath removal of lees. Project conclusions and recommendations follow.

Two articles were written during the project and these are included in Appendix A. At the 16th Australian Wine Industry Technical Conference in July 2016 a workshop was also convened as part of the project. This included a presentation summarising project work as well as presentations from wine companies on their experiences with new generation lees filtration/reprocessing equipment. Slides from this workshop are provided in Appendix A together with slides from an earlier presentation to a Winery Engineering Association conference.

[1]Lees is used as a general term in this report to describe all juice or wine sediments, sludges, floats, etc. generated during the winemaking process.

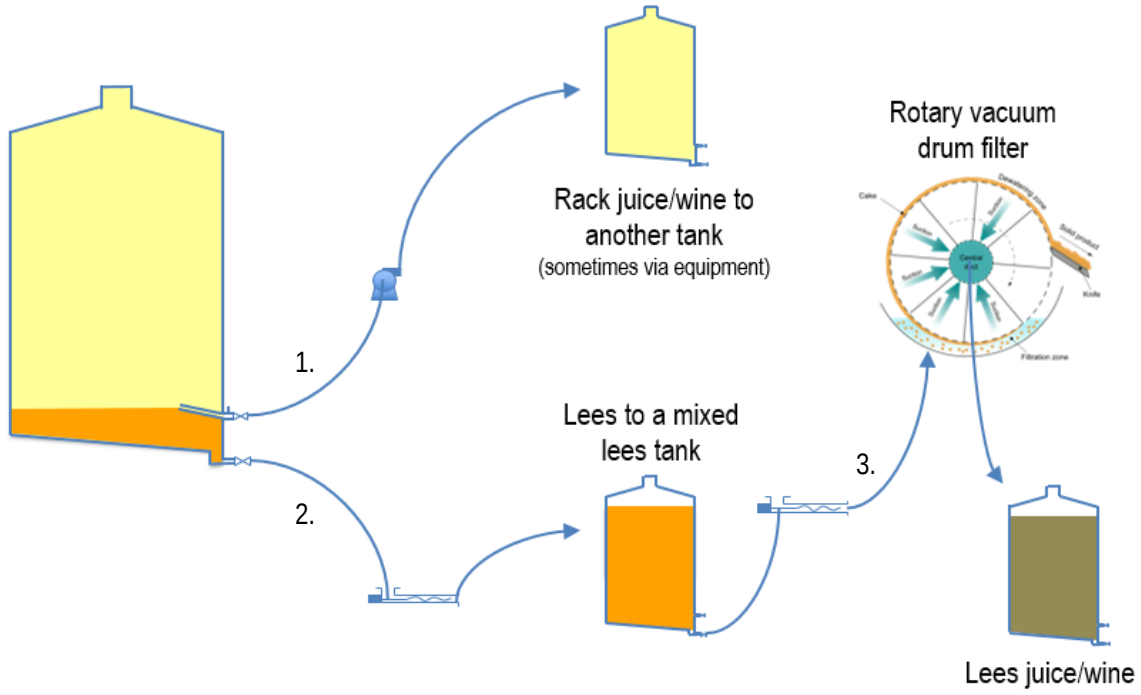


Figure 1.1: Typical juice/wine racking and recovery processes at large wineries

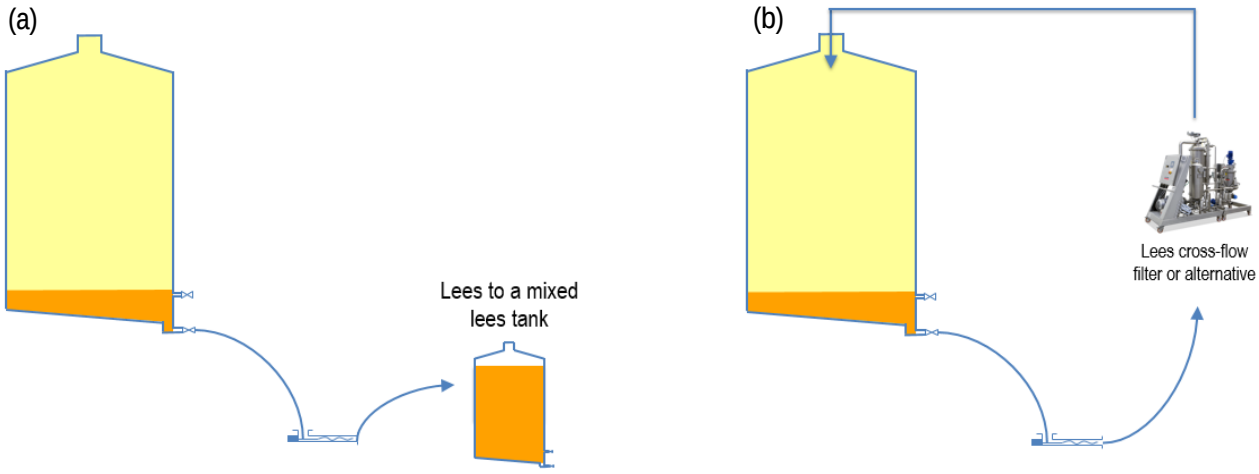


Figure 1.2: Idealised lees racking from underneath clear juice/wine, (a) to a mixed lees tanks, and (b) through a lees cross-flow filter back into the same tank

2. Sources of lees

2.1. Materials and methods

Data on lees were collected from four collaborating wineries. This included data extracted from winery operations databases from recent years, data collected explicitly by the wineries during 2014, and information gathered from discussions with winemakers and operations personnel. All four wineries were large, having annual crushes of more than 10,000 tonnes. Lees volume fractions were calculated using the formulas [(Volume in – Volume clears out)/Volume in] or [Volume lees out/(Volume lees out + Volume clears out)] depending on the format of available data.

Winery data were supplemented by data from laboratory settling experiments in 2 L measuring cylinders. This included juice settling after treatment with common fining agents, fermentations and settling with seven commercially available yeasts and wine fining with common fining agents. Unclarified juice used for juice settling experiments was enzyme treated free-run/soft pressings (membrane press ~ 660 L/tonne) Chardonnay juice from a collaborating winery. Juice settling experiments reported were performed at 4°C for 26 hours. The same batch of juice was also collected from the collaborating winery after clarification (centrifugation + flotation) for use in laboratory fermentations. Laboratory fermentations were repeated with the first set being settled for 17 days after fermentation and the second set being allowed to settle for 65 days after fermentation. Chardonnay wine collected from the same winery was used for wine fining experiments, with the experiments reported being performed at 22 °C with eight days settling time.

The above laboratory experiments were also used to generate additional lees samples for analysis that is discussed in Section 3.

2.2. Results and discussion

Typically, the largest volumes of lees come from the grape. In white winemaking grape-derived solids are mainly removed prior to fermentation, whereas in red winemaking they are usually removed after fermentation where they are combined with yeast.

An illustration of relative lees volumes in white wine production is provided in Figure 2.1. Cold settling gave 10% juice lees. In contrast, fermentation gave lees volumes between 1% and 3%. Fining agents at typical doses also produced relatively small quantities of lees, except for bentonite, which is widely known for producing large volumes of lees (6% in this experiment).

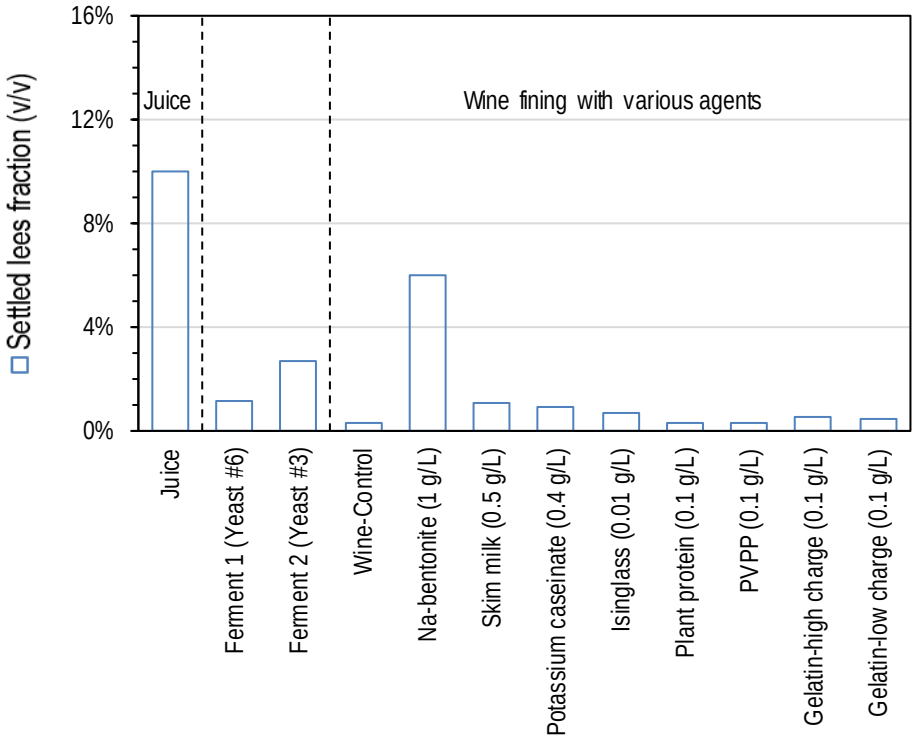


Figure 2.1: Indicative lees volumes at different stages of white wine production from laboratory settling experiments

At a winery scale, a range of techniques are used for white juice clarification. Alternatives to cold settling, include flotation and multi-stage clarification processes such as centrifugation followed by flotation (performed in a semi-continuous manner), and centrifugation followed by cold settling.

Figure 2.2 presents a comparison of lees volumes obtained with different techniques at three wineries. At Winery A, with cold settling, 16% of the initial juice was separated as lees, while with flotation only 7% was separated as lees. With flotation, the solids are lifted with nitrogen gas bubbles and therefore there is less juice tied up with the solids than occurs with cold settling. Winery B used flotation alone or centrifugation followed by cold settling. Even after many of the larger solids had been removed by centrifugation, the volume of lees obtained after cold settling was still higher than using flotation alone (13% compared with 9%). Winery C used centrifugation with injection of nitrogen gas for flotation on the outlet of the centrifuge with semi-continuous racking of clears from underneath floats in a buffer tank. This process gave a lees volume of only 3%.

This much lower lees fraction at Winery C than at Wineries A and B is likely to be partly a consequence of the use of centrifugation to remove the larger, denser solids and the subsequent use of flotation to remove the lighter solids (both technologies which produce lees with low juice content). It is also likely to be partly a consequence of Winery C's exclusive use of membrane presses for draining and pressing, which may have resulted in lower initial juice solids levels than occurred at Wineries A and B where inclined or static drainers and screw presses were used for some operations. Types and modes of operation of crushing, draining, and pressing equipment are important in limiting lees volumes in the winemaking process.

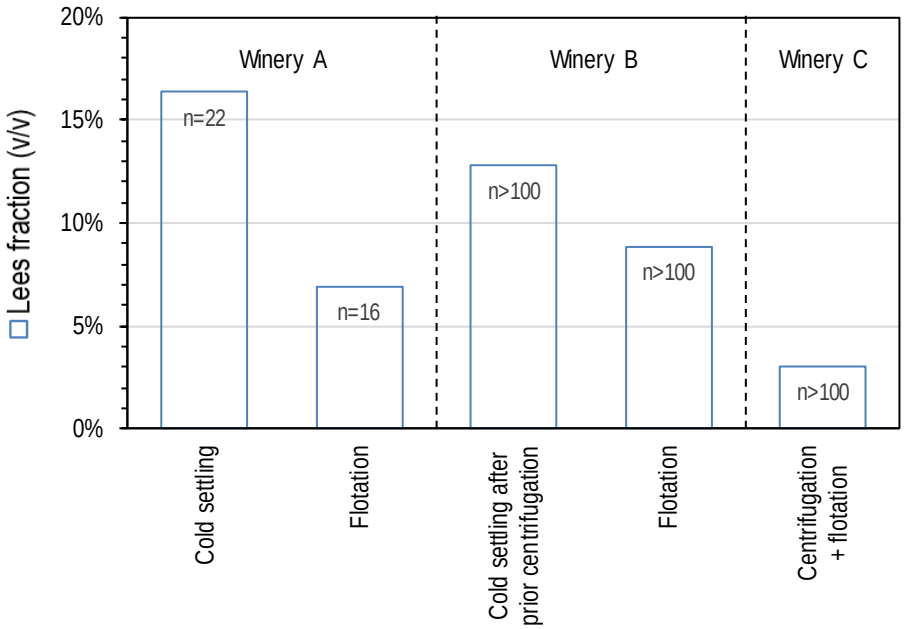


Figure 2.2. Median lees volumes from different white juice clarification methods at three wineries (n=number of batches)

As illustrated in Figure 2.1, bentonite is also a major potential source of lees in white wine production. Data on bentonite lees volume were extracted from one winery's database. This winery coupled wine fining with sodium bentonite at the rate required to remove proteins and induce heat stability with chilling to precipitate tartrates and induce cold stability. Over more than 500 batches, the median settled bentonite/tartrate lees volume was 5.1%.

Winery data were also collected on lees volumes during red wine production. Winery B which removed gross red ferment lees after draining/pressing by settling had a median settled volume of gross red ferment lees of 9.6% across more than 500 batches. Lees fractions at different stages of red wine production at Winery D are illustrated in Figure 2.3. This reiterated the observation that the largest source of lees in red wine production is the lees containing red grape solids and yeast. The red wine ferment lees fraction at Winery D was considerably lower than at Winery B, likely because Winery D clarified its fermentations after draining/pressing by centrifugation as opposed to settling.

Data on recovery rates during reprocessing by RVDF were also obtained from wineries A and B. Over many hundreds of batches at winery B, recovery rates were 89% for juice lees (mainly cold settled and float lees), while they were slightly lower at 82% for white wine lees (mainly settled bentonite and tartrate lees) and at 84% for red wine lees (mainly settled red gross red ferment lees). At winery A, over 19 batches, the recovery rate from cold settled juice lees was 86% on average.

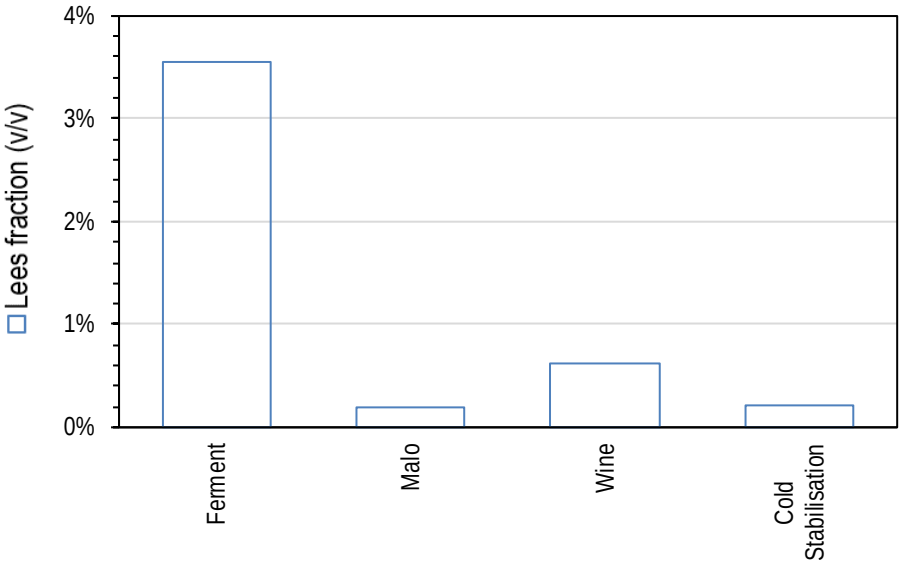


Figure 2.3 Aggregated lees fractions at different stages of red wine production at Winery D

2.3. Section conclusions

1. Grape solids are the largest source of lees. In white wine production, these are removed prior to fermentation, while in red wine production they are removed after fermentation in combination with yeast.
2. Bentonite is the other major source of lees in white wine production.
3. Flotation appears to be a means of achieving low lees volumes compared with settling, with less capital investment than required for centrifugation.

3. Properties of lees

3.1. Materials and methods

A range of lees samples was collected from collaborating wineries during site visits in 2014. Samples were collected from different locations, including from the bottom valve of tanks prior to the clears being racked, through tank doors after clears had been racked, from sample taps on mixed lees tanks, and from sample taps on other equipment. Samples were preserved for later analysis by the addition of 1 g/L of potassium metabisulfite and storage at 4°C. Lees samples were also generated during the laboratory experiments as described in Section 2. Some laboratory experiments involved excessive additions of fining agents to generate sufficient lees volume for analysis.

Wet solids content of lees was determined by centrifugation (50 mL, 3,000 x g, 5 minutes – Figure 3.1) and all results are reported in percentage solids by volume. Dry solids content was determined using oven drying and weighing. Approximately 5 g of both the lees sample and 5 g of the same sample (or associated supernatant) that had been filtered through a 0.2µm syringe filter were heated to 70°C for 24 hours (Figure 3.2). This allowed the determination of both the dry dissolved and suspended solids content of the lees. All dry solids measurements reported are dry suspended solids content by weight.

Particle size analysis was performed by laser diffraction using a Malvern Mastersizer 2000. Microscopy was performed on samples using a Celestron PentaView LCD Digital Microscope at magnifications of 40-400x.

Static yield stress of samples was determined using the vane shear technique described by Nguyen and Boger (1983) with a speed of 0.1 rpm. A Haake VT550 controlled rate Searle type viscometer (Figure 3.3a) was employed with either a FL100 or FL10 (Figure 3.3b) sensor fitted depending on the yield stress of each sample. The vane was inserted into the sample by raising the sample on a laboratory jack (Figure 3.3a). The sample was allowed to relax for 5 minutes after vane insertion before analysis began. The minimum shear stress officially within the bounds of the instrument was 0.5 Pa and any results lower than that have been reported as < 0.5 Pa. Static yield stress was not generally determined for laboratory derived samples because of insufficient sample volume (dynamic yield stress results were relied upon for laboratory-derived lees samples as described below).

A stepped shear rate flow loop was performed with the Haake VT550 with measurements at shear rates of 5, 10, 50, 100, 200, 300, 400, 500, 400, 300, 200, 100, 50, 10, and 5 s^{-1}. At each shear rate 15 seconds of equilibration was allowed before the average measurement was collected over the next 30 seconds. For high viscosity lees samples an MV2P profiled sensor with MVP profiled cup (2.6 mm gap, Figure 3.3c) was used, while for low viscosity lees samples an NV sensor and NV cup (1 mm gap) was used. To protect the instrument and avoid erroneous measurements, lees samples tested with the MV2P/MVP sensor/cup were first passed through a 1 mm sieve and lees samples tested with the NV/NV sensor/cup were first passed through a 300 µm sieve. Dynamic yield stress was determined by extrapolation of the flow loop to a shear rate of 0 s^{-1}. Tabulated viscosity measurements for comparison in this report are at a shear rate of 500 s^{-1}, not because this is the most relevant shear rate, but because the instrument is most accurate at higher shear rates for some of the thinner lees samples encountered. Unless otherwise stated, tests were conducted at 20°C. During the stepped shear rate loop, the sample temperature was maintained using an external temperature-controlled recirculating bath.

Selected lees samples were also analysed in conjunction with a Rheological consultant using their high-end Haake Mars III controlled stress/controlled rate rheometer (Figure 3.4) to verify the behaviour observed on the much cheaper Haake VT550 instrument. Yield stress measurements were performed by slowly increasing the stress levels in controlled stress mode and measuring deformation. Flow loops were performed in controlled rate mode by increasing the shear rate from 1

to 500 s^{-1} and back again. 35 mm profiled plate and plate sensors were used for all measurements on the Haake Mars III with a gap of 1 or 1.5 mm.



Figure 3.1: Wet solids content measurment, example samples after centrifugation (a) juice lees with bentonite, and (b) red ferment lees



Figure 3.2: Dry solids content measurement, example samples (a) before, and (b) after heating

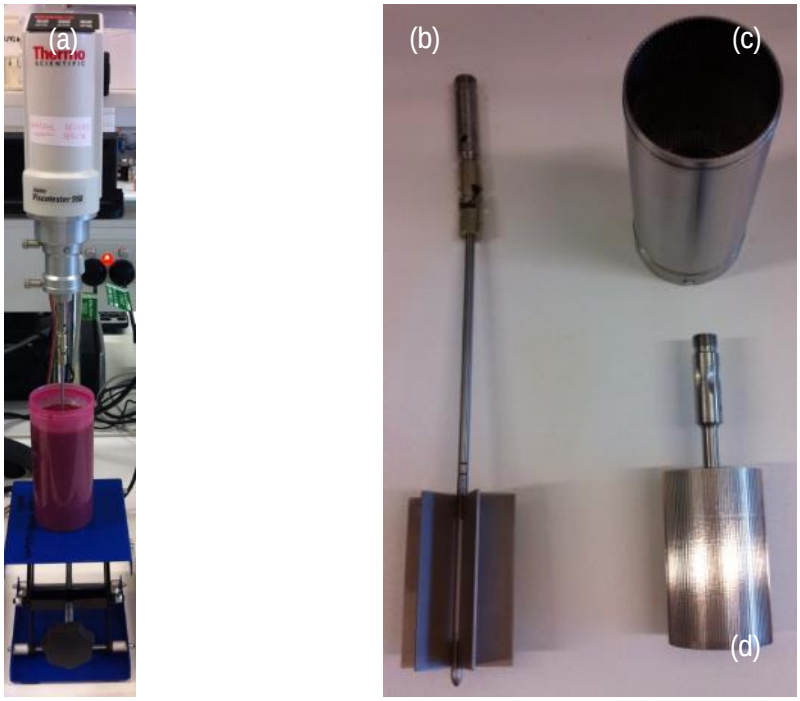


Figure 3.3: Haake VT550 controlled rate viscometer, (a) overview with vane sensor inserted in sample, (b) FL10 vane sensor for static yield stress measurement, (c) MVP profiled cup, and (d) MV2P sensor for stepped shear rate flow loop measurements

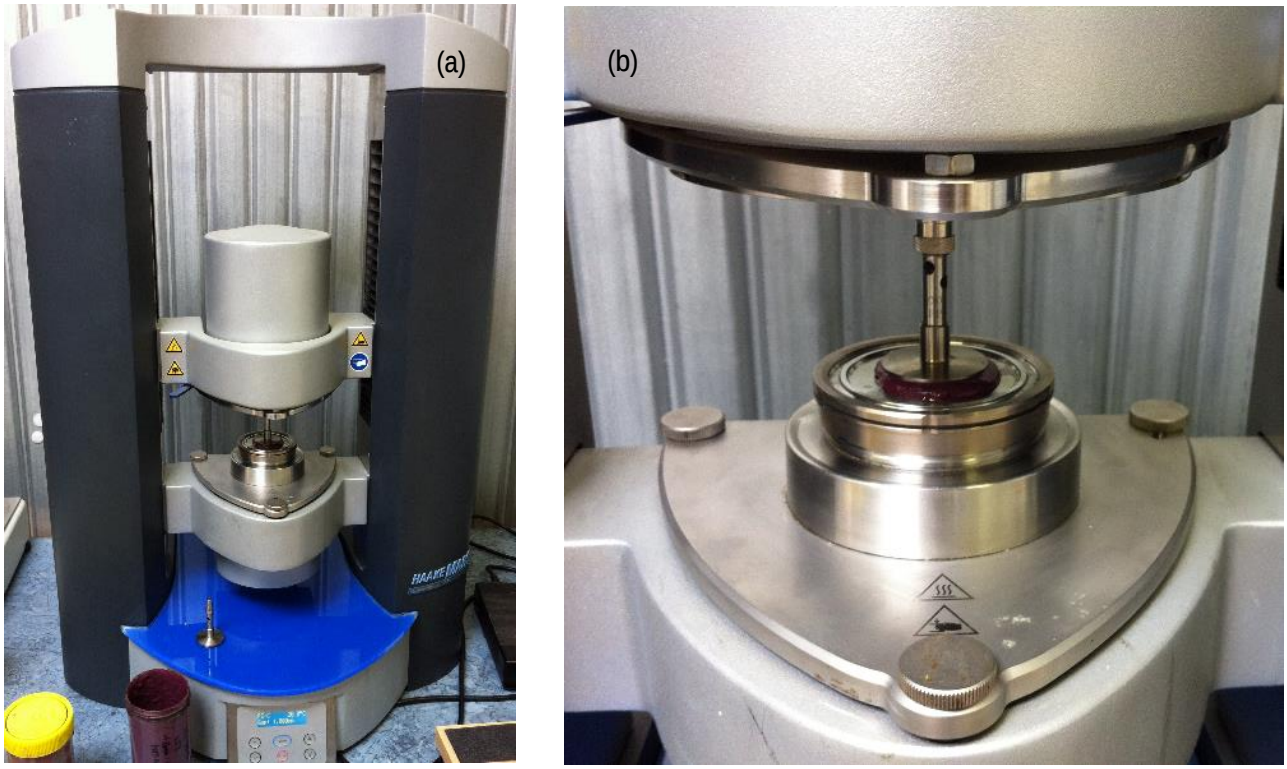


Figure 3.4: Haake MARS III controlled stress/controlled rate rheometer, (a) overview, and (c) close-up with excess sample visible from between profiled plates

3.2. Results and discussion

Data on lees properties are presented in the following sub-sections. Additional data are included in Appendix D.

3.2.1. Particle size distribution

Figure 3.5 presents particle size distributions for selected juice lees samples separated in different manners at collaborating wineries. It includes lees from single stage juice clarification by settling or flotation, as well as from two stage juice clarification with centrifugation as the first step and settling or flotation as the second step. Single stage settling and flotation had broad particle size distributions. Centrifugation lees from two-stage clarification processes featured larger particles, with lees from the second stage clarification by settling or flotation being dominated by the remaining smaller particles. Generally, juice lees particle size distributions were quite broad reflecting their composition of grape solids at various stages of breakdown and of tartrate crystals at various stages of crystal growth.

The settling sample in Figure 3.5 was collected from the bottom valve of a tank in which the lees had settled but the clears had not yet been racked. Samples were also collected from this tank at different heights within the lees bed by moving the tank racking arm to different positions. Particle size distributions for all samples from this tank are shown in Figure 3.6. At the bottom of the tank, the wet solids content of the lees was 27% and the particle size distribution is quite broad with a noticeable peak around 300 µm. Higher up in the lees, this particle size distribution became less heterogeneous. The wet solids content of the lees also decreases to 23% at 0.5 m, 18% at 0.9 m, 9% at 1.2 m and <2% at 1.7 m. The lees bed effectively ended somewhere between 1.2 m and 1.7 m.

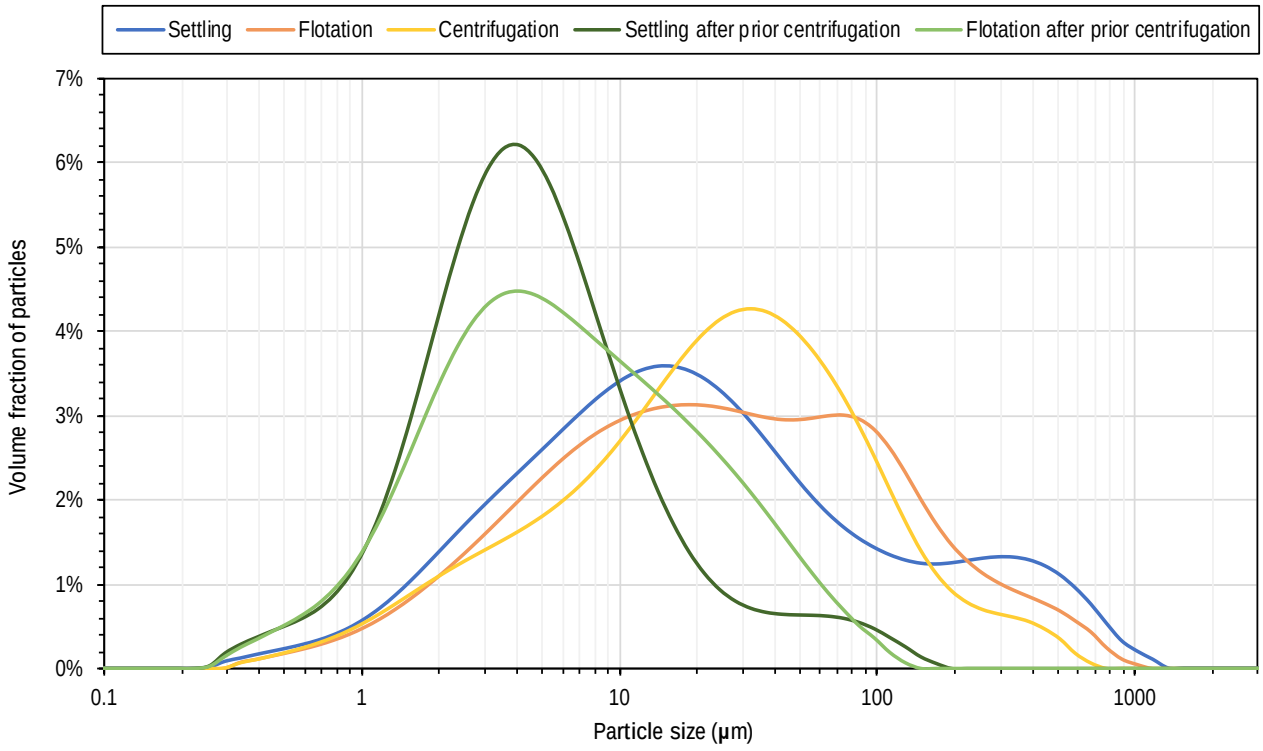


Figure 3.5: Particle size distribution of juice lees separated with different techniques

Figure 3.7 compares the particle size distribution of settled lees from different stages of wine production. White wine bentonite lees featured a peak in particle size distribution centred around 4 µm. White ferment lees had a tighter particle size distribution centred around 4 µm corresponding with yeast cells. Gross red ferment lees were very different. While they featured a peak in particle size distribution around 4-5 µm corresponding with yeast cells, they also featured another

peak with a much larger particle size over 100 µm. This was a feature of all red ferment lees samples. In microscopy of red ferment lees samples, regular yeast cells together with larger irregular aggregate material were visible (Figure 3.8).

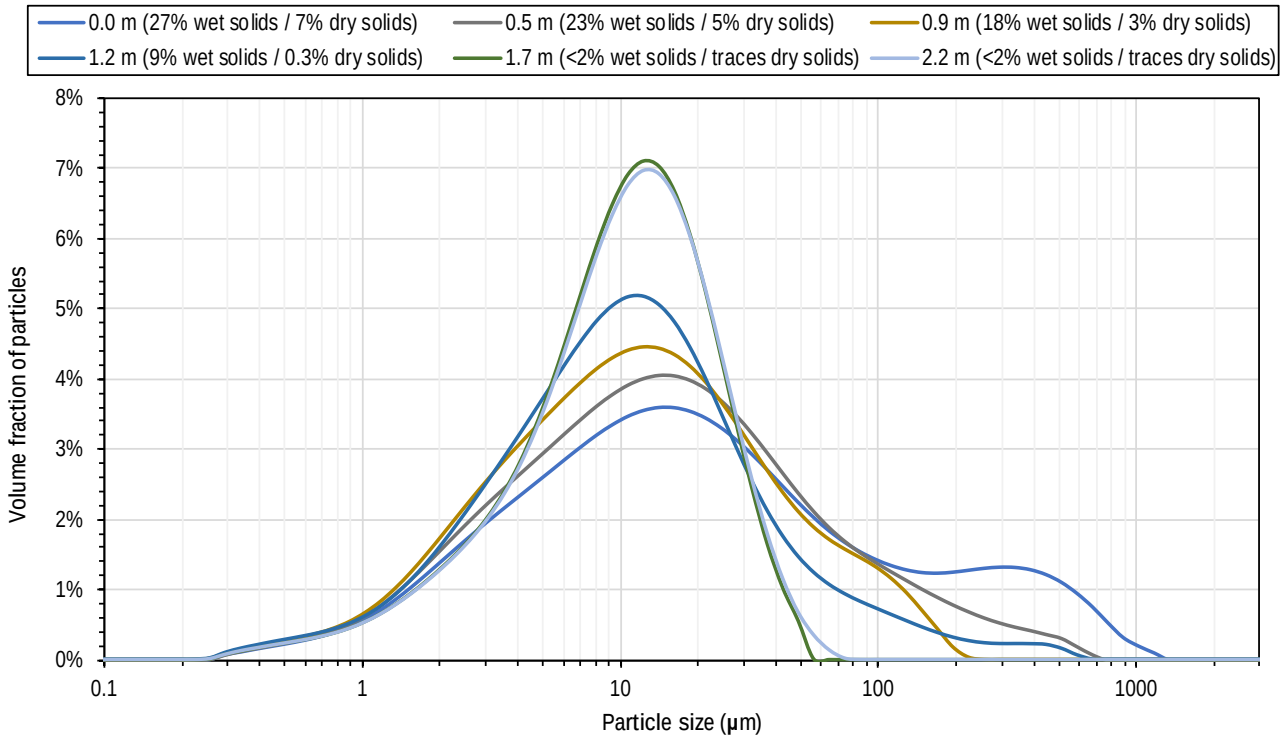


Figure 3.6: Particle size distribution of settled juice lees at different heights in a 10m tall tank

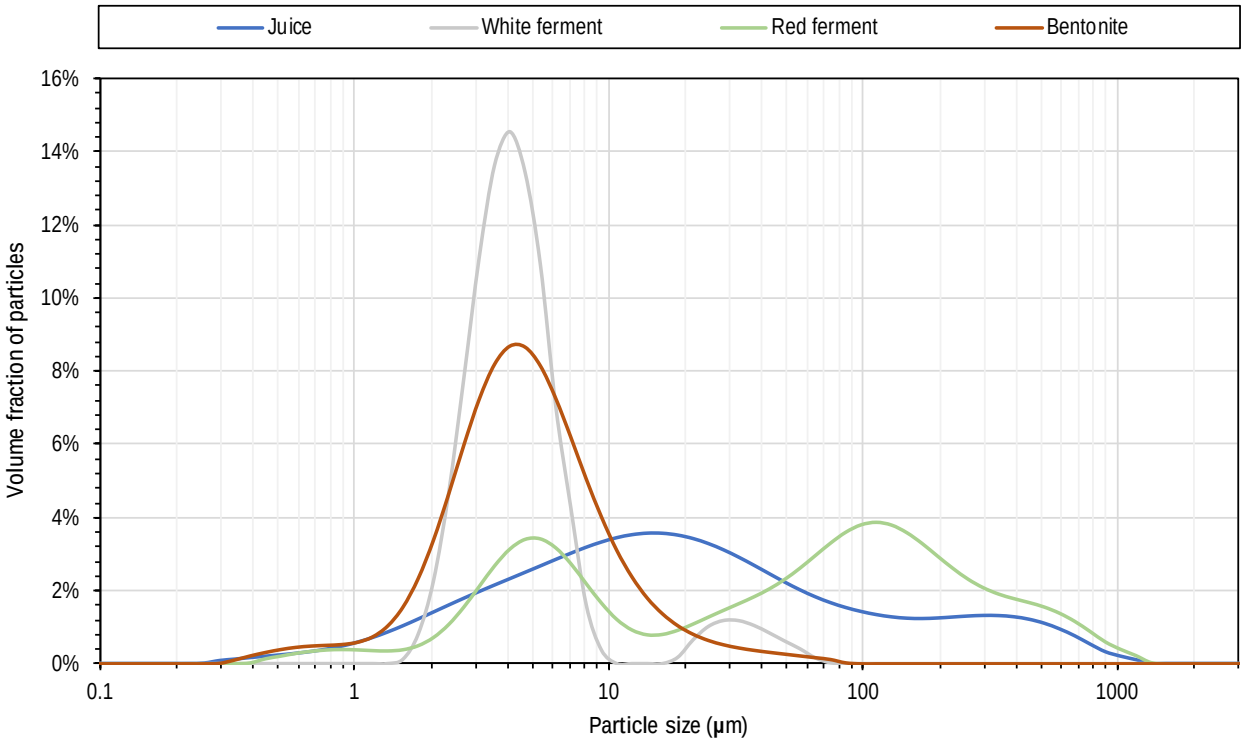


Figure 3.7: Particle size distribution of different lees separated by settling

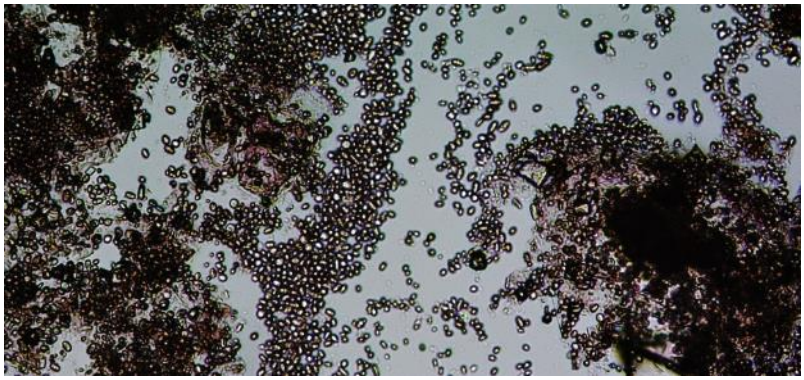


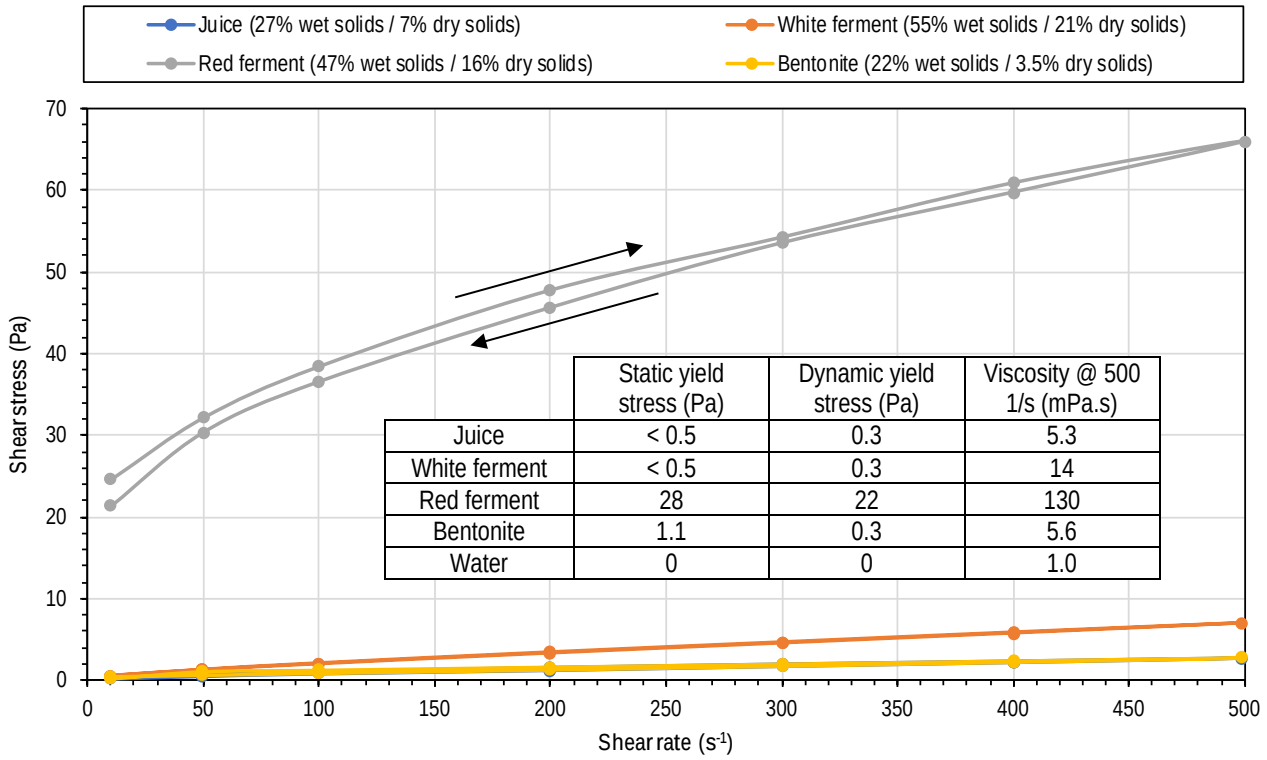
Figure 3.8: Microscopy (100x magnification) of a red ferment lees sample spread on a microscope slide, with regularly shaped yeast cells as well as larger irregularly shaped aggregate material visible

3.2.2. Rheology

Figure 3.9 summarises the rheological behaviour of some illustrative winery lees samples. Figure 3.10, presents the same plot with the gross red ferment lees series removed to allow rescaling and closer inspection of the other series. The main observation was that the rheology of the gross red ferment lees is completely different to all the other lees. Unlike the other lees, it featured a noticeable yield stress (the minimum stress needed to initiate flow – the point of intersection of the curves in Figures 3.9 and 3.10 with the y-axis). With our end goal in-mind, this is an important finding as it suggested that gross red lees would be more difficult to remove from a tank than other lees. The relatively high yield stress of the gross red ferment lees was not purely related to its solids content as white ferment lees with similar solids contents exhibited only small yield stresses.

Lees samples exhibited some degree of shear thinning behaviour over the range of shear rates measured (i.e. their apparent viscosity, the slope of the shear stress vs. shear rate curve, decreased with increasing shear rate). They also exhibited a degree of thixotropy (i.e. the apparent viscosity showed some time-dependent thinning behaviour, as illustrated in Figures 3.9 and Figure 3.10 by the shear stress curve being lower as the shear rate was reduced from its peak shear rate than it was when it was raised to its peak shear rate).

Table 3.1 presents the range of rheological values for the different categories of winery lees samples collected (these were sourced from a range of clarification processes as detailed in Appendix D). Sample analysis using the more advanced rheometer also showed the same trends in relative behaviour for different categories of lees (Table 3.2).



	Static yield stress (Pa)	Dynamic yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)
Juice	< 0.5	0.3	5.3
White ferment	< 0.5	0.3	14
Red ferment	28	22	130
Bentonite	1.1	0.3	5.6
Water	0	0	1.0

Figure 3.9: Rheology of representative settled winery lees (literature values for water included for comparison)

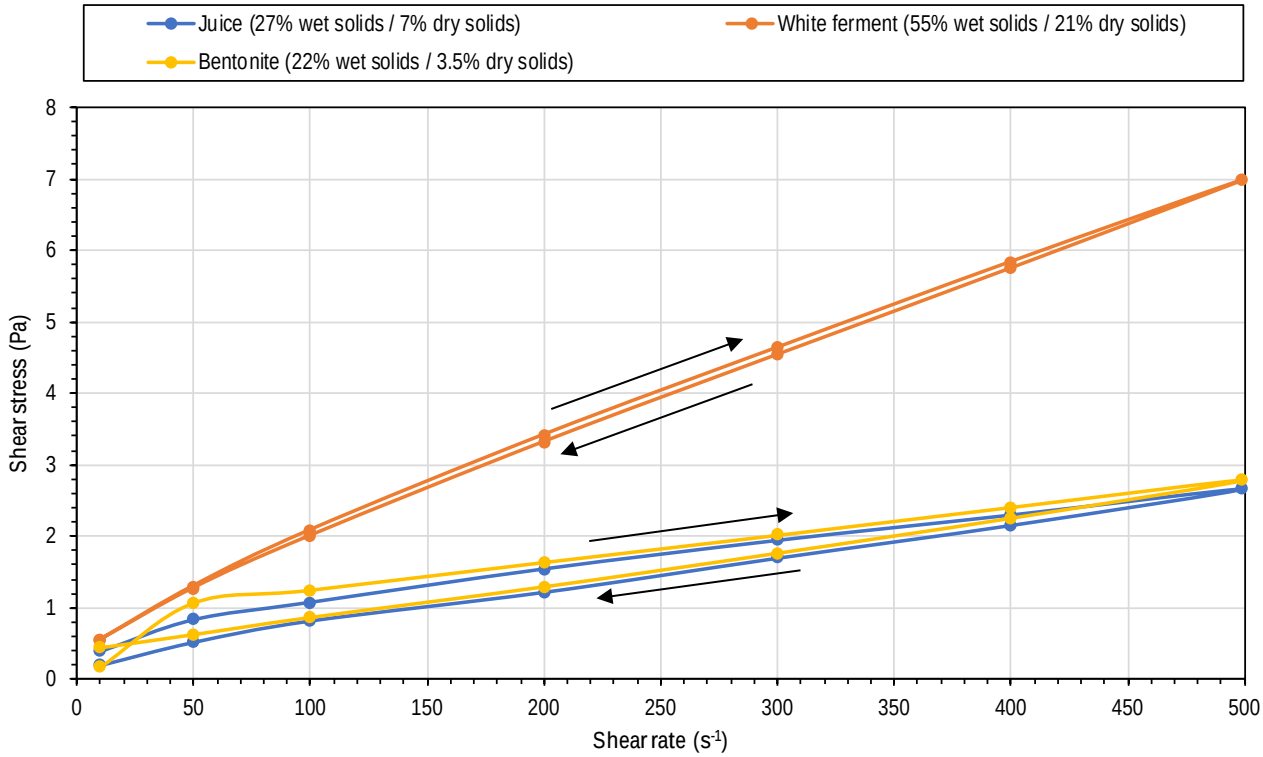


Figure 3.10: Rheology of representative settled winery lees

Table 3.1: Range of solids contents and rheological properties of winery lees samples

	Wet solids content (v/v)	Dry solids content (w/w)	Static yield stress (Pa)	Dynamic yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)
Juice (n=19)	7 – 76%	0.8 – 27%	< 0.5 – 17.5	0 – 12	2.7 – 6.3
White ferment (n=7)	39 – 67%	13 – 29%	< 0.5 – 2.2	0 – 1.5	8.2 – 37
Red ferment (n=13)	38 – 90%	12 – 29%	12 - 130	13 - 110	73 - 280
White/rose wine bentonite (n=2)	22 – 28%	3.5 – 10%	0.9 – 1.1	0.55 – 0.6	5.6 – 7.2

Table 3.2: Comparison of rheological results from the Haake VT550 viscometer and MARS III rheometer

			VT550		MARS III	
	Wet solids content (v/v)	Dry solids content (w/w)	Static yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)	Static yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)
Juice	27%	7.0%	< 0.5	5.8	0.18	7.8
White ferment	51%	15%	< 0.5	14	0.14	20
Red ferment	47%	16%	28	130	38	190

To probe whether white ferment lees may have properties more like the red ferment lees if different yeast types were used, lees from laboratory white ferments with seven different types of yeasts were analysed (Figure 3.11). Some laboratory-derived white ferment lees did exhibit higher apparent viscosities than observed in the samples collected from wineries. However, in all cases the yield stress was still very low. The highest dynamic yield stress observed was 4.5 Pa, which was lower than the lowest yield stress observed in red ferment lees samples collected at wineries.

The relative rheological properties of the red and white ferment lees are also demonstrated visually in Figure 3.12. The white ferment lees is obviously viscous, but it does flow as evidenced by the slow-moving strands running off the hand. In contrast, the red ferment lees holds together and only falls of the hand in blobs, consistent with its high yield stress. The different behaviour of the red and white ferment lees is also consistent with the different particle size distributions presented in Figure 3.7. There are larger particles apparently extracted or formed during red fermentation on grape skins that give the red ferment lees its enhanced structure.

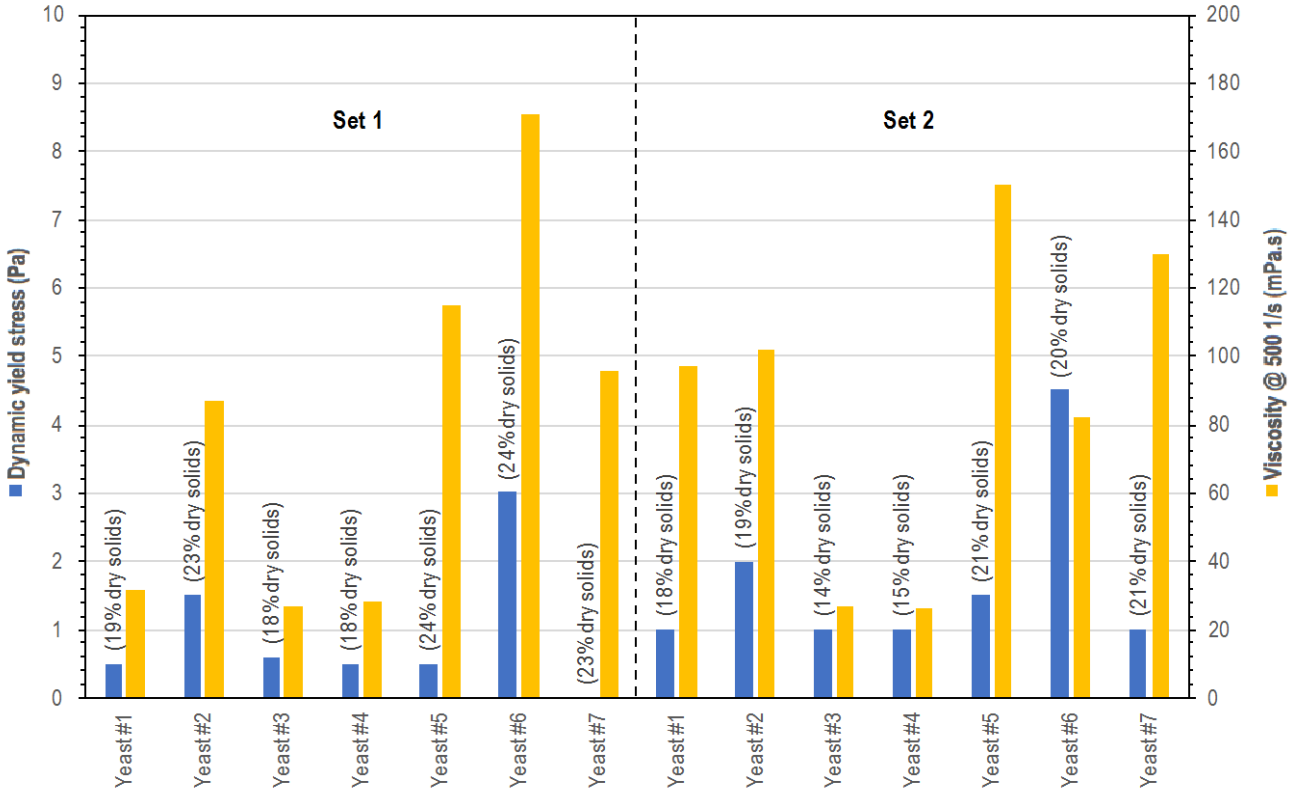


Figure 3.11: Dynamic yield stress and viscosity of laboratory settled white lees following fermentation with 7 different yeasts

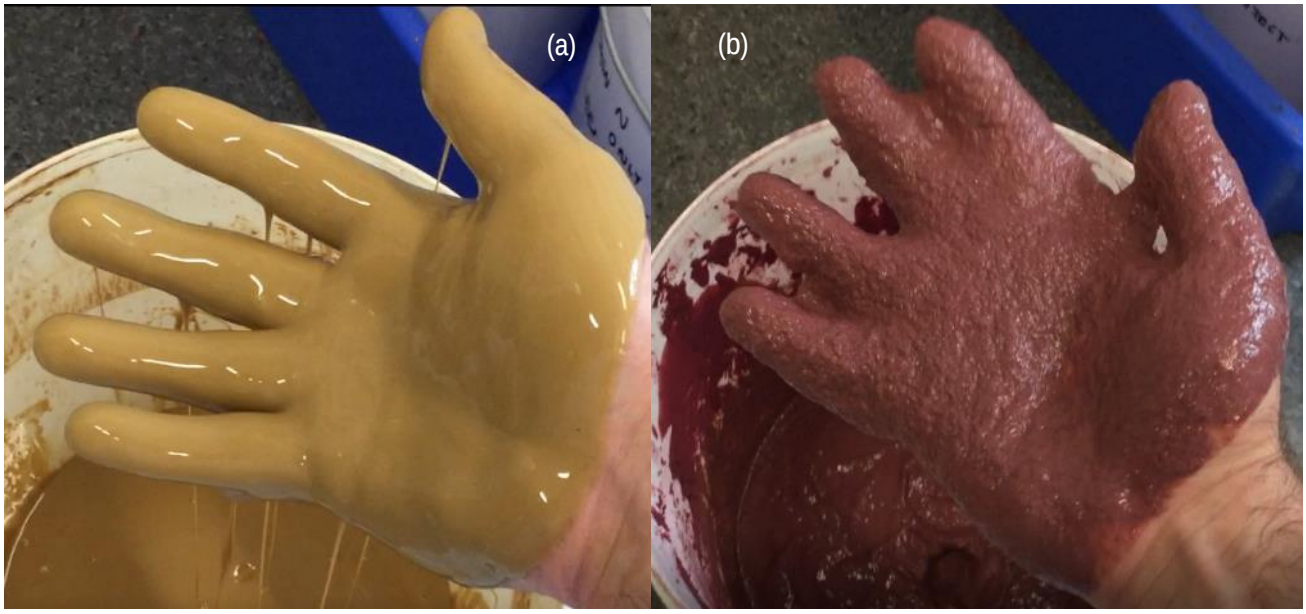


Figure 3.12: (a) white ferment lees, and (b) red ferment lees

Rheological results for settled juice lees from laboratory experiments are presented in Figure 3.13. Data were consistent with winery juice lees samples, with settled juice lees having low yield stresses and low apparent viscosities. Notably, the addition of a range of fining agents had little influence on the rheological properties of juice lees, partly because in most cases the juice particles themselves were the main contributor to the lees (although bentonite was a significant contributor to the lees volume when added).

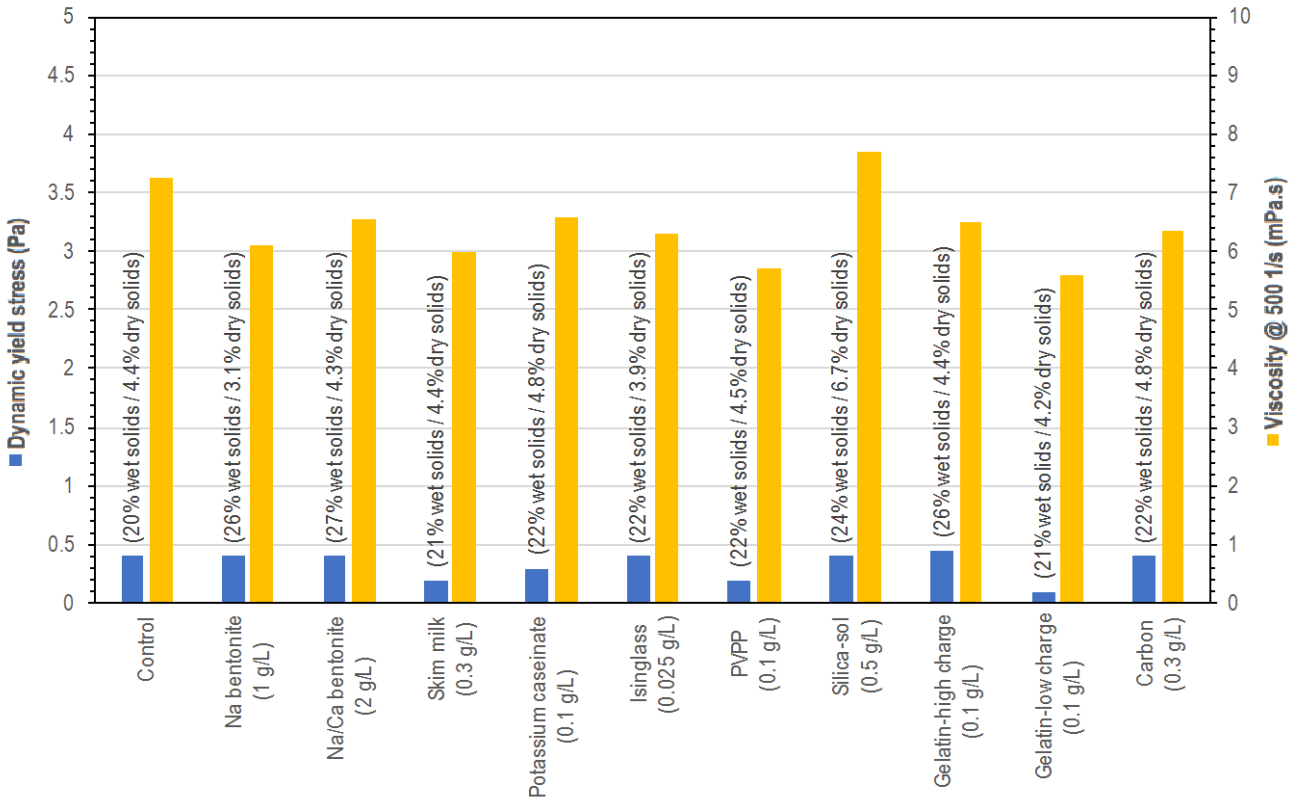


Figure 3.13: Dynamic yield stress and viscosity of laboratory settled juice lees after fining with various agents

Rheological properties of white wine after fining with agents at elevated doses to generate sufficient sample volume for analysis are presented in Figure 3.14. The yield stresses of all lees were quite low. The apparent viscosity varied between samples. PVPP and carbon had relatively high viscosities, but this was likely to be mainly related to their very high solids contents. Isinglass also produced relatively viscous lees despite having a lower solids content.

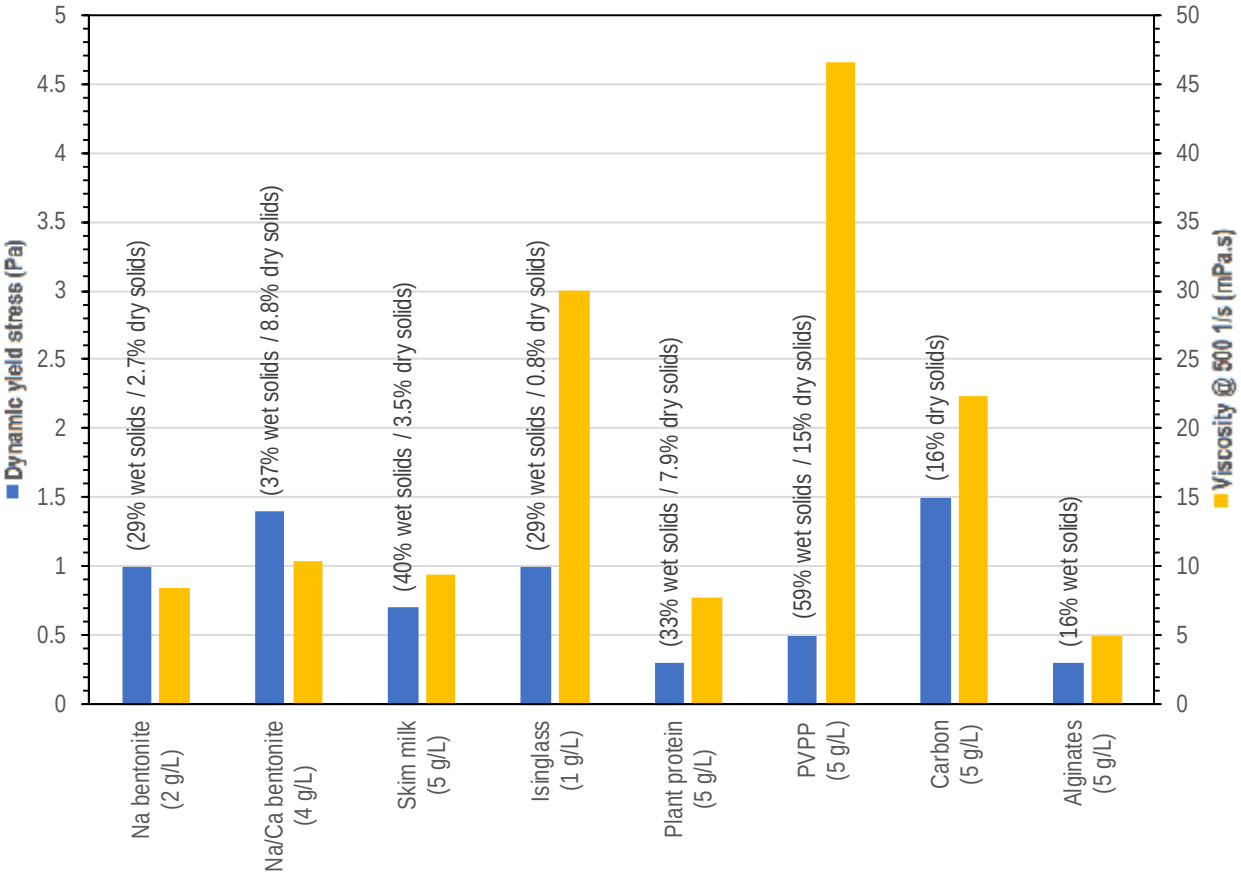
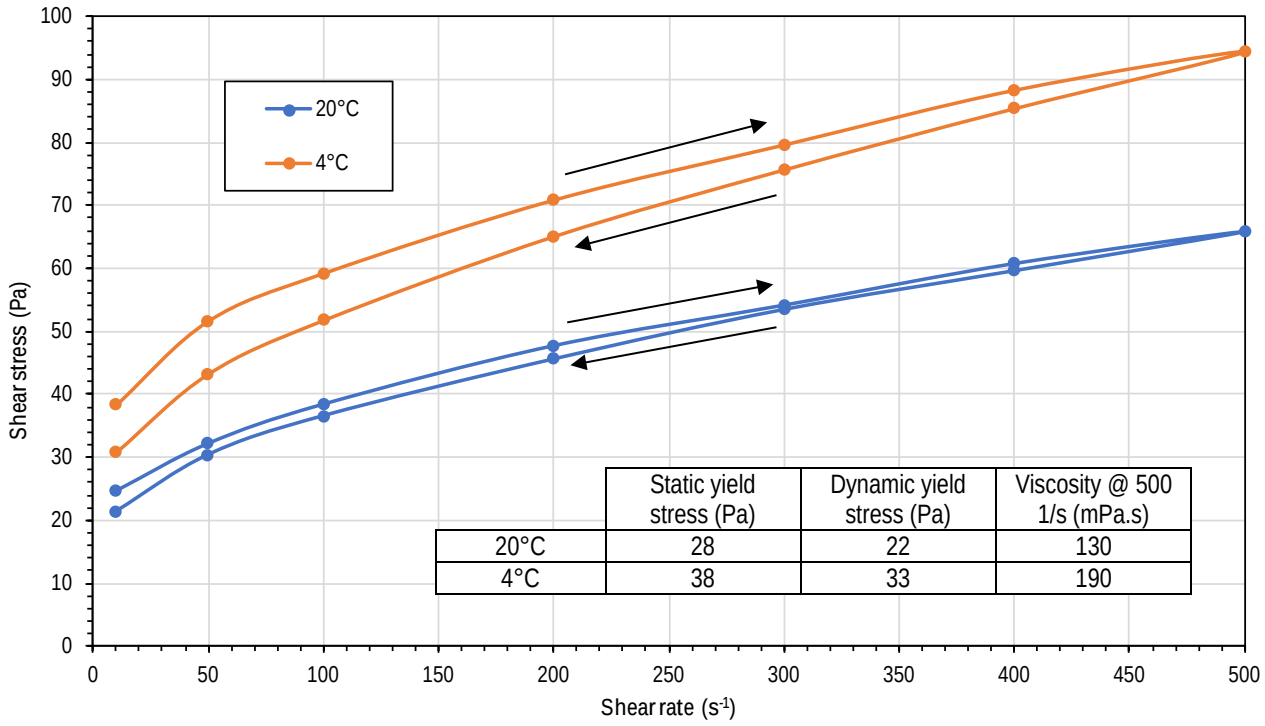


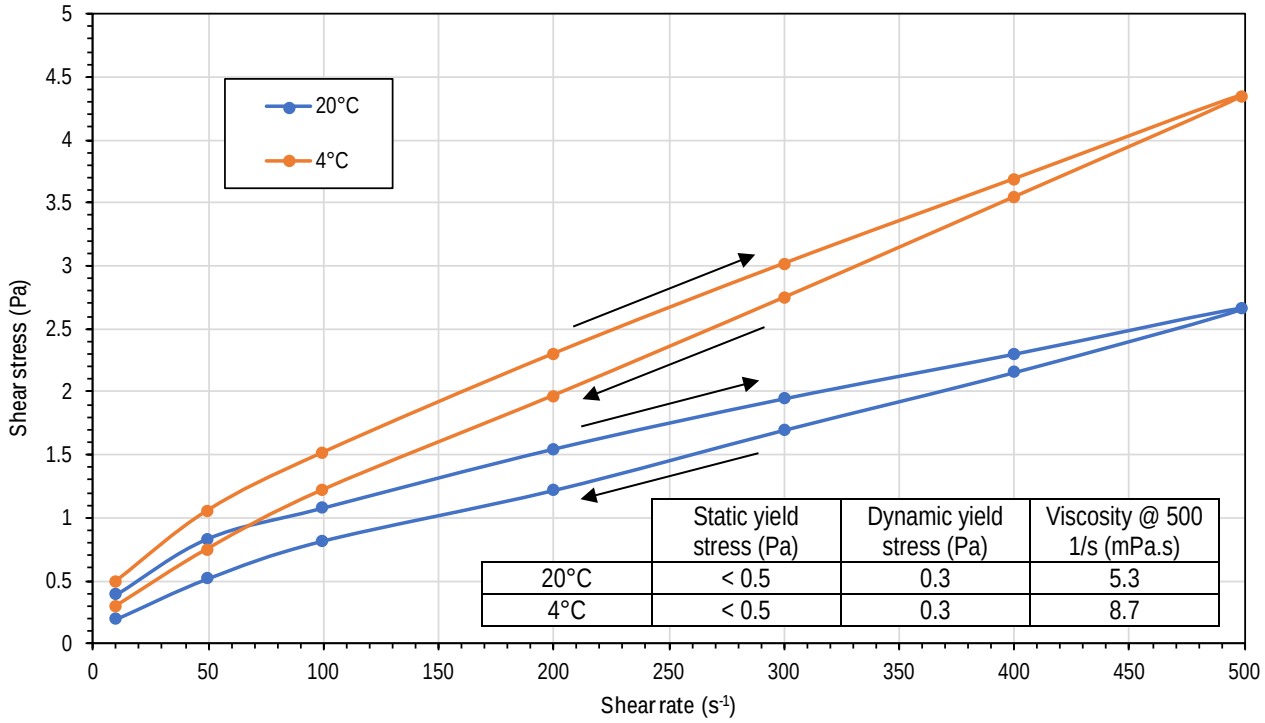
Figure 3.14: Dynamic yield stress and viscosity of laboratory settled white wine fining lees

The rheological behaviour of lees is also temperature dependent. Analyses reported so far have been at 20°C, but in Figures 3.13 and 3.14 the rheological behaviour of lees at 4°C is also included. At 4°C the yield stress in the red ferment lees samples was higher as was the apparent viscosity. Similarly, at 4°C the apparent viscosity of the juice lees samples was also higher than it was at 20°C.



	Static yield stress (Pa)	Dynamic yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)
20°C	28	22	130
4°C	38	33	190

Figure 3.13: Influence of temperature on the rheology of a red ferment lees sample (47% wet solids / 16% dry solids)



	Static yield stress (Pa)	Dynamic yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)
20°C	< 0.5	0.3	5.3
4°C	< 0.5	0.3	8.7

Figure 3.14: Influence of temperature on the rheology of a white juice lees sample (27% wet solids / 7% dry solids)

At Winery B, where most red ferment lees samples were collected, small oak chips were typically added during red ferments. In the settling tanks after draining and pressing, there was often a layer of oak chips (Figure 3.15a) present on the tank floor below the rest of the lees (Figure 3.15b). Yield stress measurements were performed on a sample of the oak chip-containing lees and of the lees above it in the same tank (Table 3.2). Not surprisingly the yield stress of the oak chip-containing lees was even higher than for the other red lees. These chips made it difficult for the cellar hands to remove the red ferment lees from the tanks after the clears had been racked.

It was an initially a surprise that oak chips could find their way through the draining and pressing process into the settling tank. At the winery, fermenters were drained via trommel rotary draining screens (Figure 3.16.) with the large solids going to continuous screw presses and the drained wine passing to the settling tank (via a buffer tank from which some wine was drawn to jet out fermenters). The slots in the rotary draining screens were approximately 2 mm wide. Wine from the continuous screw presses also went to the settling tank, via the same buffer tank after first passing through another style of rotary screen with slots approximately 1 mm wide. It is most likely that the oak chips in the settling tanks had passed through the 2 mm slots in the trommel rotary draining screens.

There is a small possibility that a very small particle size fraction of oak chips could even have been responsible for the high yield stresses in all the red ferment lees samples, even those without any visible oak chips, but it seems unlikely.

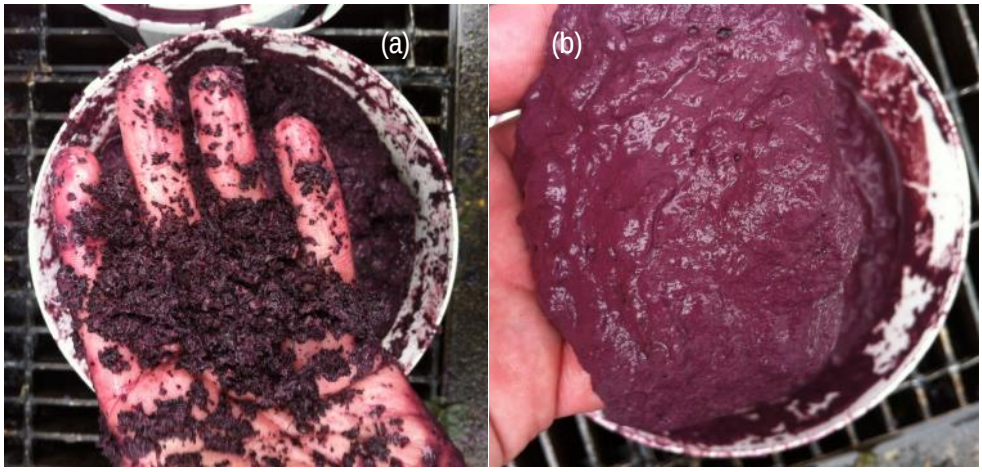


Figure 3.15: Samples from red ferment settling tank of (a) oak chips from tank floor, and (b) lees from above the oak chips

Table 3.3: Static yield stress of red ferment lees comprising oak chips or not

	Wet solids content (v/v)	Dry solids content (w/w)	Static yield stress (Pa)
Oak chips lees on tank floor	n.m.	33%	280
Lees above oak chips	60%	19%	60



Figure 3.16: Rotary trommel draining screen, (a) overview, and (b) close-up of screen showing the 2 x 40 mm drainage slots (behind the protective cage)

3.3. Section conclusions

1. Most winery lees samples analysed were quite thin and had relatively low yield stresses. The exception was red wine ferment lees, which had very high yield stresses. This was not solely dependent on their relative solids content, as white ferment lees with similar solids contents did not behave in this manner.
2. Winery lees samples generally exhibited some degree of shear thinning and thixotropic behavior.
3. Oak chips in red ferments that bleed through to settling tanks create processing difficulties and where this occurs, means to prevent their bleed through should be explored.
4. The low yield stresses observed with most winery lees samples (except red ferment lees) seemed promising (at that point in time) with regards to being able to remove the lees from underneath clears.

4. Removing lees from underneath juice/wine

4.1. Materials and methods

An experimental laboratory apparatus was designed and built to study the possibility of removing lees from underneath juice or wine in 2015 (Figure 4.1). This included transparent tanks with switchable lower sections. Tank configurations studied included cylindroconical tanks (brewery-style tanks with a 55° slope), and standard winery-style tanks (tanks with a 5° slope from back to the front) with and without modifications. The working section of tanks was designed to be geometrically similar to a 200,000 L tank based on several construction drawings supplied by collaborating wineries and inspection of tanks at wineries. Progressing cavity pumps with variable speed drives were used to remove lees from underneath clears at a controlled rate as measured by an electromagnetic flow meter. The most common flow rate used in experiments was 3.5 L/hr, which was calculated to be approximately dynamically equivalent (across the lees bed) to pumping lees at a rate of 20,000 L/hr from a 200,000 L tank.

Lees for use in experiments were sourced from collaborating wineries. These were preserved with up to 4 g/L of potassium metabisulfite to allow for long-term storage at ambient temperature. The main lees used in experiments were Riesling juice lees and a Chardonnay wine sodium bentonite lees. Both had been obtained by settling at the wineries. To recreate the lees under a clear phase in the laboratory, a portion of the lees was mixed with water and allowed to settle overnight. The settled lees were then pumped out at the designated rate to perform each experiment. To verify that this was a suitable practical method for studies of lees, Chardonnay wine was fined with 1 g/L sodium bentonite in one of the tanks and the resulting settled lees pumped out to see that it followed similar general behaviour to the mixtures of sodium bentonite lees and water.



Figure 4.1: Experimental apparatus for studying lees removal from underneath juice or wine

4.2. Results and discussion

Cylindroconical tanks with a 55° slope were reasonably successful in facilitating the removal of juice lees or wine bentonite lees out from underneath water (Figure 4.2). Around 95% of the juice lees could be pumped from the tank before the water broke through the lees. The results were not quite as good for the bentonite lees, but 80% of the lees was still able to be removed before the water broke through the lees.

Cylindroconical tanks are commonly used in breweries. However, we do not believe that they are a viable solution for wineries. Avoiding juice/wine movements and tank cleaning is generally of most benefit in larger complex wineries. Larger cylindroconical vessels are likely to be significantly more expensive than large simple wine storage tanks, since they require additional tank support structures to facilitate the steep cone. This additional expense is not such an issue for breweries that have a small number of tanks since a batch of beer only has a brewery lifetime before bottling of days or weeks. This contrasts with wine production, where enough tank/vessel volume to hold at least a whole year's worth of production is generally required (i.e. juice/wine from the whole vintage). Furthermore, the Australian wine industry has already been through its massive wine volume boom in the 1990s and 2000s, during which time many large tanks of simple design were installed, so there is likely to be little appetite for installing a lot of new tanks.

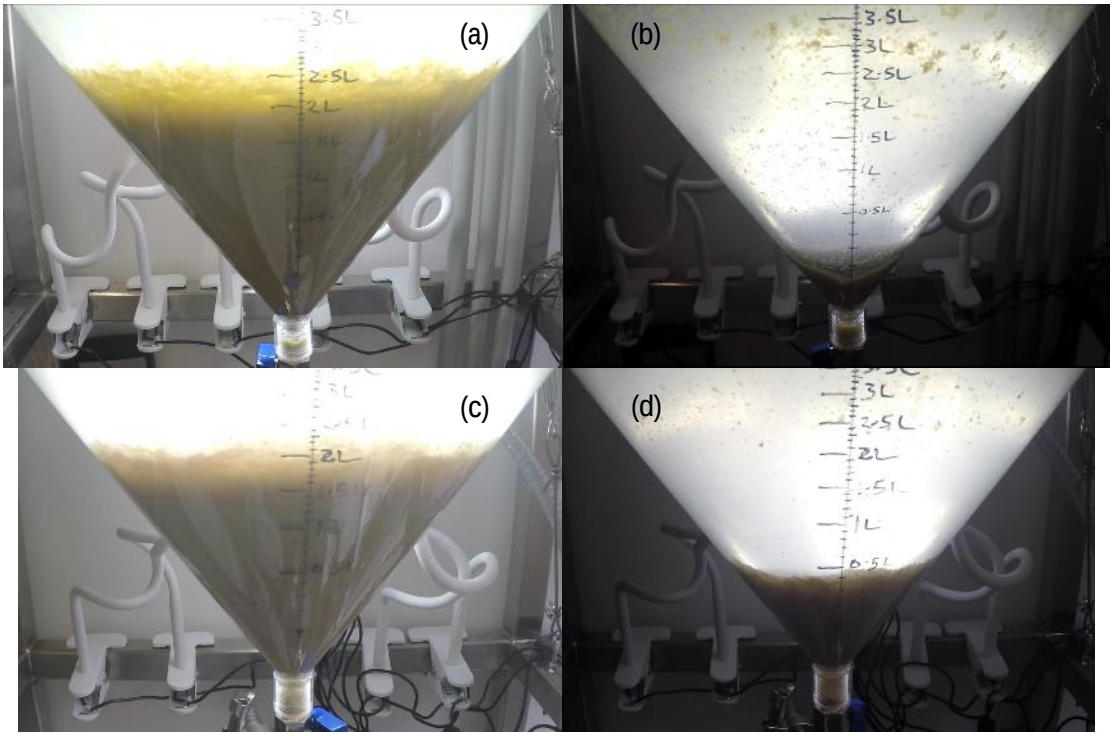


Figure 4.2: 55° sloped conical bottomed tank pumping out lees at 3.5 L/hr from underneath water - juice lees (a) initially, and at (b) water breakthrough, and sodium bentonite lees (c) initially, and at (d) water breakthrough (watch video on YouTube: https://www.youtube.com/watch?v=GG4YXSFOT5Q)

Figure 4.3 presents results from similar experiments, with a 5° sloped winery-style tank. As soon as the pump was turned on, a hole was immediately sucked in the lees and water ran through. Despite bentonite and juice lees being shown in Section 3 to have much lower yield stresses than the red ferment lees, the yield stress was still high enough to prevent the lees flowing. Similar behaviour was seen at lower flow rates (Figure 4.4) and with real wine fined with bentonite (Figure 4.5) as opposed to mixtures prepared from winery lees and water. With large lees beds (Figure 4.6) the water did not break through straight away, but still did so with much of the lees remaining in the tank.

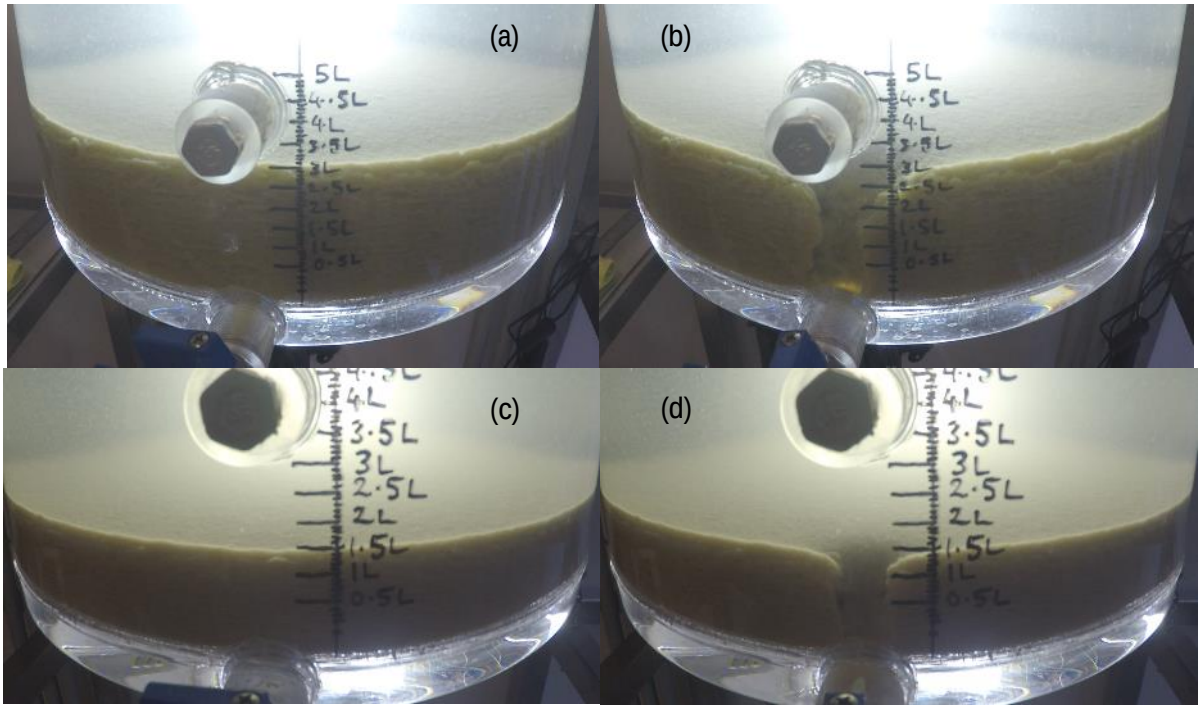


Figure 4.3: 5° sloped winery tank pumping out lees at 3.5 L/hr from underneath water, juice lees (a) initially, and at (b) water breakthrough, and bentonite lees (c) initially, and at (d) water breakthrough (watch video on YouTube: https://www.youtube.com/watch?v=fjDC6C7xCgE)

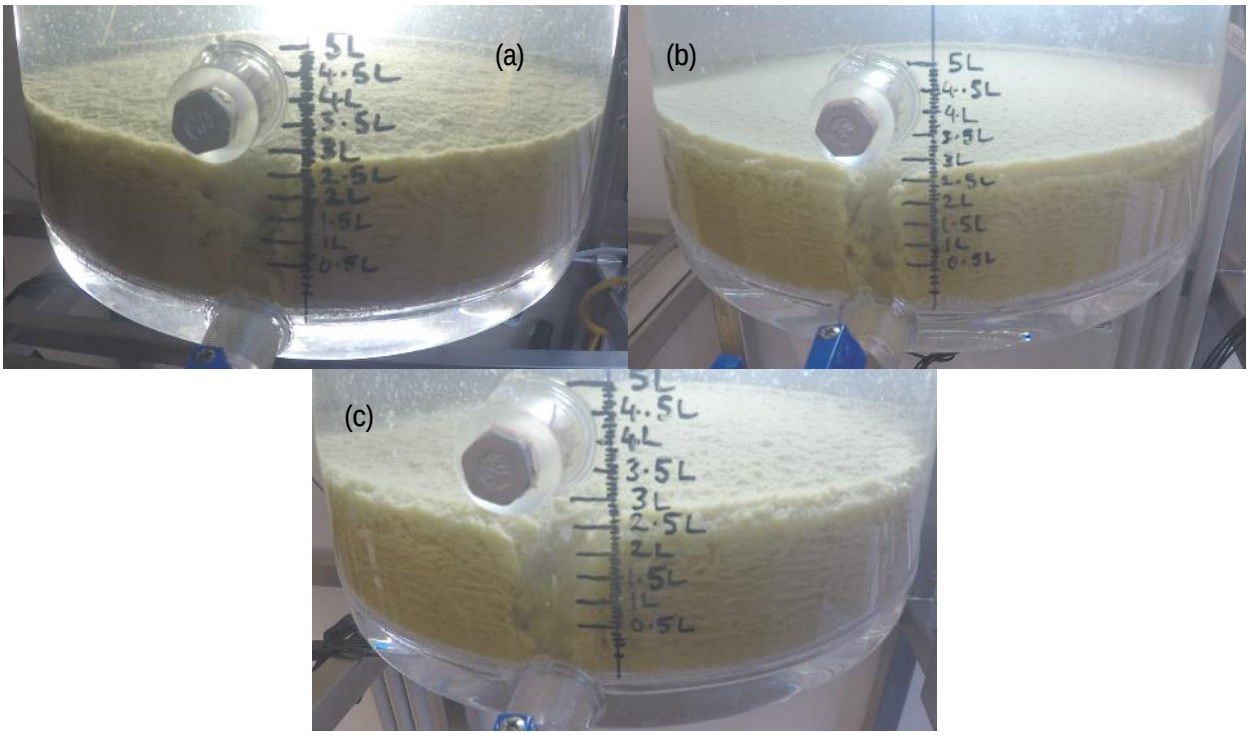


Figure 4.4: Juice lees at water breakthrough, with pump flow rates of (a) 0.7 L/hr, (b) 1.7 L/hr, and (c) 3.5 L/hr

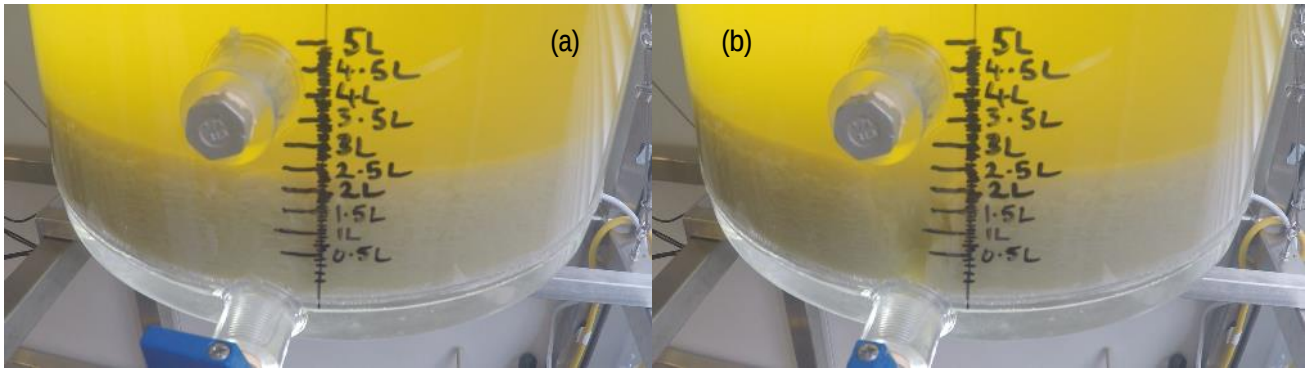
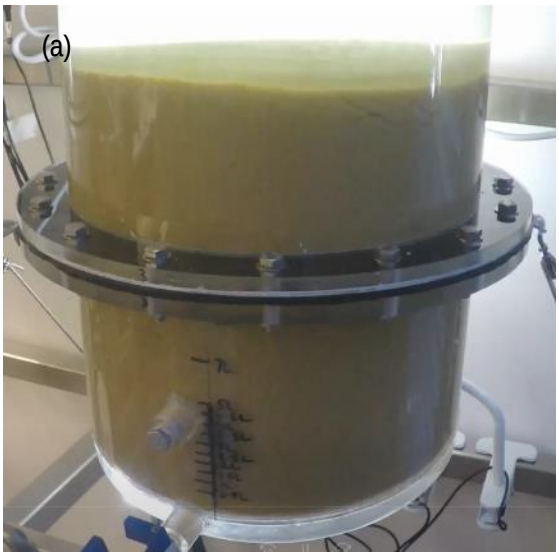


Figure 4.5: Wine fined with 1 g/L of sodium bentonite and settled lees being pumped out at 3.5 L/hr, (a) initially, and (b) at wine breakthrough



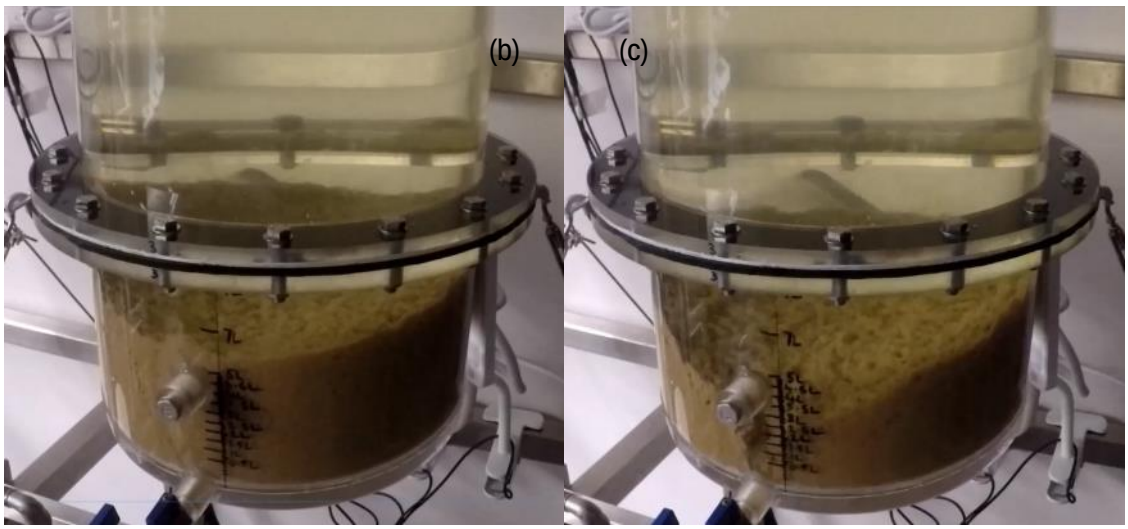


Figure 4.6: Large bed of juice lees being pumped out at 3.5 L/hr from underneath water (a) Initially, (b) part-way through, and (c) at water breakthrough (watch video on YouTube: https://www.youtube.com/watch?v=FXw-mNSMqSI)

To counteract the breakthrough effect with winery-style tanks (which was always expected to some extent, but not quite as definitively and instantly as it occurred), several strategies were trialled. Firstly, a baffle was fitted above the bottom valve sump to try to prevent the water channelling along the tank wall through the lees (Figure 4.7). This just moved the location of breakthrough, without materially improving lees removal.

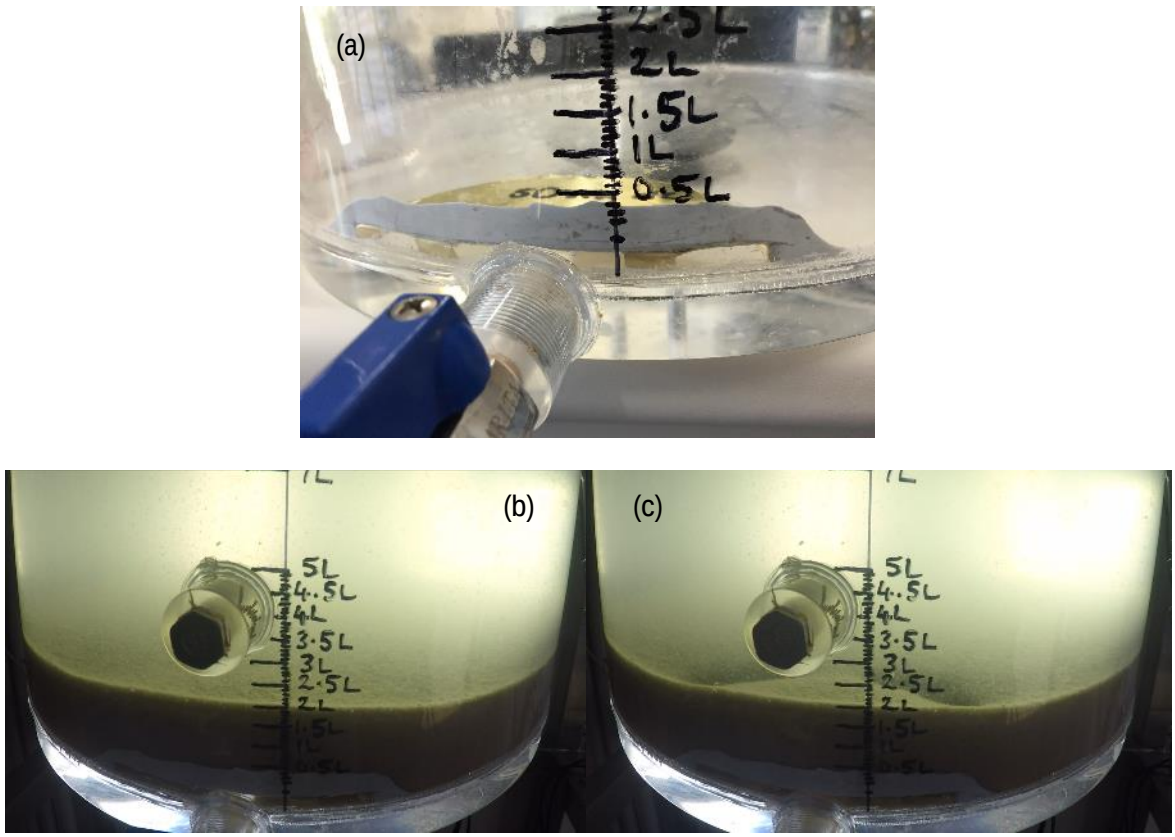


Figure 4.7: Bentonite lees being pumped out at 3.5 L/hr with a baffle above the sump, (a) Baffle in empty tank, (b) before beginning to pump, and (c) at water breakthrough (watch video on YouTube: https://www.youtube.com/watch?v=o7L7XMBGwiY)

The next modification trialled was to use a suction foot that would remove the lees via a hose and could be moved around the tank (Figure 4.8). Magnets were placed on the bottom of the suction foot and corresponding magnets were placed on the underside of the tank so that the suction foot could be moved. This arrangement was able to remove much of the lees provided the suction foot was moved to exactly where the lees still were. As soon as the lees were exhausted in a specific location, the water would breakthrough until the suction foot was moved back into the lees. Automated movement around the floor is a major issue for any lees removal device of this general style. The general concept of the suction foot is similar to a suction side pool cleaner like the 'Kreepy Krauly' (Figure 4.9). There is a flapper valve in that device that diverts flow between two passages. As the flow is halted each time, the kinetic energy of the suction flow is transferred to the device causing it to move. Floats, weights, and other fittings help steer the device so it eventually covers the entire wall of the pool. This slow, somewhat random motion would not be suitable for winery lees because it would eventually go back over areas where the lees has already been removed, and pump clears. The inclusion of a device like this inside a winery tank is also not very hygienic. Generally, the most hygienic arrangement will be one where the lees are removed through the normal bottom valve of the tank.

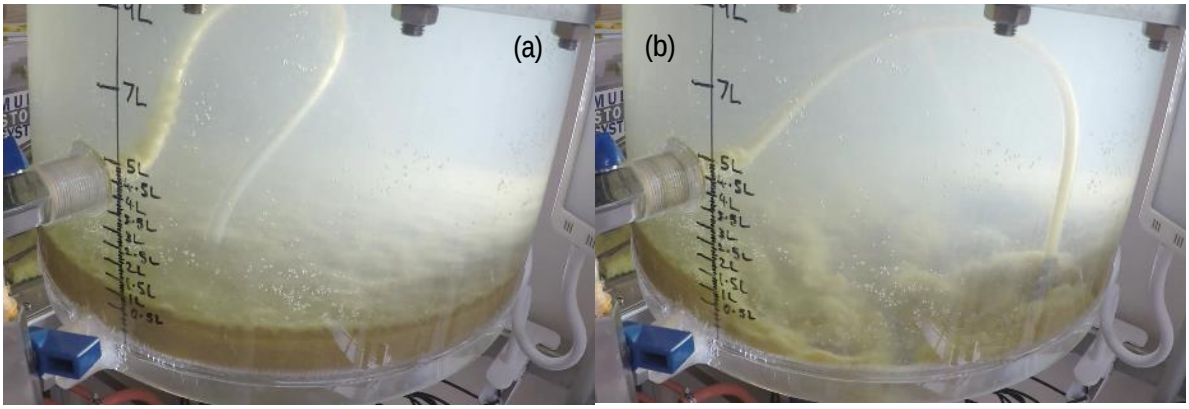


Figure 4.8: Juice lees being pumped out at 3.5 L/hr using a moving suction foot (a) Before beginning to pump, and (b) during pumping (watch video on YouTube: https://www.youtube.com/watch?v=3XjhfObElgg)

Flapper valve (16) diverts flow intermittently between two passages (40). As flow is halted each time, the kinetic energy of the suction flow is transferred to the device, causing it to move.

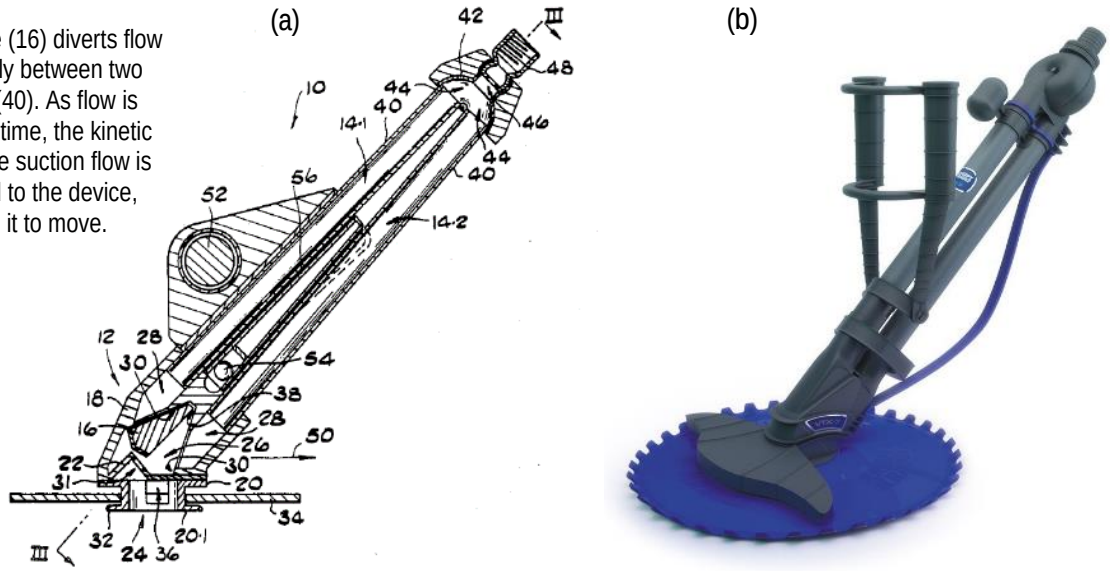


Figure 4.9: Kreepy Krauly suction-side pool cleaner, (a) diagram from patent US4023227, and (b) modern version

The next modification trialled to avoid clears breakthrough in the winery-style tank was the installation of a large sweeping arm in the bottom of the tank (Figure 4.10). A motor with a sweeping arm was fitted on the outside of the tank and this turned a matching free sweeping arm inside the tank my means of magnets on both arms. Experiments were initially performed with the arm moving at 0.6 rpm. This showed some promise. Clears would begin to breakthrough the lees, but then as the arm came around it would close the hole and reform the lees. Experiments were then performed at 2 rpm. This speed was high enough such that the hole would never form. The lees held together and as the sweeping arm moved around the tank there was a noticeable wave in the lees. It was only as the lees level decreased to the point where the sweeping arm started to break the lees surface that lees began to be resuspended. A sweeping arm like this is again not really a viable solution for wineries because it would involve a major retrofit to every tank.

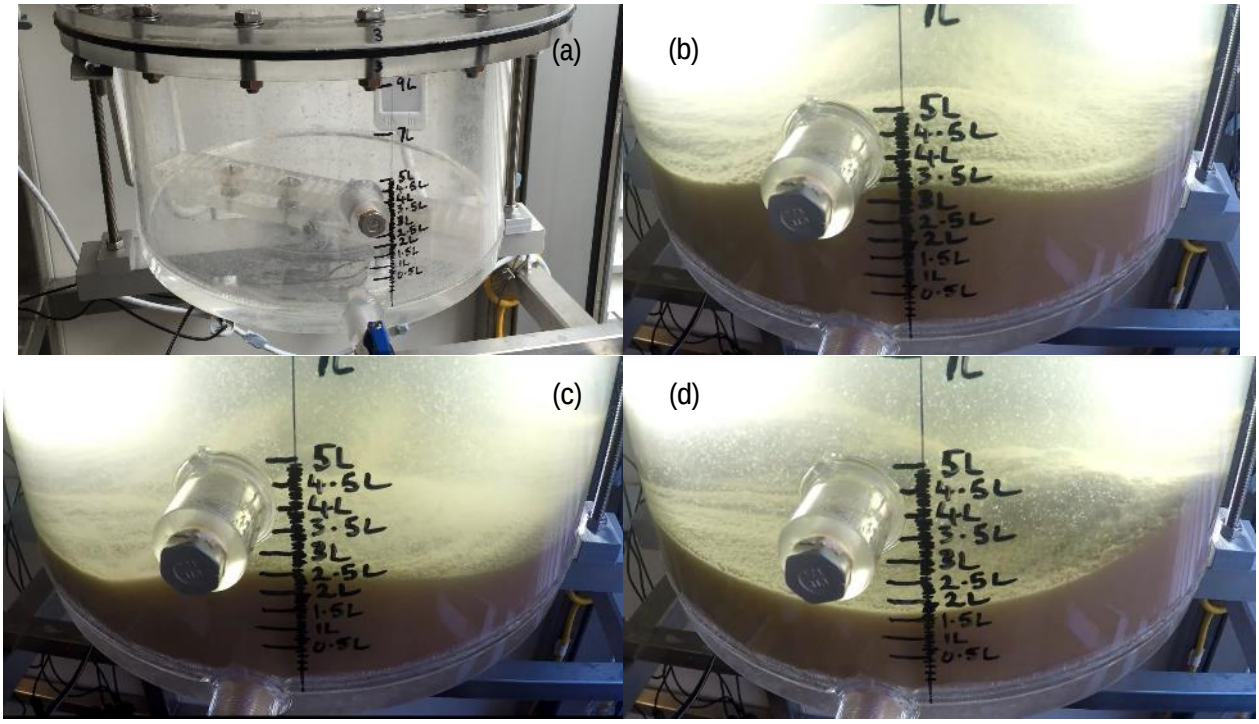


Figure 4.10: Pumping sodium bentonite lees from underneath water with a sweeping arm on the floor moving at 2 rpm at 3.5 L/hr, (a) empty tank, and (b), (c) and (d) during pumping (watch video on YouTube: https://www.youtube.com/watch?v=TUckCGQsSbI)

To try and replicate the underneath lees agitation effect, an experiment was also performed where lees were drawn from the tank at one side and reintroduced at the other side tangential to the wall (Figure 4.11). This was unsuccessful. It resulted in some resuspension of lees and it did not keep the lees moving enough to prevent breakthrough of the clears. It may have been more successful in creating the swirling effect if there were many inlet points, but even still, there would always be a point where as the lees dropped below a certain point, the swirl would start to resuspend the lees at the rear of the tank. It would also require some form of complex manifold to be installed on tanks and the agitation of the lees at the perimeter of the tank would likely not have been transmitted sufficiently to the centre of the tank floor to keep all the lees moving.

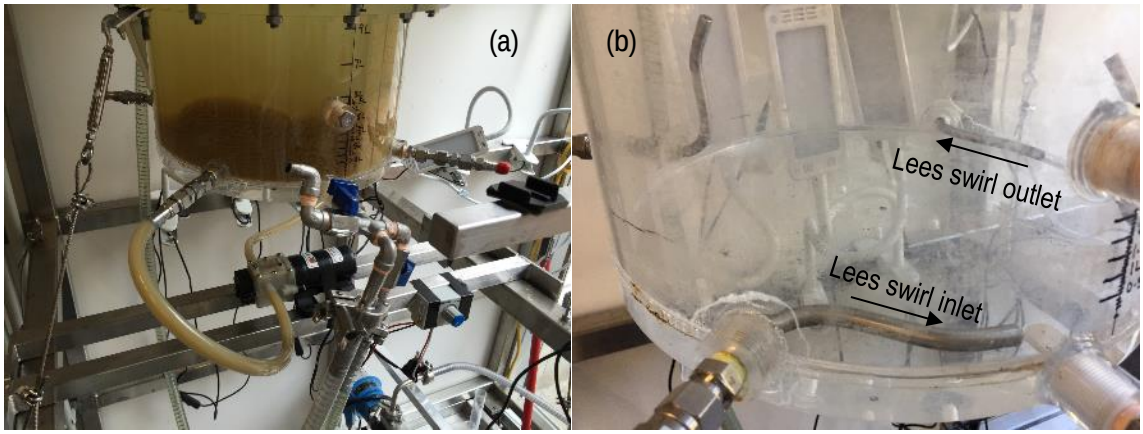


Figure 4.11: Attempted tangential swirling of juice lees while pumping out from bottom valve at 3.5 L/hr, (a) while operating, and (b) empty tank showing location of tangential inlet and outlet

Really the most desirable solution is to try to keep the lees moving using an arrangement that involves introducing a simple, cheap object into a tank that is then made to move around by a more complex external device that can be easily moved between tanks. As a step towards this and to further understand underneath agitation of lees, it was planned to build a chain of electromagnets that would wrap around one of the laboratory tanks and connect this to some form of a control system that could turn the different electromagnets on and off in any pattern designed. For example, a ball-bearing, could be made to move around the perimeter of the tank with the electromagnets, either continuously in one direction or alternating in direction (stopping before the rear of the tank each time as the lees level drops to try to avoid resuspension of the lees). Electromagnets available at reasonable prices were considered but were found to not have sufficient pulling power at the distance that they would require to be able to pass a ball-bearing between them. Furthermore, this arrangement may not have worked anyway, as similarly to pump-induced swirling arrangements, the agitation of the lees at the perimeter of the tank may not have been transmitted to the centre of the tank floor.

With no real way forward that was likely to allow for lees removal by relatively simple tank modifications, the experiments were ended and it was not deemed worthwhile to develop a winery prototype. The experimental apparatus is still intact and if a new idea was developed it could be revisited, but at this stage the chances of success are low.

4.3. Section conclusions

1. Some success was achieved in removing lees from underneath clears using brewery-style cylindroconical tanks with a 55° slope, but this is not a viable solution for large wineries since it would require the purchase of expensive new tanks.
2. Using normal winery-style tanks with a 5° slope from back to front, the clears broke through the lees almost immediately.
3. Some limited success was experienced in removing lees from underneath clears when the lees were agitated underneath the surface by a sweeping arm, but efforts to recreate this using other less capital-intensive techniques were not successful.
4. Overall, laboratory trials were not sufficiently successful to justify development of a winery prototype device or tank modification.

5. Conclusions & recommendations

(Recommendations are provided in italics)

1. Grape solids are the largest source of lees in wineries. In white wine production, these are removed prior to fermentation, while in red wine production they are removed after fermentation in combination with yeast.

    - *More work could be performed on the optimisation of draining and pressing processes to minimise grape-derived-lees. This could include the evaluation of press alternatives like decanter centrifuges that may avoid juice lees generation altogether.*

2. Bentonite is the other major source of lees in white wine production.

    - *Alternatives to bentonite for heat stabilisation should continue to be sought.*

3. Flotation appears to be a means of achieving low juice lees volumes compared with settling, with less capital investment than required for centrifugation.

    - *Flotation should be considered as an option for juice clarification by medium and large wineries currently using settling and further studies should be performed to optimise flotation processes.*

4. Most winery lees were quite thin and had low yield stresses. The exception was red wine ferment lees, which had high yield stresses. This was not solely dependent on their solids content as white ferment lees samples of similar solids contents did not behave in the same manner.

5. Winery lees samples generally exhibited some degree of shear thinning and thixotropic behavior.

6. Oak chips in red ferments that bleed through to settling tanks appear to be a processing challenge.

    - *For wineries experiencing oak chips bleeding through draining and pressing processes it may be worth considering using slightly larger oak chips that won't bleed through or tighter screens that may retain the oak chips.*
    - *Research could be performed on alternatives to oak chips for colour stabilisation during fermentation.*

7. Some success was achieved in removing lees from underneath clears using brewery-style cylindroconical tanks with a 55° slope.

8. With normal winery-style tanks with a 5° slope from back to front, clears broke through the lees almost immediately.

9. Some limited success was achieving in removing lees from underneath clears when the lees were agitated underneath the surface by a sweeping arm, but efforts to recreate this using other less capital intensive techniques were not successful.

10. Overall, laboratory trials were not sufficiently successful to justify development of a winery prototype or winery scale trials of underneath removal of lees.

- *Removal of lees from underneath clears is not worth pursuing further for now.*
- *The ideal solution would involve some means of trying to keep the lees moving without breaking the lees-clears interface. It would involve a simple, cheap object that can be added to a tank and that is made to move around by an external device that can be easily moved between tanks as required.*

11. A workshop on lees was convened at the 16th Australian Wine Industry Technical Conference. This included presentations from wineries on their experiences with new lees reprocessing equipment. Several discussions were also held with wineries on the use of new lees reprocessing equipment during the project. A question raised by one wine company that had trialled a range of lees reprocessing equipment was how much of the downgrading that occurs with some lees reprocessing technologies is just a consequence of the juice/wine being occluded in different types of lees as opposed to the technology used to recover it from the lees.

    - *Further research to understand lees-occluded juice/wine interactions could be worthwhile.*

6. References

Chauvier, F.L.O.J. (1976) Apparatus for cleaning submerged surfaces. US patent 4,023,227.

Nguyen, Q.D., Boger, D.V. (1983) Yield Stress Measurement for Concentrated Suspensions. J. Rheol. 27(4): 321-349.

7. Appendix A - Communication

7.1. Winery Engineering Association Conference 2014

A presentation entitled “Lees: reverse racking, rheology and recovery” was given to the Winery Engineering Association Conference on 18 June 2014 at the Serafino winery McLaren Vale. The slides are provided below.

WineEng 2014

The Australian Wine Research Institute

Lees: Reverse Racking, Rheology and Recovery



Simon Nordestgaard
The Australian Wine Research Institute

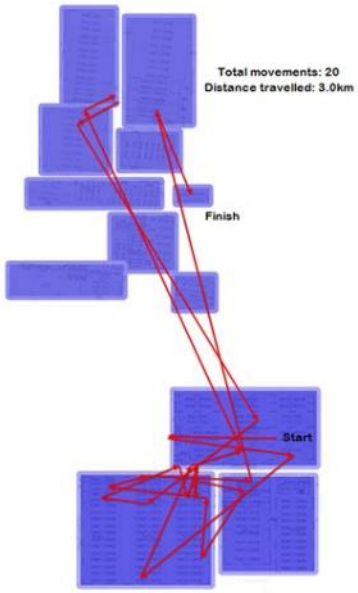
Outline

The Australian Wine Research Institute

- Background – the problem with wine movements
- Reverse racking – a different approach to lees removal
- Rheology – the science of material (e.g. lees) flow
- Recovery – new(ish) technologies for lees processing

Wine movements

The Australian Wine Research Institute



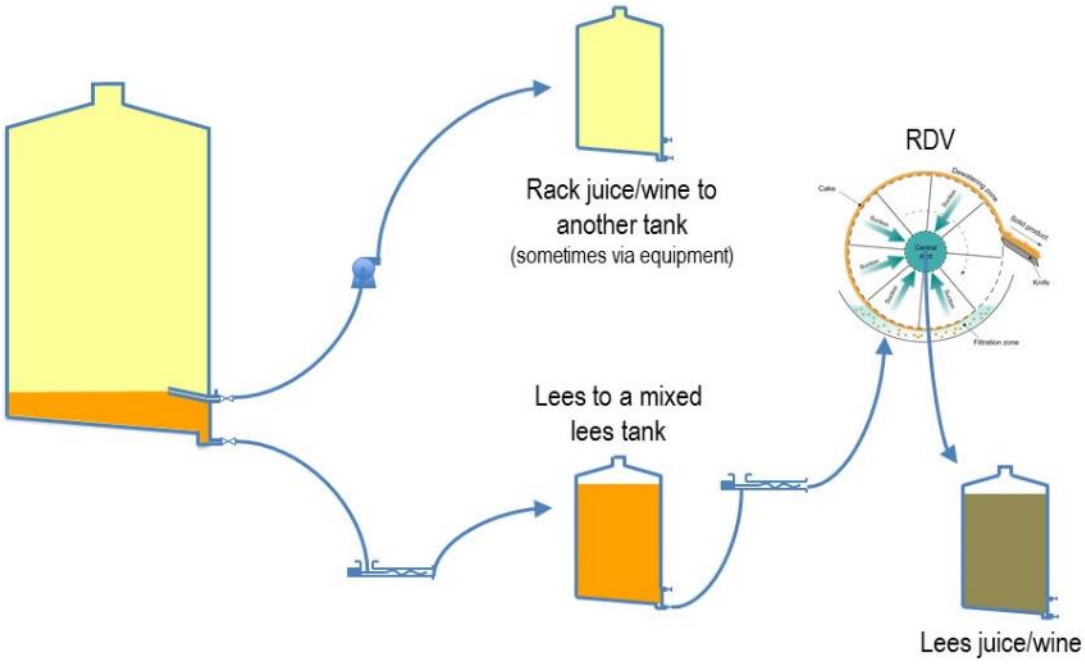
Problems with wine movements

- Labour (setup, pushes, tank cleaning)
- Water use / wastewater production
- Tank availability

- Interested in practices and technologies that allow wine to remain in the same tank, while still achieving the same processing outcome

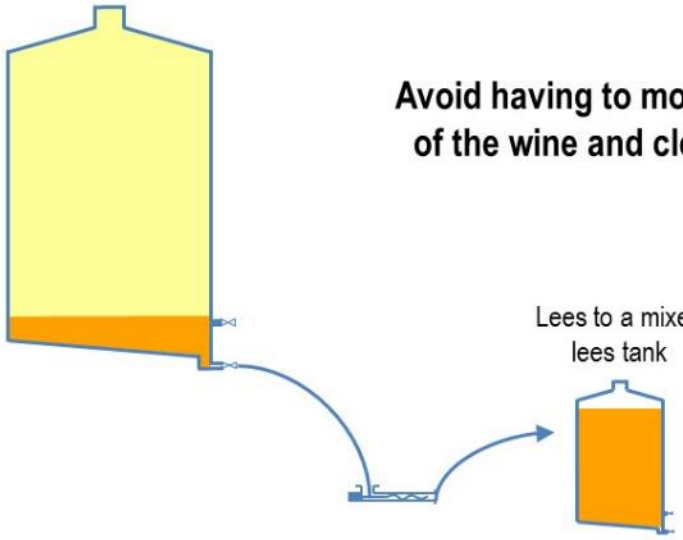
Normal racking

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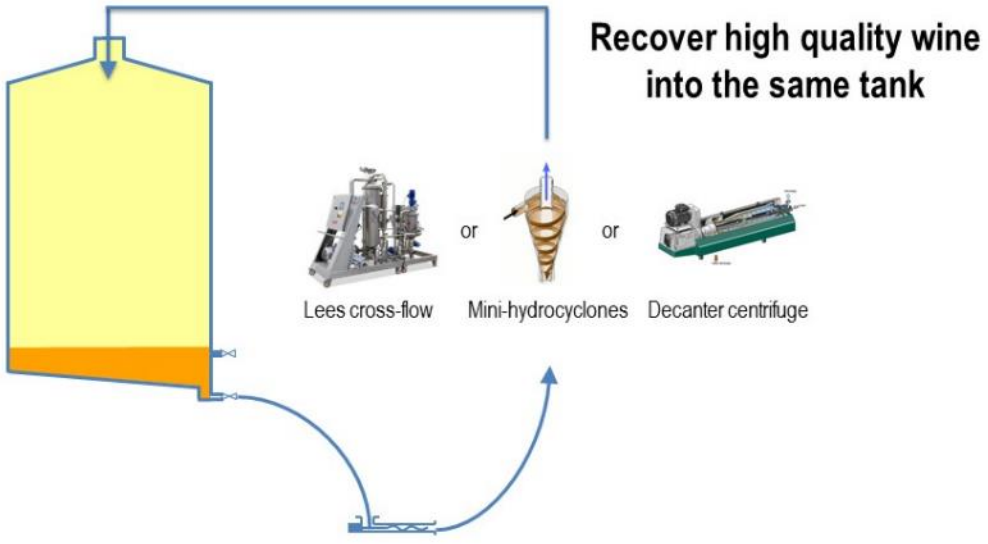
Reverse racking

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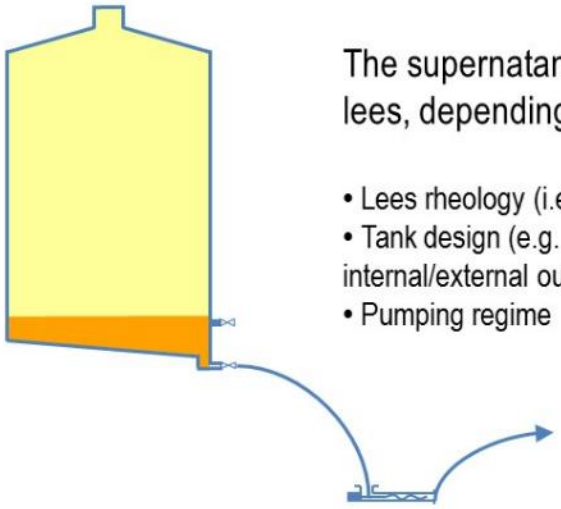
Reverse racking

The Australian Wine Research Institute



Reverse racking - challenges

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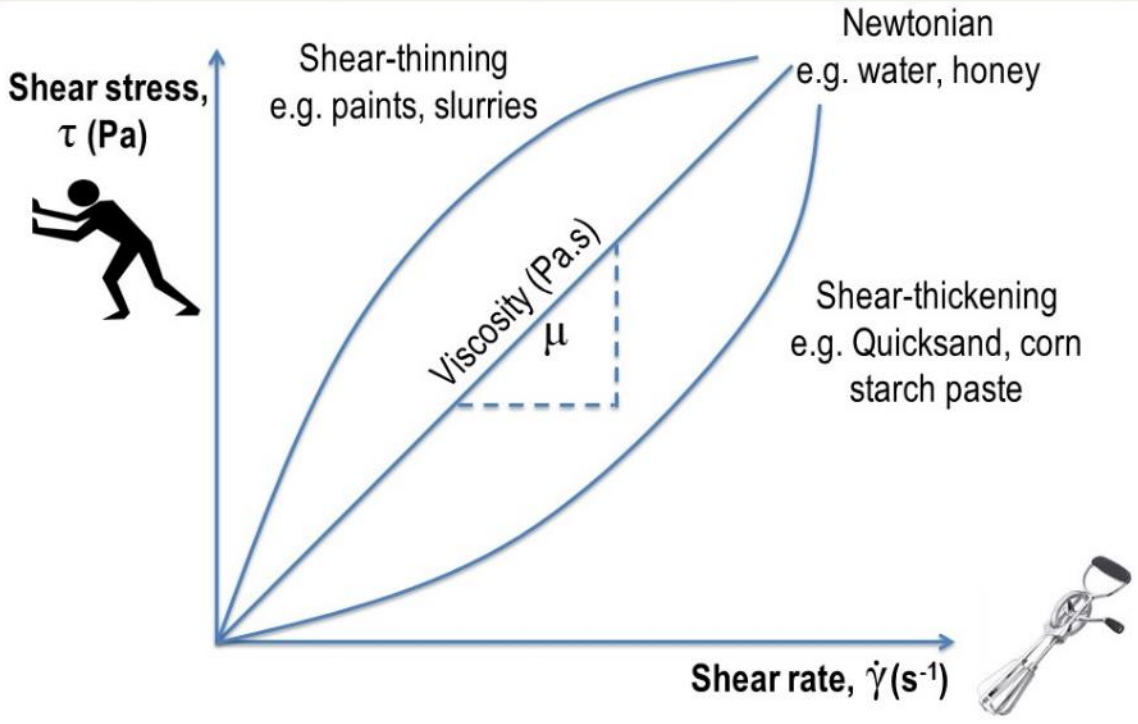


The supernatant can channel through the lees, depending on:

- Lees rheology (i.e. flow characteristics)
- Tank design (e.g. floor angle), surface finish, and internal/external outlet sump/pipe work
- Pumping regime

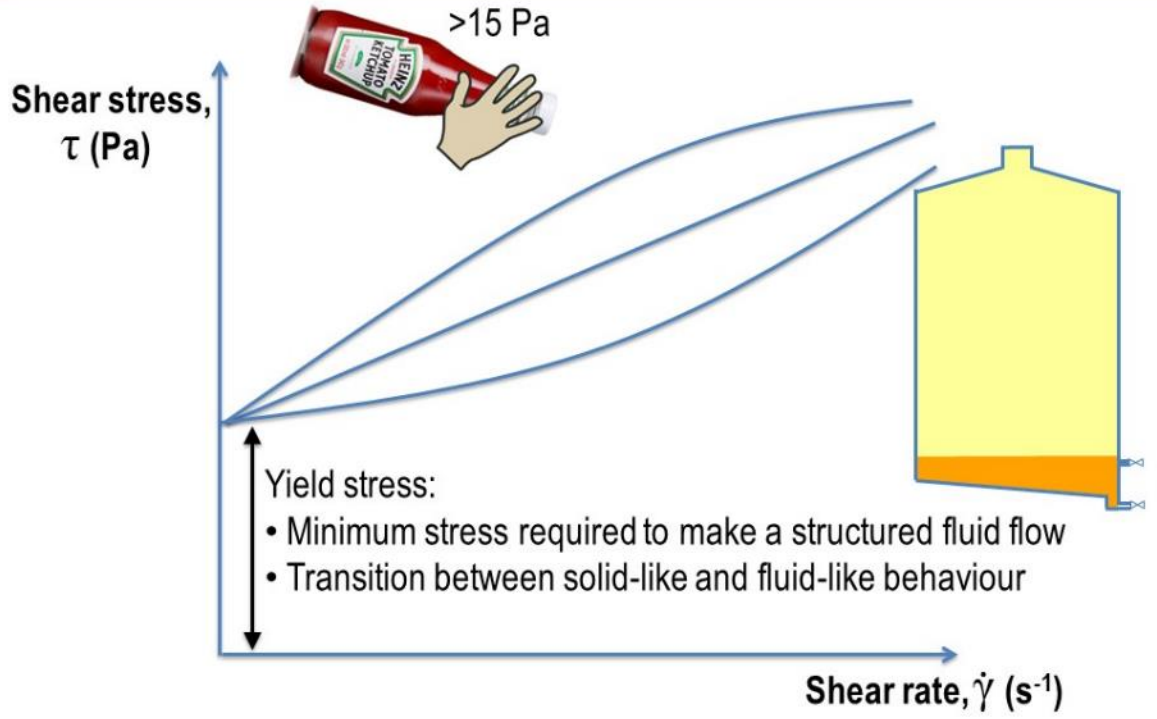
Rheology basics (*rheo*: to flow)

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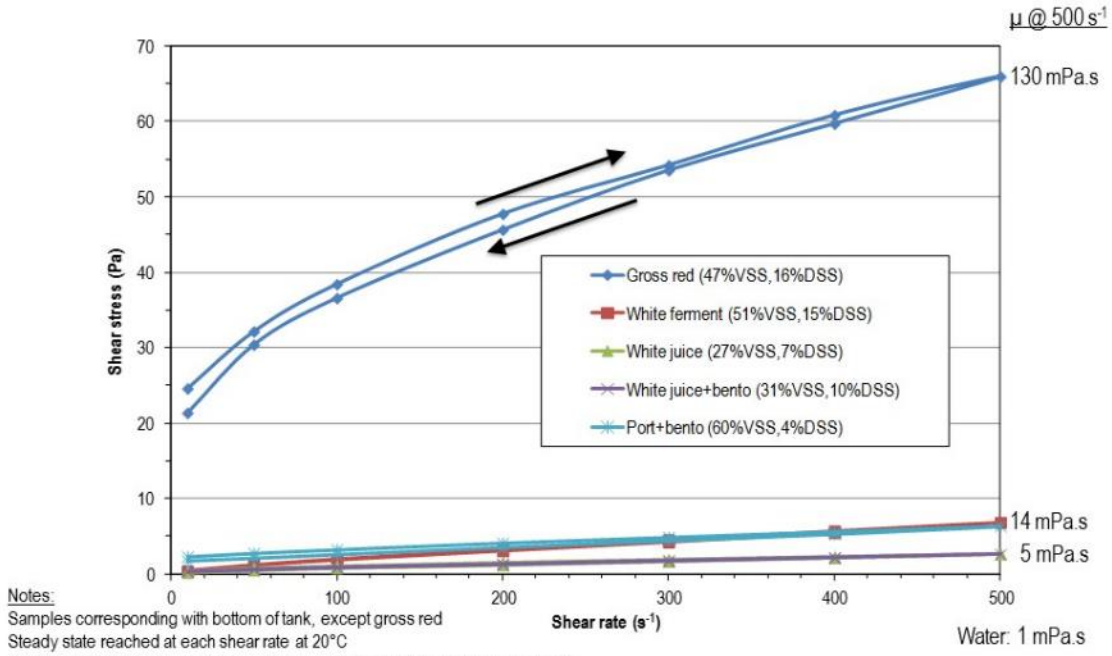
Rheology basics – yield stress

The Australian Wine Research Institute



Rheology – lees samples

The Australian Wine Research Institute



Notes:
Samples corresponding with bottom of tank, except gross red
Steady state reached at each shear rate at 20°C
Have only analysed one white ferment lees sample so far, getting more samples
Volume suspended solids (VSS): 3,000 x g, 5 minutes
Dry suspended solids (DSS): 70 °C, 24 hours (corrected for soluble solids using 0.2μm filtered control)

Rheology – lees samples

The Australian Wine Research Institute

Lees type	Yield stress (Pa)	App. viscosity @ 500s^{-1} (mPa.s)	VSS (v/v)	DSS (w/w)
Gross red	28	130	47%	16%
White ferment	<0.5	14	51%	15%
White juice	<0.5	6	27%	7%
White juice with bentonite	<0.5	5	31%	10%
Port with bentonite	3	13	60%	4%





Notes:
Samples corresponding at bottom of tank, except gross red
Have only analysed one white ferment lees sample so far, getting more samples
Rheological analysis at 20°C
Volume suspended solids (VSS): 3,000 x g, 5 minutes
Dry suspended solids (DSS): 70 °C, 24 hours (corrected for soluble solids using 0.2µm filtered control)

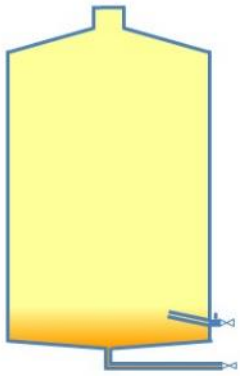
Temperature effects on rheology

The Australian Wine Research Institute

Lees type	Yield stress (Pa)		App. viscosity @ 500s^{-1} (mPa.s)	
	20°C	4°C	20°C	4°C
Gross red	28	38	130	190
White juice	<0.5	<0.5	6	9

Settled white juice – example of gradients

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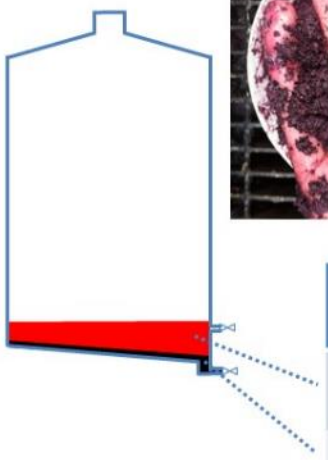


Height (m)	VSS (v/v)	DSS (w/w)	App. viscosity @ 500s^{-1} (mPa.s)	$d_{0.5}$ (µm)
10	n.m.	0%	1.9	n.m.
2.2	<2%	0%	2	11
1.7	<2%	0%	2.3	11
1.2	9%	0.3%	2.9	11
0.9	18%	3%	4.3	12
0.5	23%	5%	4.6	14
0	27%	7%	5.8	18

Notes:
Rheological analysis at 20°C
Volume suspended solids (VSS): 3,000 x g, 5 minutes
Dry suspended solids (DSS): 70 °C, 24 hours (corrected for soluble solids using 0.2µm filtered control)
Particles size by laser diffraction (Malvern Mastersizer 2000)

Oak chip effects on rheology

The Australian Wine Research Institute











Lees layers	Yield stress (Pa)	VSS (v/v)	DSS (w/w)
Grape and yeast derived lees	60	60%	19%
Oak chips lees on tank bottom	280	n.m.	33%

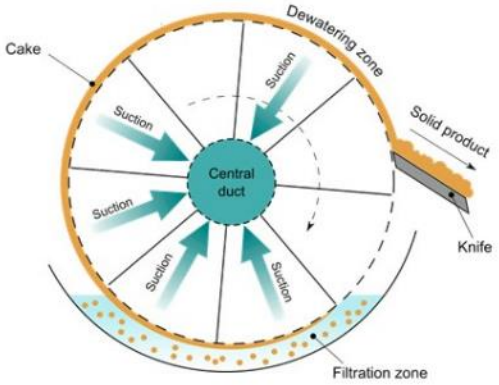
- Oak chips provide structure to the lees and prevent it from flowing (high yield stress)
- Alternatives: 'oak-bomb' tanks, commercial liquid oak/tannins (regulatory issues?)

Recovery – RDVs (prevailing practice)

The Australian Wine Research Institute

- RDVs have been the lees processing workhorse at wineries for many years
- Reasons that alternatives are being considered:
  - Quality downgrades for higher value products resulting from oxidation and dilution with water
  - Product can still be relatively turbid
  - High labour requirements
  - Filter aid (perlite or DE) needs to be purchased and spent material dealt with
  - Operator safety? Perlite seems to mainly be used instead of DE so appears to be much less inhalation risk than when working with DE (perlite contains <0.1% crystalline silica)

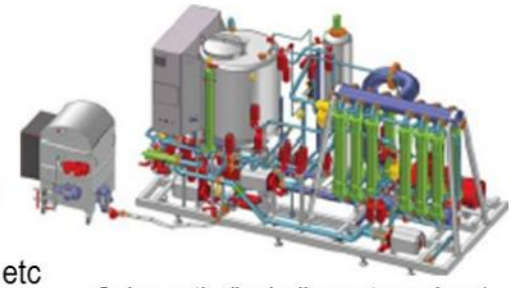




Pall Oenoflow HS

The Australian Wine Research Institute

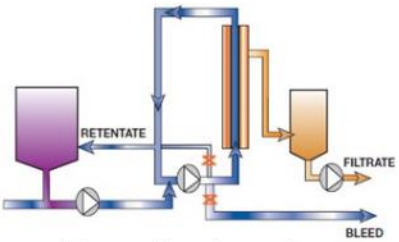
- Similar to standard cross-flow
- PVDF symmetric membrane
- Wide bore hollow fibres (~3mm?)
- Upwards rather than downwards flow (maybe helps prevent settling, clogging)
- Versatile – most types of lees & wine
- Rotary sieve to remove seeds, petioles, etc



Schematic (including rotary sieve)



Filter skid (cut-away of a filter module inset)



Flow path schematic

Bucher-Vaslin Flavy FX (adapted) & Leestar

The Australian Wine Research Institute

1. Adaptation of normal Flavy FX wine X-flow to use on settled must lees (largest volume of lees)
- Must lees or wine (no fining agents allowed in either)
- PES asymmetric membrane
- Wide bore hollow fibres (3mm instead of 1.5mm)
- Rotary sieve to remove seeds, petioles, etc
- Head cleaning system to prevent blockages



Rotary sieve + filter + head-cleaning + wide bore

2. Leestar
- TiO_2 membrane on sintered SS support
- Very wide bore (18mm)
- Versatile – most types of lees (too slow for wine?)
- Requires cooling – a lot of heating? (low filtrate per recirculation)



Unit with flow schematic and internal config.

Della Toffola Omnia CFKF

The Australian Wine Research Institute

- Ceramic membrane on titanium support
- Wide bores in filter monoliths (3.5 – 6mm)
- Versatile – most types of lees and wine
- Rotary brush strainer to remove seeds, petioles, etc
- Head cleaning system with brushes and aspirator



Filter unit (including rotary brush strainer on the right)



Filter monoliths in housing



Head cleaning system

TMCI Padovan Dynamos

The Australian Wine Research Institute

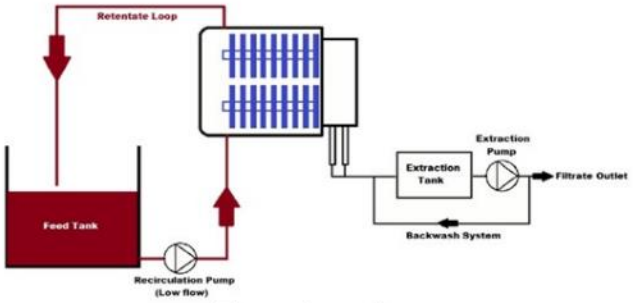
- Cross-flow cleaning action on membrane generated by rotating filter as opposed to recirculation flow
- Ceramic membrane
- Versatile – most lees types (too slow for wine?)



Ceramic rotary filter discs



Filter unit



Flow schematic

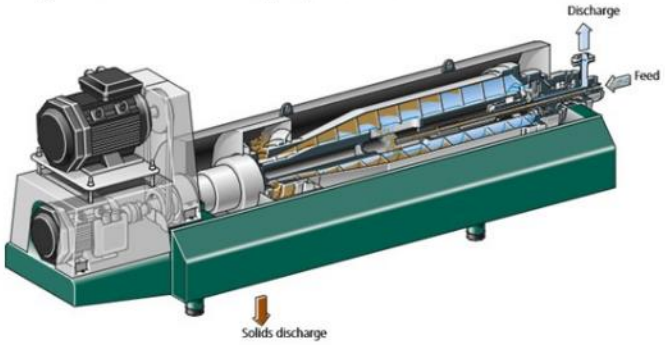
Decanter centrifuges (e.g. GEA Westfalia, Alfa-Laval)

The Australian Wine Research Institute

- Separation principally by centrifugal force as opposed to by screening
  - Depends on a solid-liquid density difference
  - More effective at removing larger rather than smaller particles

$$v = \frac{d^2(\rho_s - \rho_l)r\omega^2}{18\mu}$$

- Lower cake moisture content and potentially higher throughput than lees cross-flow filters
- Turbid product relative to lees cross-flow filtration – additional filtration required
  - Is a pretreatment rather than a final clarification step
- One-pass as opposed to recirculating operation



RDV alternatives - summary

The Australian Wine Research Institute

- Difficult to know which of the alternatives is best without controlled comparative trials on a range of different lees over a long period
- Lees filters described provide much clearer product than RDVs
- Equipment generally features increased level of automation over RDVs
- Lower wine recovery than RDV with some of the devices discussed, but lower turbidity and higher quality
- Very short payback periods (<2 years) are claimed by several suppliers – but payback period may be quite winery dependent, e.g.:
  - Labour use for RDVs at the winery? (is 1 person operating 1 or 5 RDVs)
  - Level of downgrade from RDV use at the winery? (e.g. $20/L → $1/L vs. $1/L → $1/L)
  - Perlite disposal arrangements

Thank you – any questions?

The Australian Wine Research Institute



Acknowledgements

- Australian grape growers and winemakers and the Australian government for funding through the GWRDC

GWRDC GRAPE AND WINE RESEARCH AND DEVELOPMENT CORPORATION

- Wineries who have given us access to data and allowed us to collect samples
- Equipment manufacturers who have supplied information on their equipment

7.2. Australian & New Zealand Grapegrower & Winemaker magazine article – November 2014

An article entitled “Reverse racking and clarification” was published in the November 2014 issue of Australian & New Zealand Grapegrower & Winemaker magazine. The article is provided below.

Reverse racking and clarification

Simon Nordestgaard, Australian Wine Research Institute senior engineer, has been studying the possibility of 'reverse racking' as a new way to achieve clarification without as many tank transfers.

CLARIFICATION is a major reason for moving juice and wine between tanks at wineries – whether it be racking off lees after a period of static settling, or to pass wine through a centrifuge or filter. Each movement needs a clean tank for the clarified product to go into. Tank cleaning and the movement of wine require labour, water and cleaning chemicals and generate wastewater that needs to be managed. Furthermore, significant quantities of juice/wine can be tied up in lees and undergo major quality downgrades when recovered from lees by the most common method, rotary drum vacuum filtration (RDVF).

The AWRI is working on a new project studying the possibility of 'reverse racking' as a new way to achieve clarification without as many tank transfers. In this process the small quantity of lees in tanks is removed from underneath the clear juice or wine so that the bulk may remain in the same tank. In the first phase of the project, lees samples were collected during the 2014 vintage and their flow properties (rheology) were measured to provide insight into their possible behaviour during reverse racking.

Reverse racking lees means that the bulk of the batch of wine can remain in the same tank. As the lees are being reverse racked, in an idealised configuration, they could be immediately clarified using an RDVF alternative that does not degrade the quality of the juice/wine and returned to the top of the same tank (Figure 1).

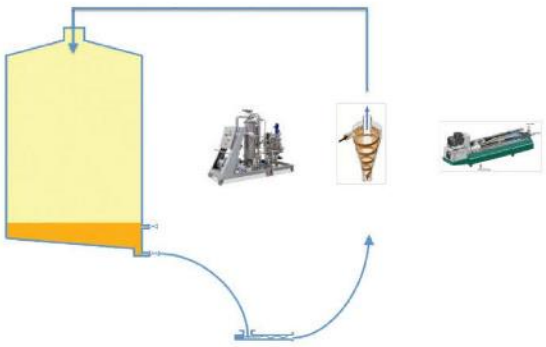


Figure 1: Idealised reverse racking – immediate clarification of lees and return of recovered wine into the top of the same tank (clarification technologies are illustrative only – those shown may or may not be appropriate)

The removal of sediment from underneath a clear product is already practised in other industries. For example, in beer production, cylindroconical tanks are commonly used for fermentation. After fermentation the conical bottom on these tanks allows the reverse racking of sedimented yeast if desired. In the wine industry, reverse racking has been used by some wineries when they have cold settled juice lees in tanks with no racking arm, in order to get the lees level down below the racking valve so that normal racking can then be conducted.

The challenge with reverse racking is that there will be some tendency for the clear product above to channel through the lees before all or much of the lees have been removed from the tank. The degree to which this will occur is likely to depend on:

- Rheology of the lees – how easily the lees can flow;
- Tank design (height, aspect ratio, floor shape and angle, surface finish, outlet sump design etc.); and
- Pumping regime (e.g. speed and pulsing).

Unlike the brewing industry, where cylindroconical tanks having bottom cones with floor angles of 55° down from the horizontal are common, large winery tanks typically do not have a conical bottom, just a gentle slope from the back to the front of the tank of the order of 5°. The Australian wine industry has already been through its major expansion in the 1990s and early 2000s and has made a significant investment in tanks. This project aims to develop a device and protocol for reverse racking of lees that can be used with existing tanks.

As discussed, the rheology of lees is likely to have a large influence on the ability to reverse rack them. One measurable rheological property of lees likely to be important is the yield stress. The yield stress is the minimum stress that needs to be applied to make a structured fluid flow.

When the bottom valve of a tank is opened, the pressure head of liquid in the tank creates local stresses on the lees adjacent to the valve that are larger than their yield stress, which drives them out of the tank. However, further away from the valve, the local stresses applied to the lees will be lower and if the lees have sufficiently high yield stress, they will not move fast enough and the clear liquid above will channel through. This means that lees with very high yield stress values are likely



Table 1: Rheology of lees samples

Lees type[a]	Yield stress[b] (Pa)	Apparent viscosity[c] (mPas)	Volume solids[d]	Dry solids[e]
Gross red	28 (38)	130 (190)	47%	16%
White ferment	<0.5	14	51%	15%
White juice	<0.5 (<0.5)	6 (9)	27%	7%
White juice + bentonite	<0.5	5	31%	10%
Port + bentonite	3	13	60%	4%
Water (for comparison)	0	1	0%	0%

[a] Collected from bottom of settling tanks apart from the gross red lees samples, which were collected from a mixed lees tank (other gross red lees samples that have been collected from the bottom of settling tanks typically showed even higher yield stresses and apparent viscosities).
[b] Vane shear technique – Haake VT550 with FL10 vane, 0.1 rpm, at 20°C (except bracketed results that were measured at 4°C to study the impact of temperature).
[c] Controlled rate – Haake VT550 with NV/NV or MVP/MV2P cup/rotor, 500 s-1 shear rate, at 20°C (except bracketed results that were measured at 4°C to study the impact of temperature).
[d] Spin test – 50 mL, 3,000 x g, 5 minutes.
[e] Drying – ~ 5 g, 70°C, 24 hours (corrected for soluble solids by drying a 0.2 µm filtered sample).

to be less suited to reverse racking than lees with lower yield stress values.

In 2014 a range of lees samples were collected and analysed and indicative data are presented in Table 1. The overriding observation of this work was that with the exception of gross red lees (red ferment lees after draining/pressing and settling) most lees samples had low yield stress and low apparent viscosity values. Notably, the concentration of solids did not necessarily correspond with the rheology of the lees – for example, the white ferment lees and gross red lees had similar solids concentration but very different yield stress and apparent viscosity. This seems likely to relate to the different nature of the solids and soluble components extracted from red grape skins during fermentation. At this stage only a limited number of white ferment lees samples have been collected; further samples will be obtained shortly to confirm the preliminary results for this lees type.

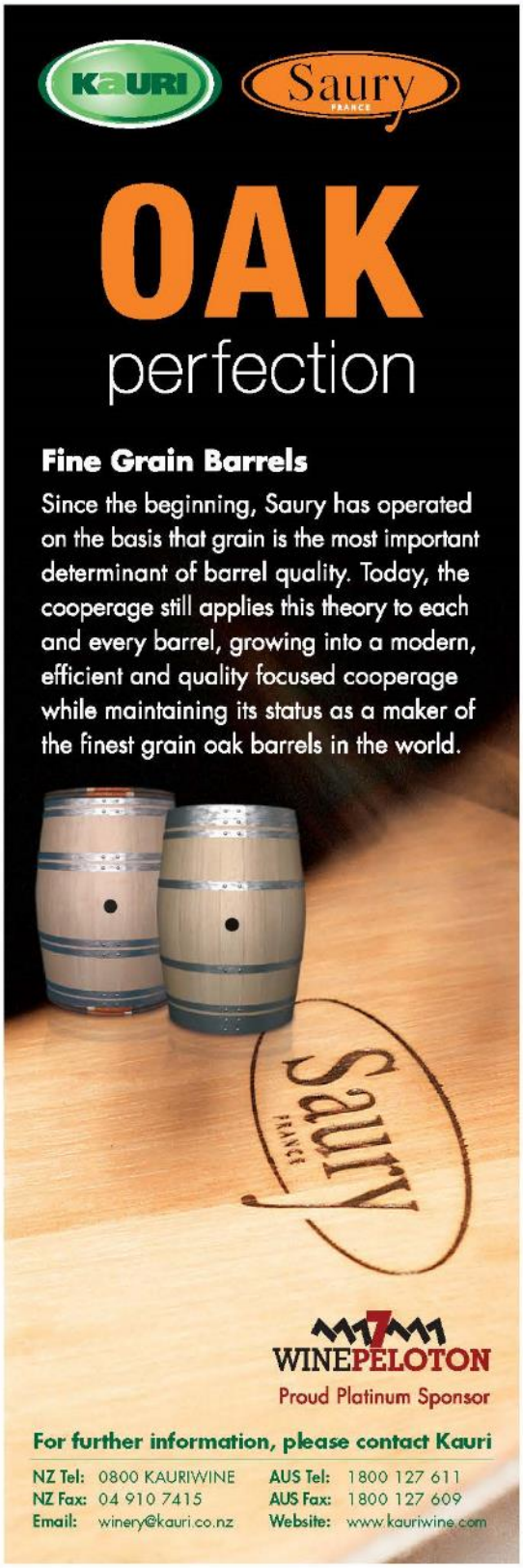
The rheological results, the yield-stress measurements in particular, suggest that red gross lees are likely to be the most difficult to reverse rack of all winery lees.

There is a further complicating factor in that red gross lees also may contain remnants of oak chips that have passed through draining and pressing operations. This vintage, these oak chips were seen to form a layer on the floor of the tank below the grape and yeast-derived lees. These two layers had very different rheological properties, with the oak chip lees having much higher yield stress than the grape and yeast-derived lees. These results suggest that residual oak chips are likely to be an obstruction to the successful reverse racking of red gross lees. Furthermore, they are a hindrance even in removing lees from tanks after normal racking, making the process more time-consuming and labour-intensive than necessary. Generally the addition of oak chips into many tanks is problematic and techniques such as the preparation of small numbers of tanks with very high oak concentrations, which are then clarified and that wine distributed to tanks requiring oak treatment could be pursued as a more efficient strategy.

Following on from the initial work that has focused on understanding the fundamental properties of lees, next vintage the project will move on to laboratory scale trials of different devices that could be retrofitted to existing winery tanks to facilitate reverse racking.

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GW



7.3. Australian & New Zealand Grapegrower & Winemaker magazine article – March 2016

An article entitled “Winery lees: Minimising volumes and recovering better quality juice and wine” was published in the March 2016 issue of Australian & New Zealand Grapegrower & Winemaker magazine. The article is provided below.

Winery lees: Minimising volumes and recovering better quality juice and wine

The AWRI is convening a workshop on winery lees at the 16th Australian Wine Industry Technical Conference in Adelaide in July. This workshop will consider sources of winery lees, methods of lees minimisation and techniques for juice and wine recovery. In this article, AWRI engineers **Simon Nordestgaard** and **Tadro Abbott** provide some preliminary data from recent AWRI research on winery lees. More details will be included in the July workshop.

IN WINEMAKING, lees are solids-containing mixtures that have been separated from juice or wine by gravity settling, centrifugation, flotation or other techniques. The solids can include grape material, tartrate precipitates, yeast cells, fining agents and oak chips. Since 2013, the AWRI has been working on a research project that aims to better understand the physical characteristics of different types of lees and investigate alternatives to traditional racking processes.

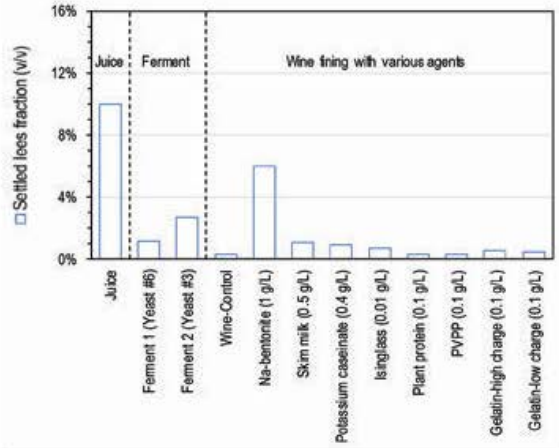


Figure 1. Lees volumes at different stages of white wine production from laboratory settling experiments

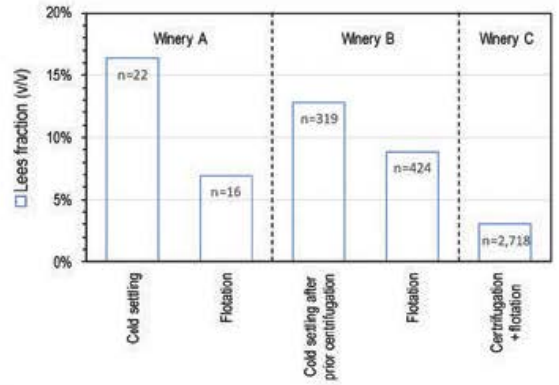


Figure 2. Median lees volume fractions resulting from different white juice clarification methods at three wineries (n=number of batches)

SOURCES AND VOLUMES OF LEES

Typically, the largest volumes of lees come from the grape. In white winemaking grape-derived solids are mainly removed prior to fermentation, whereas in red winemaking they are usually removed after fermentation when they are combined with yeast.

As an illustration of the relative lees volumes generated at different stages of wine production, data from some simple laboratory white juice/wine settling experiments performed in 2L cylinders are presented in Figure 1.

Cold settling gave 10% juice lees. In contrast, fermentation gave lees volumes between 1% and 3% (eight yeast types trialled - highest and lowest results shown).

Fining agents at typical doses also produced relatively small quantities of lees, with the exception of sodium bentonite, which is widely known for producing large volumes of lees (in this experiment 6% of the wine volume).

The solids content of the different lees varied – fermentation lees had four to five times the dry solids content of juice or bentonite lees.

WINERY DATA

To better understand lees volumes at a production scale, data from four large wineries were analysed. Figure 2 shows the lees volumes resulting from different methods of white juice clarification at three of the wineries (A, B and C).

Juice lees volume fractions were calculated using the formula (Volume of juice in – Volume of clear juice out)/Volume of juice in. At Winery A, with cold settling 16% of the initial juice volume was separated as lees while with flotation only 7% was separated as lees.

With flotation, the solids are lifted with gas bubbles and therefore there was less juice tied up with the solids than occurs with settling. Winery B used flotation alone or centrifugation followed by cold settling to achieve clarification.

Even after many of the larger solids had first been removed by centrifugation, the volume of lees obtained through cold settling was still higher than using flotation alone (13% compared with 9%). Winery C used centrifugation with flotation on the outlet of the centrifuge and this process produced a lees volume of 3%.

This lower lees fraction than at Wineries A and B is likely partly a consequence of the use of centrifugation to remove the larger denser solids and subsequent use of flotation to remove the lighter solids (both technologies which produce lees with low juice content).

It is also likely partly a consequence of Winery C's use of membrane presses for draining and pressing, which may have resulted in lower initial juice solids levels than occurred at Wineries A and B where inclined or static drainers and screw

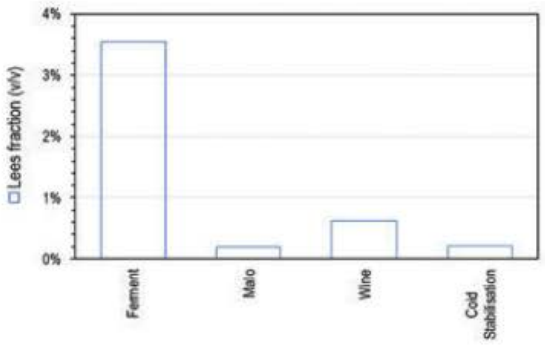


Figure 3. Aggregated lees fractions at different stages of red wine production at Winery D

presses were used for some operations. Types and modes of operation of crushing, draining and pressing equipment are important in limiting lees volumes in the winemaking process.

Bentonite lees volumes from one winery were also examined. Where sodium bentonite was used for heat stabilisation and this operation was coupled with cold stabilisation, the median settled lees volume fraction was 5.1% across 624 batches (data not shown).

The project also assessed lees volumes generated during red wine production. One winery, which removed gross red lees by settling, had a median settled volume of gross red lees of 9.6% across 518 batches.

At another winery, red wine lees volumes were assessed at different stages of production (Figure 3).

This analysis showed that gross red lees after fermentation contributed the highest percentage of lees compared to other stages of red wine production.

RECOVERY OF JUICE/WINE FROM LEES

The importance of lees volumes depends on how much product is tied up in the lees, how much product can be recovered, whether the recovered product is downgraded (either from being bound up in the lees or by the recovery process) and the cost and effort required for the recovery.

Rotary drum vacuum filtration (RDVF) is widely used for juice and wine recovery from lees. This technology is well suited to processing high solids feedstocks with very high recovery rates, but can degrade juice or wine quality through oxidation. It also employs perlite filter aid that requires disposal.

In recent years, equipment suppliers have introduced cross-flow filtration systems for processing lees, claiming that they are more automated and can recover higher quality juice and wine with lower turbidity.

Some of the new systems are only suitable for light juice lees, while others are also designed to handle thicker fermentation lees and abrasive fining lees.

Many of the new lees filters are similar to the suppliers' existing wine cross-flow filters but with some important adaptations – e.g. wider bore capillaries, brushing/sweeping systems at capillary inlets and rotary pre-screens to remove coarse contaminants like seeds.

Another common configuration of lees filters has the filter surface on discs instead of on the inside of the capillaries and achieves the cross-flow filter surface cleaning action by rotating the discs in the lees instead of pumping the lees through the capillaries.

Decanter centrifuges are also being used to process lees prior to further filtration. In another interesting development, an Australian manufacturer is offering a variation on the RDVF. ▸







Figure 4. Pumping juice lees from underneath water in (a) a brewery-style tank with a 55° sloped conical bottom, and in (b) a winery-style tank with a 5° back-to-front sloped base. Lees channelling can be seen in the winery-style tank.

This new device employs a permanent titanium membrane that does not require perlite and can be operated in an enclosed oxygen-free environment.

THE SEPARATION OF LEES FROM UNDERNEATH CLEAR JUICE OR WINE

Clarification is a major reason for moving juice and wine between tanks at wineries. After clarifying a product by settling, the clear liquid is racked to a clean tank and the lees are then typically pumped to another tank (often a mixed lees tank) for later reprocessing.

The original tank then has to be cleaned.

AWRI researchers have been studying the possibility of removing the lees directly out from underneath the clear liquid, so that the liquid can remain in the same tank, reducing both transfer steps and tank cleaning.

The practical challenges with this concept are in avoiding channelling of the clear liquid through the lees and in directing as much lees as possible towards the removal point without disturbing the lees-liquid interface.

To facilitate this research, a laboratory apparatus with transparent tanks was constructed to be able to see how different tank designs and modifications might influence lees removal. The apparatus includes scale-model cylindroconical brewery-style tanks (55° sloped bottom cone, Figure 4a) and winery-style tanks (5° bottom slope from back to the front of the tank) as is (Figure 4b) or retrofitted with baffles, suction feet, acoustic and other vibration equipment or sweeping arms.

To date the only techniques that have been reasonably successful in removing lees from below juice or wine are cylindroconical tanks and to a lesser extent sweeping arms.

Neither of these is really a desirable solution because they would both require significant investment to implement - either purchase of a new tank (a cylindroconical tank) or a major retrofit to an existing tank.

At the time of writing, work is being performed to investigate if there are other ways to achieve the sweeping arm effect with a non-permanent (and therefore less expensive) fixture.

CONCLUSION

The lees workshop at the Australian Wine Industry Technical Conference will expand upon the topics discussed in this article. There will be presentations from AWRI researchers on local and international research, and from industry speakers on their experience with different styles of equipment for juice/wine recovery from lees.

For more information, please contact Simon Nordestgaard:
P: (08) 8313 6600
E: simon.nordestgaard@awri.com.au.
Conference registrations are now open at:
www.awitc.com.au/registration.

Acknowledgements

The authors thank the wine companies that donated materials for experimentation and provided information.

They also thank Mark Braybrook for his assistance and expertise in the construction of experimental apparatus.

This work was supported by Australian grapegrowers and winemakers through their investment body Wine Australia, with matching funds from the Australian Government.

The Australian Wine Research Institute is a member of the Wine Innovation Cluster in Adelaide.

7.4. Workshop W37 at 16th Australian Wine Industry Technical Conference 2016

A workshop was convened on the topic "Lees: minimising volumes and recovering better juice and wine" at the 16th Australian wine Industry Technical Conference at the Adelaide Convention Centre on Wednesday 27 July 2016. An abstract for the workshop is provided below, followed by a copy of the slides from all presenters. There were approximately 30 attendees.

16th AUSTRALIAN WINE INDUSTRY Technical Conference

the 16th Workshop Program

W37

Date: Wednesday 27 July 2016

Time: 09:00 - 12:00

Room: City 4

Theme: Winemaking

Type: Seminar

Ticket Price: $150

Catering: Morning tea

Convenor:

Simon Nordestgaard,
The Australian Wine
Research Institute

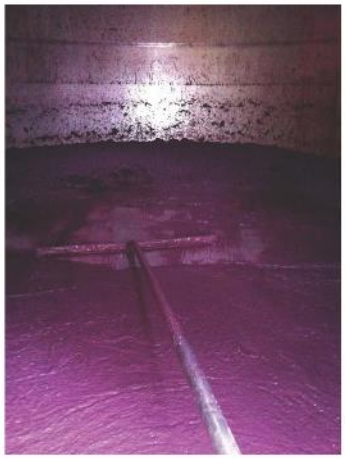
Lees: minimising volumes and recovering better juice and wine

Lees formed in tanks during wine production can tie up large quantities of juice and wine. When this juice and wine is recovered by rotary drum vacuum filtration (RDVF) it is sometimes downgraded in quality. This workshop will consider where solids are generated in the wine production process, how different equipment and practices influence solids generation, and how best to manage the resultant lees. In recent years, alternatives to RDVF for juice/wine recovery from lees have been launched by many suppliers promising recovery of juice/wine with less risk of quality degradation and increased automation. Speakers from several wineries that have trialled and/or purchased different styles of lees cross-flow filters and other equipment will talk about their experiences. There will also be a presentation on a novel RDVF that doesn't require any filter aid and operates in an inert gas environment, and a presentation on laboratory-scale trials studying the possibility of removing lees from underneath clear juice or wine in an effort to minimise tank transfers.

Dr Simon Nordestgaard has worked in wine industry research and development for approximately 10 years. This has included an engineering PhD relating to grape pressing, and industry projects relating to heat stability, refrigeration efficiency, wine transport, and lees management. Simon has a passion for winery process and equipment innovation.

AWITC Workshop 37 – Wednesday 27 July 2016

The Australian Wine Research Institute



Lees: Minimising volumes and recovering better juice and wine

Simon Nordestgaard, Luke Wilson, Tom Barry,
Rob Martyn, Vanessa Stockdale & Scott Russell

simon.nordestgaard@awri.com.au

Agenda

The Australian Wine Research Institute

Time	Presentation	Presenter
9:05 – 9:35	Sources and properties of lees	Simon Nordestgaard (AWRI)
9:35 – 10:00	Experiences with a Pall lees filter	Luke Wilson (The Yalumba Wine Company)
10:00 – 10:25	Experiences with a Bucher-Vaslin lees filter	Tom Barry (Jim Barry Wines)
10:25 – 10:45	Morning Tea	
10:45 – 11:10	Experiences with a Della Toffola lees filter	Rob Martyn (Delegat Group)
11:10 – 11:35	Experiences with Padovan and Andritz rotating disc lees filters and a Westfalia decanter centrifuge	Vanessa Stockdale (Treasury Wine Estates)
11:35 – 12:00	Trials with a rotary drum vacuum filter that operates in an inert gas environment and without filter media (SmaRtDV)	Scott Russell (AMS)







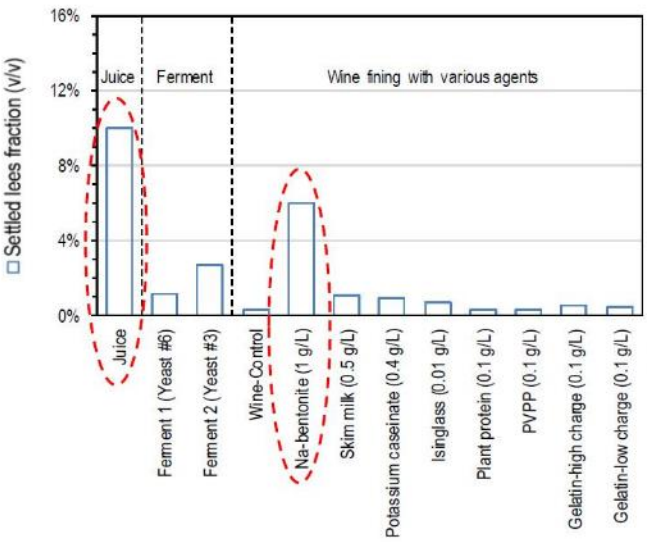






Lees volumes in white wine production – lab example

The Australian Wine Research Institute



- Settling in 2 L cylinders (Chardonnay)
- Grape solids cause a lot of lees
- Bentonite also causes a lot of lees

(when gravity settling is used, these lees also have a relatively low solids content - so relatively more juice/wine is tied up in them)

Lees properties – winery examples

The Australian Wine Research Institute



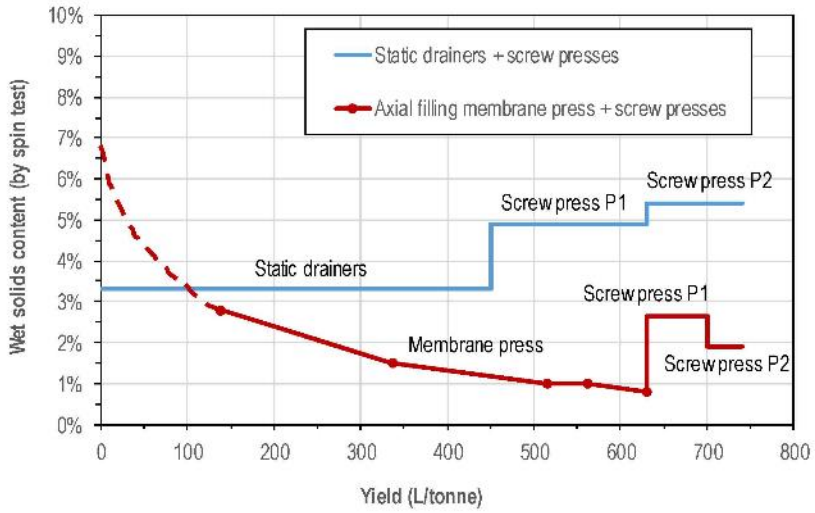
Lees type	Wet solids conc. (by spin test)	Dry solids conc.* (by heating)	Yield stress (Pa)	Apparent viscosity (mPa.s)
White juice	27%	7%	<0.5	6 (9)
White juice + Na-Ca bentonite	31%	10%	<0.5	5
White ferment	51%	15%	<0.5	14
Red ferment	47%	16%	28 (38)	130 (190)
White wine + cold-stab/Na-bentonite	22%	4%	1	6
Rosé wine + cold stab/Na-Ca bentonite	28%	10%	1	7
Water (for comparison)	*0%*	*0%*	*0*	*1*

**Corrected for "soluble solids" by also drying a filtered sample*

Rheological measurements in () at 4°C, all others at 20°C

Equipment for draining and pressing

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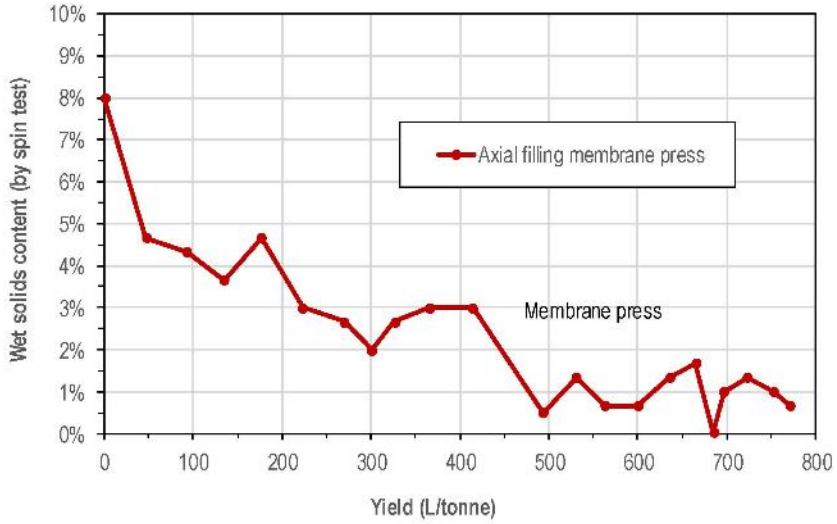


- Chardonnay

Yields estimated for static draining and screw press fractions, but measured for membrane press fractions

Membrane press

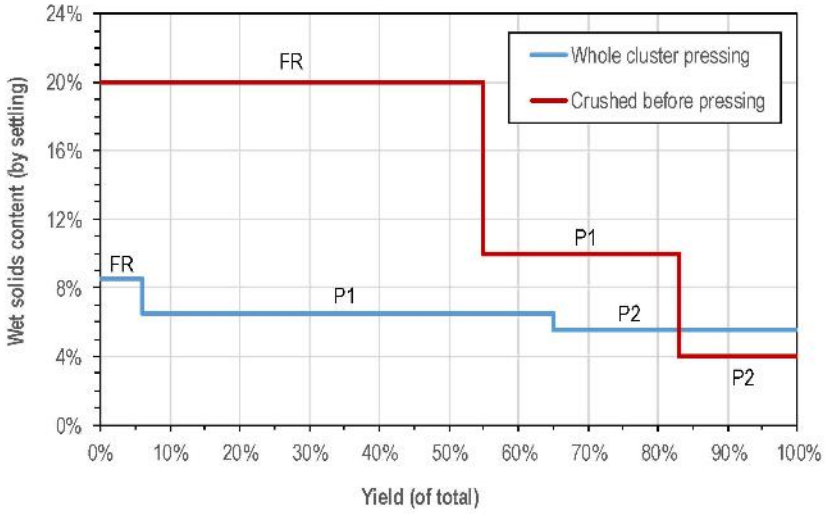
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- Chardonnay

Influence of crushing

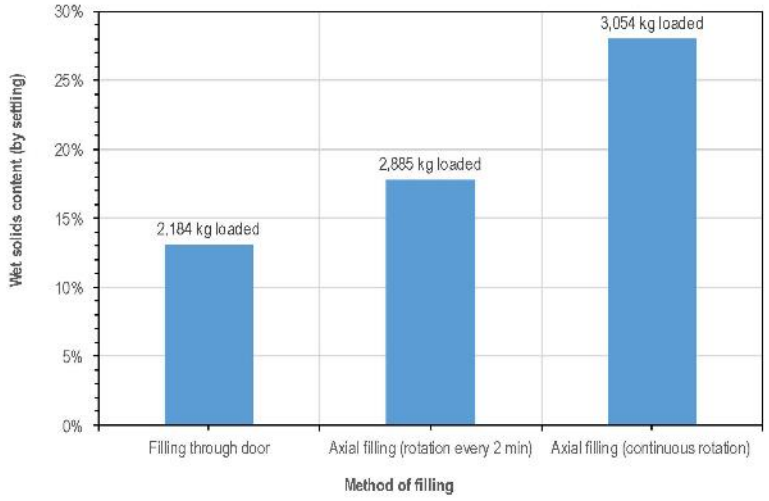
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- Riesling
- Data from Jung & Seckler (1996)

Influence of method of membrane press filling

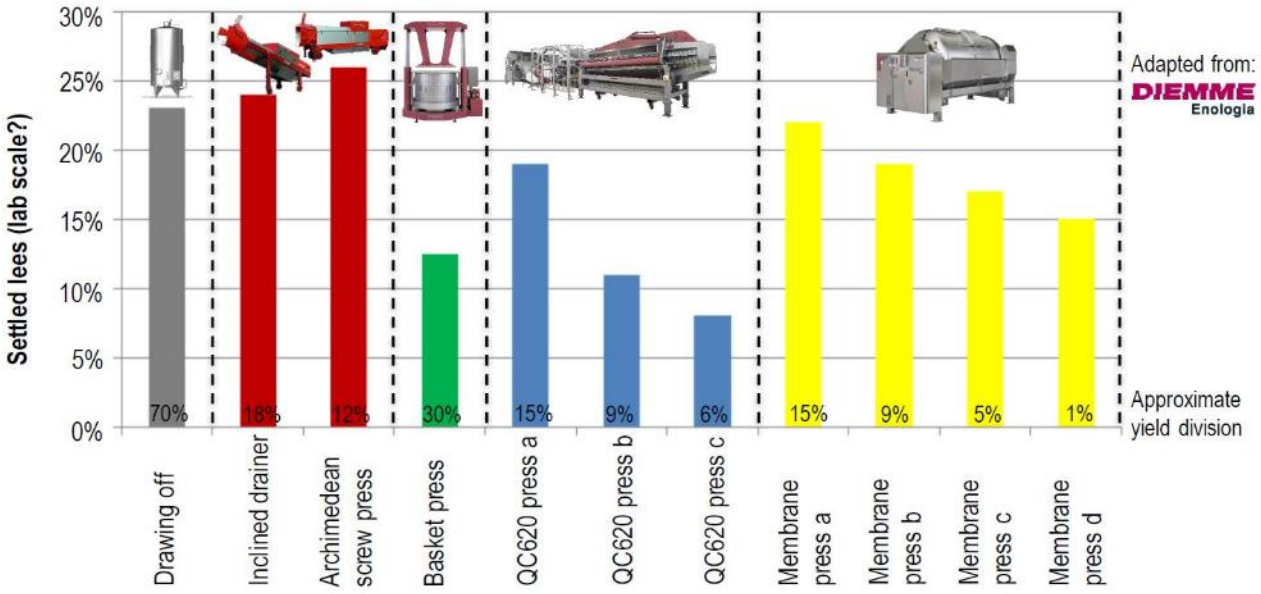
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- 1,800 L capacity press
- Riesling (25% rotten)
- Data from Jung & Seckler (1996)

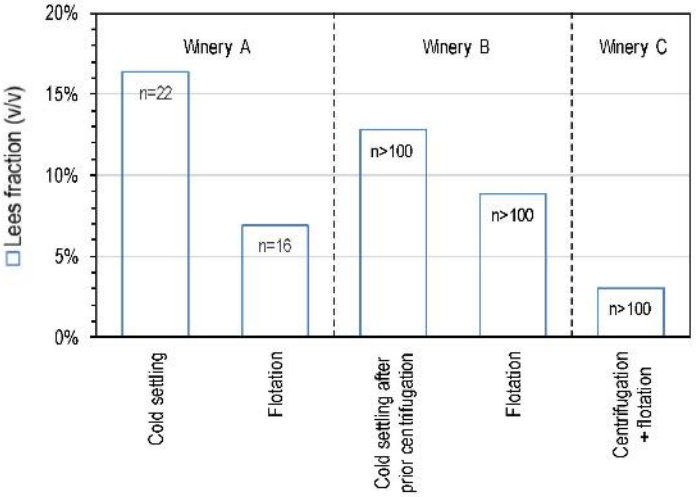
Red ferments – Equipment for pressing

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Influence of white juice clarification method

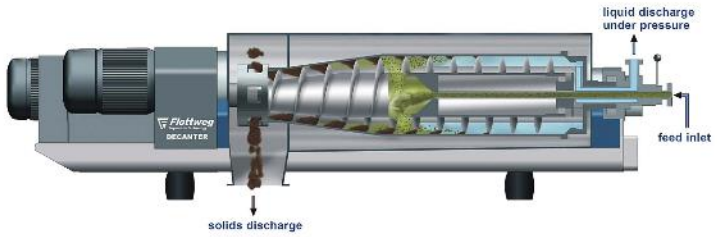
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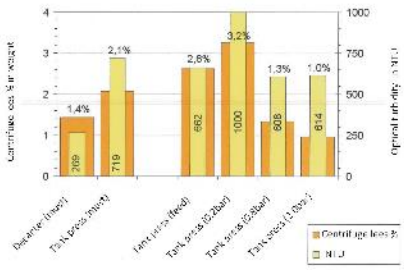


- Juice clarification technique also have major effects on lees volumes
- Not side-by-side trials, and a mix of different draining and pressing techniques used - but some tentative observations

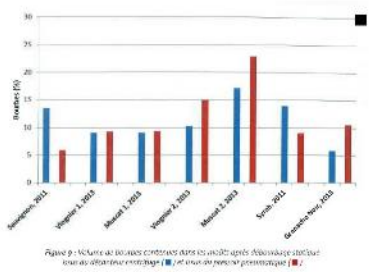
Decanter centrifuges as a press alternative?

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GEA Westfalia data

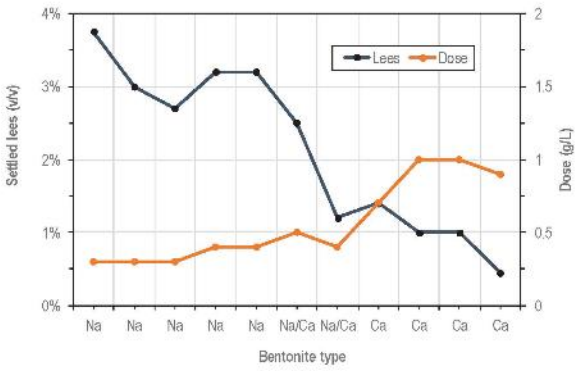


Duquene et al. (2014) – Alfa Laval co-authors

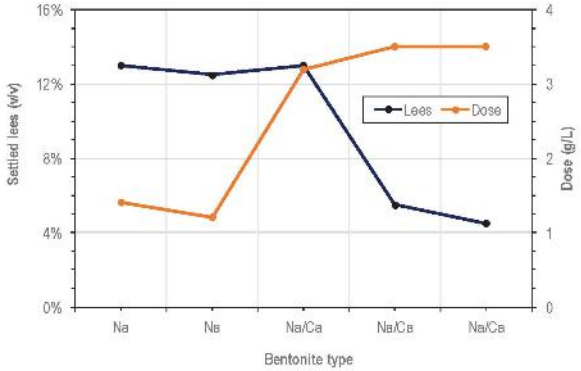
- Not new but may be some new uptake
- Current installations are mainly as part of thermovinification/ flash détente lines
- Alfa Laval have been pushing recently on decanter use with white grapes and adjuncts such that the solids are low enough to go straight to ferment without further juice clarification

Bentonite type

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Data from Morant (1990) – lees volumes extrapolated from result with 1 g/L dose

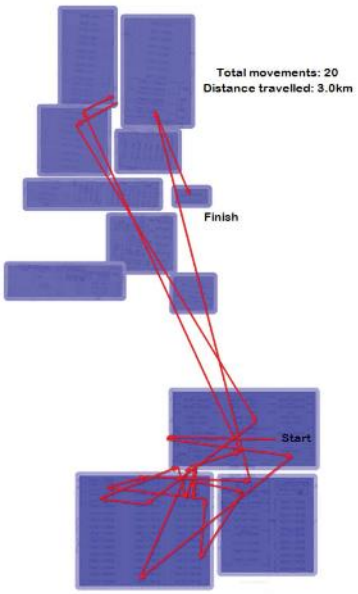


Data from Leske et al. (1995)

- Bentonite type has an effect on lees volumes – Na/Ca bentonites cost more per kg than Na bentonites, require higher doses but give lower lees volumes

Avoiding wine movements

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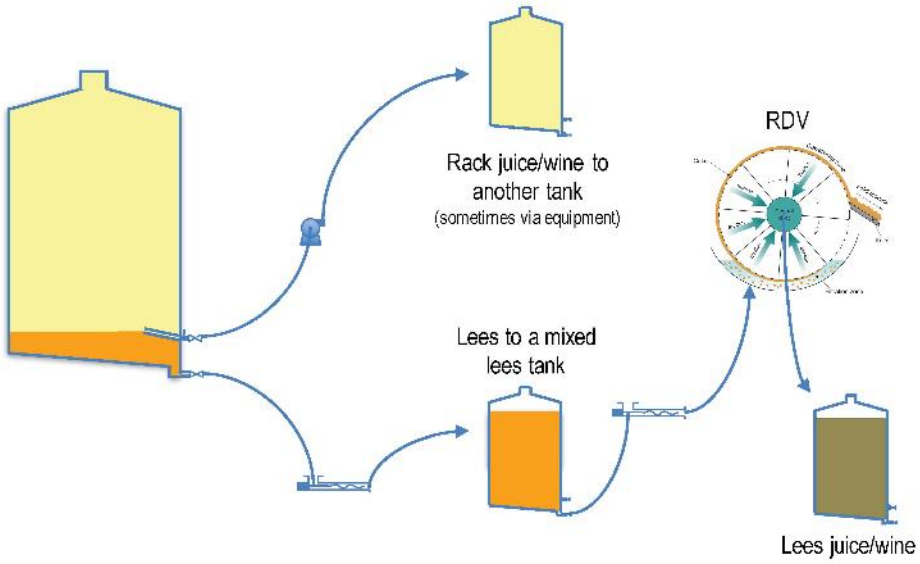
Problems with wine movements

- Labour (setup, pushes, tank cleaning)
- Water use / wastewater production
- Tank availability

Interested in practices and technologies that allow wine to remain in the same tank, while still achieving the same processing outcome

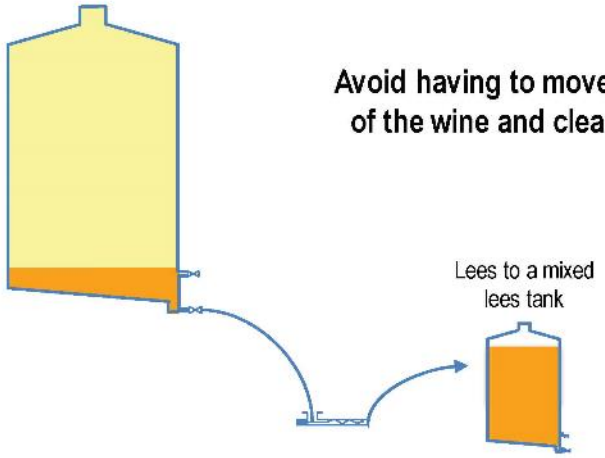
Racking juice/wine

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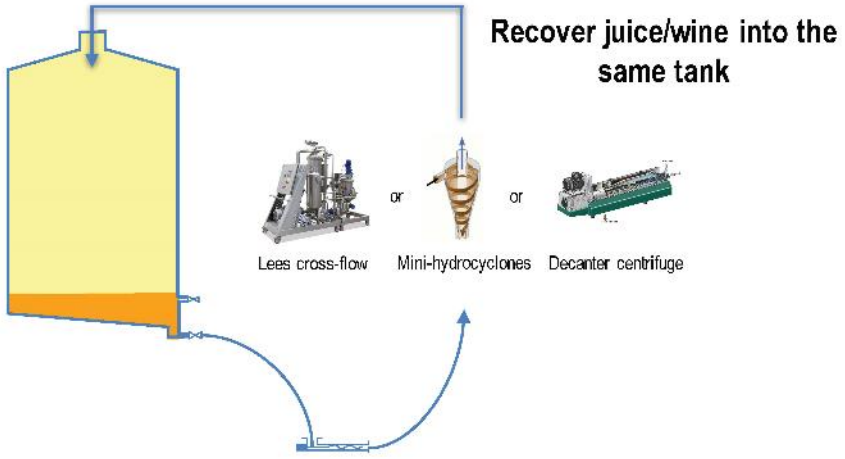
Underneath racking sludge – to a lees tank

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Underneath racking sludge – to the same tank

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Lab studies of underneath racking sludge

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55° sloped conical tank (like a brewery) @ 192x speed
1. Juice lees, then 2. Wine bentonite lees

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Watch video on YouTube: https://www.youtube.com/watch?v=GG4YXSFOT5Q

5˚ sloped winery tank @ 64x speed
1. Wine bentonite lees, then 2. Juice lees

The Australian Wine Research Institute



Watch video on YouTube: https://www.youtube.com/watch?v=fjDC6C7xCgE

5˚ sloped winery tank @ 1152x speed
Juice lees

The Australian Wine Research Institute



Watch video on YouTube: https://www.youtube.com/watch?v=FXw-mNSMqSI

5˚ sloped winery tank – baffle above sump @ 64x speed
Wine bentonite lees

The Australian Wine Research Institute



Watch video on YouTube: https://www.youtube.com/watch?v=o7L7XMBGwiY

5˚ sloped winery tank – moving foot @ 64x speed
Juice lees

The Australian Wine Research Institute



Watch video on YouTube: https://www.youtube.com/watch?v=3XjhfObElgg

5˚ sloped winery tank – floor agitator @ 1x & 384x speed
Wine bentonite lees

The Australian Wine Research Institute

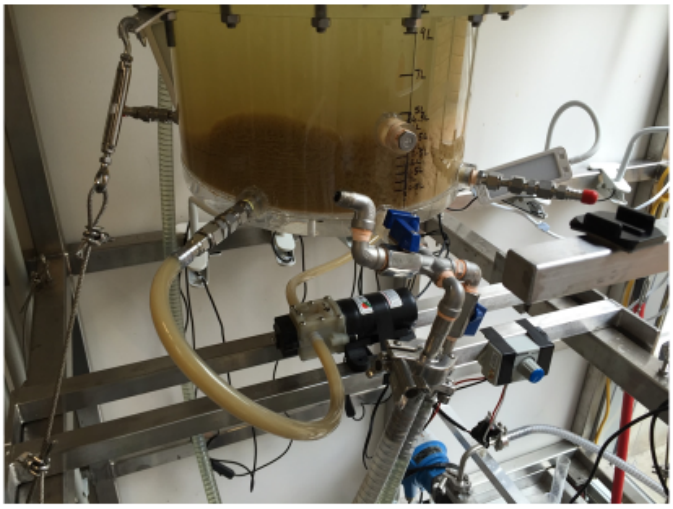


Watch video on YouTube: https://www.youtube.com/watch?v=TUckCGQsSbI

5˚ sloped winery tank – tangential pump swirling
Juice lees

Future?

The Australian Wine Research Institute



- Tangential pump swirling with only 1 feed and discharge point didn't work
- Need another way to make it work
- Ideally something that just involves throwing a simple object in the tank and is made to move by some external device around the tank or left-right-left across the front of the tank (with the external device being able to be moved between tanks as required)
- Have shelved this for now

Conclusions

The Australian Wine Research Institute

- Grape solids and bentonite are major sources of lees
- Crushing, draining, pressing and juice clarification techniques are critical in minimising lees
- Bentonite choice is also important in minimising lees
- How important the magnitude of these lees volumes are will depend on the recovery options available

Acknowledgements

The Australian Wine Research Institute

- Tadro Abbott and Mark Braybrook, AWRI
- Equipment supplier who have provided information to me previously
- This work is supported by Australia's grapegrowers and winemakers through their investment body Wine Australia, with matching funding from the Australian Government. The AWRI is a member of the Wine Innovation Cluster in Adelaide

Wine Australia

Disclaimer

The Australian Wine Research Institute

The information contained in these slides should be considered general in nature, and viewers should undertake their own specific investigations before purchasing equipment or making major process changes.

None of the information presented in this article should be considered as an endorsement or dis-endorsement of any product by the AWRI.

YALUMBA
FAMILY VIGNERONS c. 1849

Experiences with a Pall Lees filter

Luke Wilson – Senior Process Engineer
Yalumba Family Vignerons

Yalumba's Long Term Goal

1

- In 2007 Yalumba made a decision to move away from Earth Filtration with Perlite in all of our products

Yalumba's Long Term Goal

1. This was part of a broad range of winemaking goals that were set as part of our Winemaking Philosophy
2. Technology yet wasn't available to meet our goal

YALUMBA
FAMILY VIGNERONS c. 1849

Yalumba's Path to Success

1. Eliminated Earth pressure filtration
2. Decanter Centrifuge trials
3. Needed something that covered reds, whites and juice

YALUMBA
FAMILY VIGNERONS c. 1849

4 Rules of General Lees Handling

1. Better to treat once and get it right
2. Centrifuge discharge – highest Conc possible
3. Single concentrated Lees better than processing more
4. Maintaining recovered product quality was major financial incentive

YALUMBA
FAMILY VIGNERONS c. 1849

5 steps with Yalumba and Crossflow Filtration

1. 2005- Osmoflo 200m^2 0.2µm Ceramic
2. 2007 – Della Toffola 100m^2 0.2µm Ceramic
3. 2009 – Pall 64m^2 0.2µm Polymeric
4. 2010 – Pall HS Crossflow 120m^2 0.2 µm polymeric
5. 2010 – Expansion of existing crossflow surface area

YALUMBA
FAMILY VIGNERONS c. 1849

Before the Pall Lees Crossflow Filter

Earth Filtration with Lenticular Filtration

- Instances where QA had found hydrocarbon taint in Filter Earth
- Health Risks from exposure to diatomaceous earth
- Definite flavour imparted on wine
- Consumable earth an environmental burden

Strengths:

- Recovery
- Little technical knowledge required to operate
- Tried & True technology
- Consistent Flow

Weaknesses:

- Dilution
- Dissolved Oxygen
- Product to Drain
- Earth purchasing and QA
- OHS
- Working environment
- Quality

YALUMBA
FAMILY VIGNERONS c. 1849

Before the Pall Lees Crossflow Filter

- Large interface between water and wine on changeover
- Leads to wine/juice to waste water treatment
- Not only does this mean wasted product, but also increased production costs
- Increased demand during peak vintage requirements for WWTP



YALUMBA
FAMILY VIGNERONS c. 1849

Background on the Pall Lees Crossflow Filter

Reviewing priorities:

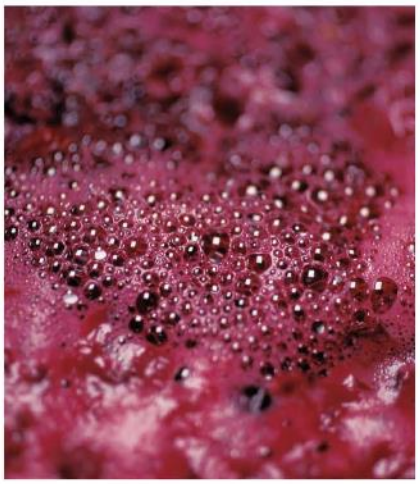
- Recovery vs dilution
- Increased Quality
- Destination of filtered product
- Increased Complexity
- Small batches vs min operating volume

YALUMBA
FAMILY VIGNERONS c. 1849

Background on the Pall Lees Crossflow Filter

Sized for two purposes

- Angaston Juice Filtration
- Angaston and OLW Wine Lees
- Transported between each site once a year

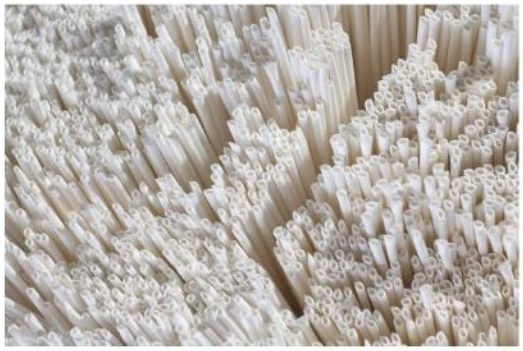


YALUMBA
FAMILY VIGNERONS c. 1849

Background on the Pall Lees Crossflow Filter

How We Use it?

- Juice Filtration
- Wine Lees Filtration
- Wine Filtration
- Final Filtration



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Background on the Pall Lees Crossflow Filter

Lees

- Up to 40% v/v

Filtered product

- Usually >1NTU

Discharge

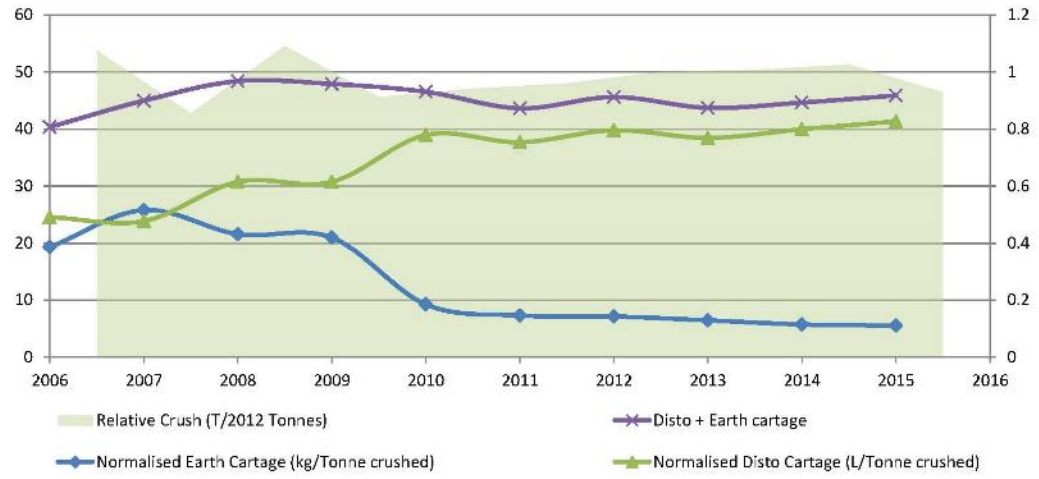
- Target >75% v/v



***Watch volumes in and out to grasp true recovery

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FAMILY VIGNERONS c. 1849

After the Pall Lees Crossflow Filter



YALUMBA
FAMILY VIGNERONS c. 1849

After the Pall Lees Crossflow Filter

What it does well

- Continuous Large batches
- Product quality
- Bentonite Lees
- Automated operation and CIP
- OLW RDV's not used outside of Vintage



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FAMILY VIGNERONS c. 1849

After the Pall Lees Crossflow Filter

Challenges

- Transporting the unit from site to site
- Small premium batches
- Viognier
- Wild Fermentation
  - Primary Juice Solids
- High loads of Carbon
- Needs experienced operators to run effectively



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FAMILY VIGNERONS c. 1849

After the Pall Lees Crossflow Filter

Summary

- Although high capital cost, a well selected machine can have a fast payback
- Depends on individual circumstances
- Excellent reception from Winemakers, Cellarhands, Cellar Management and Accountants!
- Decrease environmental impact of Lees Processing in the winery
- Less effort spent on wine that is downgraded
- Improved Wine Quality!!

YALUMBA
FAMILY VIGNERONS c. 1849

Moving Forward

- 2016 saw us have a greater proportion of Wild Ferment Lees
  - Difficult filtration and more concentrated lees
- Looking at additional filter to handle Angaston volumes with lower hold up volume and capable on sparkling



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FAMILY VIGNERONS c. 1849

YALUMBA
FAMILY VIGNERONS c. 1849

BUCHER VASLIN CROSS FLOW FX3

Tom Barry, Winemaker-
Jim Barry Wines



JIM BARRY
CLARE VALLEY

Outline

- Use of RDV
- Drivers behind decision to purchase cross flow
- Juice Management
- How it Operates
- Maintenance
- Future
- Conclusion

JIM BARRY
CLARE VALLEY

RDV earth filtration

- Oxidative
- Time consuming
- Filter Earth
- Cleaning- difficult to clean and used a lot of water
- Versatility- Batch sizes

JIM BARRY
CLARE VALLEY

Decision to purchase cross flow

- Spending money both contract filtering at winery and pre bottling
- Lees recovery
- Lower extraction varieties like Riesling played a big part in the decision
- Doubles as a wine filter
- Purchased for 2012 vintage

JIM BARRY
CLARE VALLEY

Juice Management

- Clarify juices-we use both floatation (gelatin) and cold settling (enzymes)
- Rack clean juice and leave about 20% of the tank behind-homogenise dirty juice and tank is ready to filter.
- Filter cannot handle Carbon, PVPP or Bentonite. We sometimes fine with gelatin which it can handle
- If we have to use any fining agents like the ones above we add to clarified juice pre ferment
- We find that settled bottoms go through the filter better than floated bottoms
- Cross Flow needs at least 1 chemical clean per day. We also give it 2 or 3 hot washes which take 30 minutes each.

JIM BARRY
CLARE VALLEY

How it operates

1. Juice bottoms pumped into D3 (pre-filter) until D3 full.
2. Cross Flow draws juice from the pre-filter, filters the juice and pumps it to clarified/racked tank. As the cross flow draws down the pre filter, the pre filter will then take more juice lees from tank.





JIM BARRY
CLARE VALLEY

Short You Tube clip

Watch video on YouTube: https://www.youtube.com/watch?v=x0-iJcq3vgo

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Recovery with hand picked Riesling

Variety	Harvest method	Clarification method	Starting Volume	Volume recovered	% Recovered
Riesling	Hand Pick	Float	12195	11723	96.1
Riesling	Hand Pick	Settle	1832	1750	95.5

JIM BARRY
CLARE VALLEY

Recovery with machine picked Riesling

Variety	Harvest Method	Clarification Method	Starting volume	Volume recovered	% recovered
Riesling	Machine	Float	7560	7324	96.8
Riesling	Machine	Settle	2930	2850	97.2

JIM BARRY
CLARE VALLEY

Maintenance

- General cleaning chemical- we use a chemical recommended by Bucher
- Serviced once a year- AUD$2000-$4000 depending on hours used
- We have had trouble with our flow meter which has been costly
- Service carried out by Wine Energy who sold us the Cross Flow
- Other service providers available

JIM BARRY
CLARE VALLEY

FX3 Specs

WINE MEMBRANES -1.5MM	
Mode	Flow rate/ hour
Difficult Wine	1500
Standard Wine	2500
Easy Wine	3500

JUICE MEMBRANES-3.0MM	
MODE	Flow rate/hour
Juice	900

JIM BARRY
CLARE VALLEY

Future - Bucher Lees Star

- Filter primarily for wine bottoms
- Larger membranes 18mm



JIM BARRY
CLARE VALLEY

Conclusion

Positives

- Increase in quality of our juices lees
- Increases recovery of our juice lees
- Ability to process different size batches
- Requires less labour
- Doubles up as a wine filter after vintage
- Eliminates the use of earth

JIM BARRY
CLARE VALLEY

Conclusion

Negatives

- Flow rate during peak periods of vintage- 900l/hour and drops to as low as 500l/hour
- Can be difficult- ie. This vintage is took us 8 hours to get in clean
- Cleaning chemical is expensive
- Spare parts can be expensive
- Cross flowed juice is below 1 NTU which could cause ferment issues.

JIM BARRY
CLARE VALLEY

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16TH AWITC – W37: LEES FILTRATION

Adelaide

27 July 2016



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AGENDA

- Winemaking objective
- Flotation lees
- Equipment configuration
- Performance
- Value creation - payback
- Considerations



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DELEGAT'S STRATEGIC GOAL IS TO BUILD A LEADING GLOBAL SUPER PREMIUM WINE COMPANY.

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Winemaking objectives

One SKU per varietal

=> No second tier or bulk products

=> Nowhere to hide!

Strategy is to maintain/improve quality at a super premium category price point

Value based competitive strategy



DELEGAT

Flotation juice lees – the filtration challenge

- Viscous (~40% solids)
- Contains bentonite
- Settles to 'concrete'
- Gassy (nitrogen)
- Grape berry solids
- Fibrous 'mystery' material



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DT CFKF 170/67 – key innovations for flotation lees

- Stainless steel brush strainer
- With counter flow and active discharge
- Brush and vacuum system for keeping





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Grape solids at brush strainer – pre factory modification





7

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Mystery fibrous material



8

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Mystery fibrous material



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Intake juice processing – equipment configuration

- 4 x Bucher 450 Xpert
- 5 x Bucher 320 Xpert
- 2 x Della Toffola FLCV3 (+ batch units)
- 4 x Della Toffola CFKF 170/67
- 1 x 25kL DT 'Cluster' Tank

28,000 tonnes processed

In 20 days



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Intake grape processing



11

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Intake juice clarification – DT FLCV3



12

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Intake juice lees filtration – DT CFKF 170/67 cluster tank



- Buffer vessel for flotation lees
- Homogenises lees (vortex mixer)
- Degasses lees (pump-over irrigator type mixing)
- Controls the CFKF 170/67 units
- Manages filtration demand based on throughput (cluster tank buffered volume)
- Manages unit cleaning – sequences this activity
- Continuous operation 24/7

13

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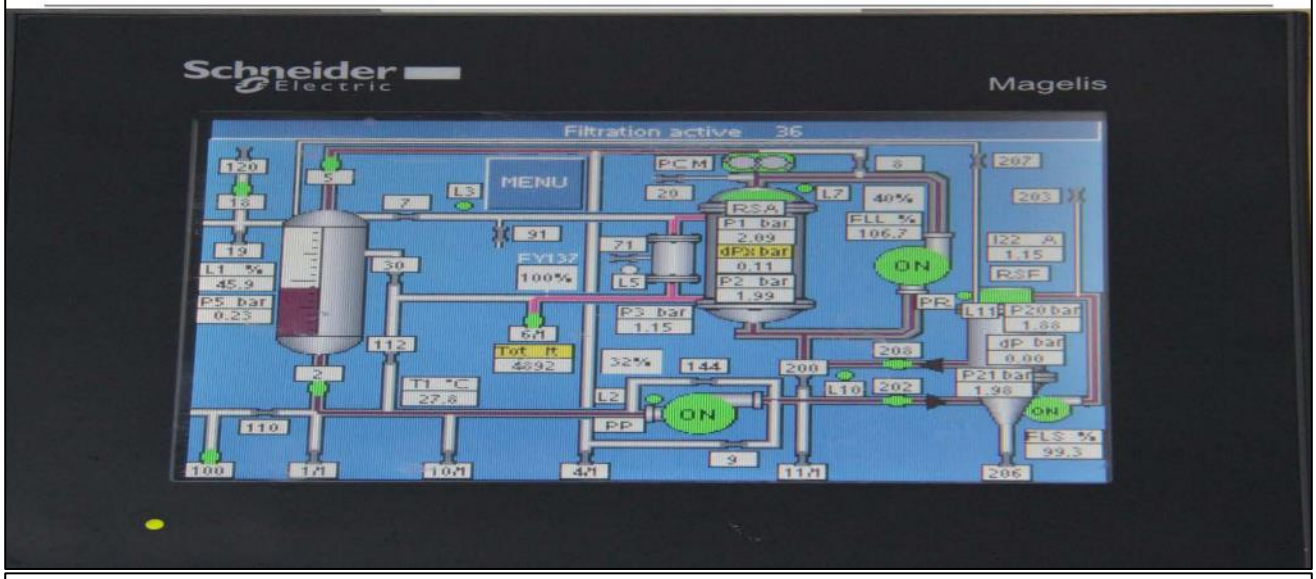
Intake juice lees filtration – DT CFKF 170/67



14

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Intake juice lees filtration – DT CFKF 170/67



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Performance – flotation juice lees



Metric	CFKF 170/67
Flotation lees % solids (input feed)	30-40% solids
Processing capacity (clears/unit)	700-1000 l/hr
Processing capacity (lees/unit)	1000-1670 l/hr
Cleaning cycle frequency (mean)	36 hrs
Cleaning cycle duration	4 hrs/cycle
Discharge % solids (mean)	85%-95% @ run
Recovery (clears/total lees volume)	73%

16

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Wine lees



17

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Operating cost comparison cf RDVF – juice flotation lees

Per 10,000 tonnes	RDVF	HSXF
Lees volume @ 10% at 760l/t	760,000 L	760,000 L
Grape Solid Waste (tonnes)	175 tonnes	175 tonnes
DE usage 3kg/tonne	30 tonnes	-
Total waste (tonnes)	205	175
Waste disposal @ $100/tonne	$20,500	$17,500
DE Cost	$42,000	-
Direct labour cost @$19.5	$9,000	$5,000
Opex cost per tonne (c/L)*	$5.10 (0.68c/L)	$2.25 (0.3 c/L)
Product Value uplift ($/L)	-	0 to ?

18

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Value creation & payback - tangible and intangible



- Juice lees product value uplift (if available)
- Wine lees product value uplift (if available)
- Automation lowers labour cost (50%)
- Lower waste disposal cost (15%)
- Significantly lower water usage (90%)
- DE cost avoidance
- Process efficiency (esp juice lees processing avoidance of degradation due to premature fermentation)
- Much less mess
- DE handling WH&S issues – cost avoidance
- Environmental impact – modest decrease

19

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Performance expectations and limitations

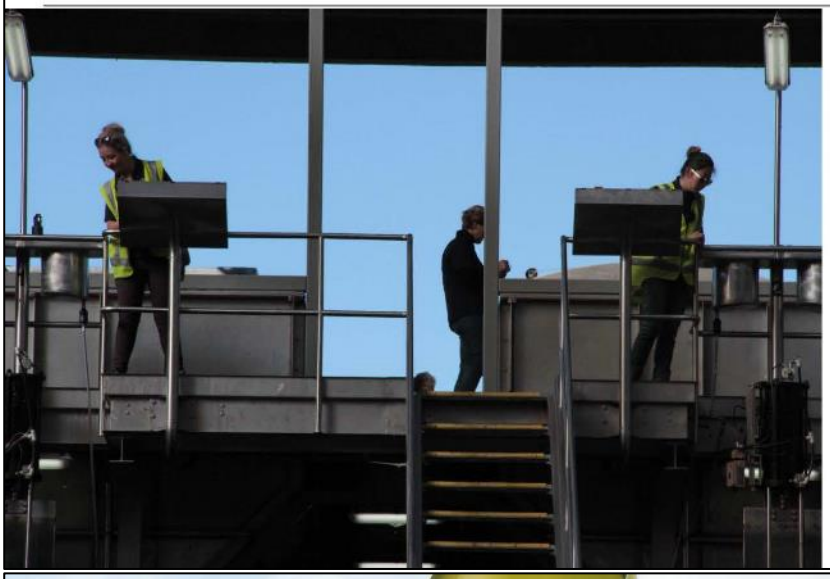


- Easy to use but operators do need some base knowledge about the machine's operation
- Few moving parts
- Ceramic filter life unknown but very stable so far (2 years – DT provide a prorata 10 year warrantee)
- 1 x CFKF170/67 ~ 20m2 RDVF work throughput
- If the in-feed lees stock is already at 70-80+% solids it won't filter
- Heavy red & white wine lees – rack lighter lees product from heavy material
- Perlite - don't do it!
- Expect to do some maintenance during vintage – brush strainer cleaning & brush replacement
- It really is this clear – juice NTU is too low!

20

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Considerations – process capacity planning



- Consider your intake & juice processing as one process
- What is the slowest process step?
- What does the v-curve look like?
- Consider down-time AND cleaning cycles in capacity calculations
- Consider vintage variations (solids, yields, extraction & volumes)
- Understand where solids are being generated
- Brochures – always state the maximum it can do under perfect conditions with no cleaning or breakdowns

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24



Experiences in Clarifying Juice Lees

TREASURY WINE ESTATES



Agenda

Dynamic Cross Flow

- Padovan and Andritz rotary ceramic disk filters or dynamic cross flow (DCN).

Decanter

- Westfalia Model GEA CF5000 decanter.

TWE

Improving juice lees clarification -

- Rotary vacuum drums (RDV'S) were reaching end-of-life.

- Oxidation, Dilution, Perlite Taint, Water usage, Waste Disposal, Product quality down grade, OH & S issues.

- 1970's technology in the 21st century.



3

TWE

Improving juice lees clarification -

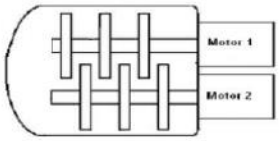
- Juice lees clarification was our main initial target.
- Required technology to fit the changing footprint of modern day wineries.
  - Consolidation of wineries
  - Complexity of sku's.
  - Compressed vintages
- Filter lees product from a "hard rack"
  - Juice 20 – 30 v/v solids %
  - White wine 40 – 55% v/v solids (bento lees).
- Rapid turn around of juice batches a priority and related to quality.

4

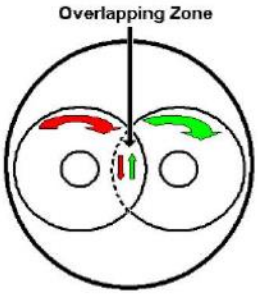
TWE

Rotary Ceramic Disk Membrane

Top view



Front view



The rotary stacks overlap themselves and maximize the cleaning effect on the discs both during filtration and washing (very low water demand).

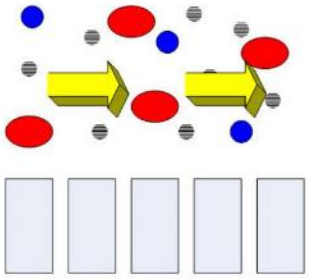
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TWE

Dynamic Cross Flow (DCF)

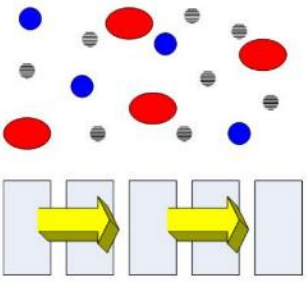
Coventional Cross Flow Filtration

1 – Static Membranes
2 – Flowing Liquid



Membrane Rotation Filtration

1 – Rotating Membrane
2 – Static Liquid



8

TWE

Padovan Dynamos 20 DCN

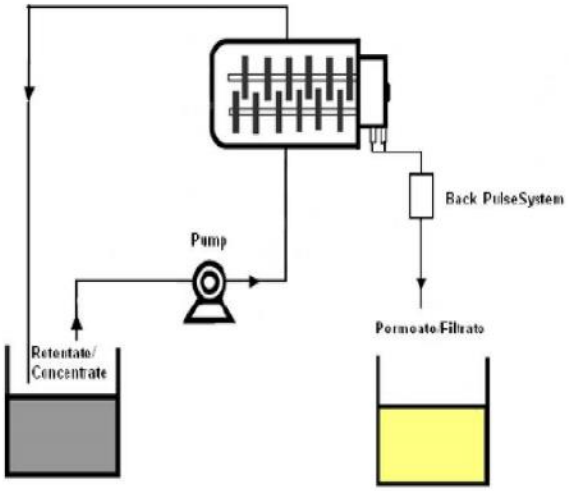
Western Australia Winery 2014



TWE

Commissioning Padovan Dynamos 20

Western Australia Winery 2014



Filtering Area 19.6 m2
Nominal Porosity 0.1 um

- For DCN technology skins and seed need to be removed using a brush strainer.
- Padovan system re-circulates via a buffer tank adequate tank mixing is required at aid circulation.

☒ Over complicated control systems with too many alarms.

☒ Lower than expected flow rates of 500 lph when filter clean.

TWE

Padovan Dynamos 20

Western Australia Winery 2014

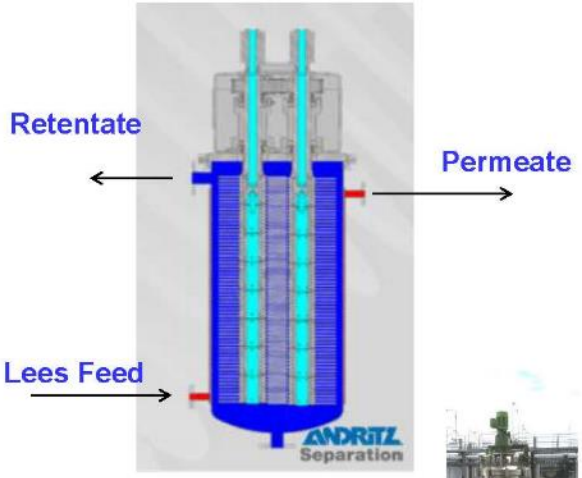


- ☑ Tank Utilisation benefit.
- ☑ Good quality product for juice lees although over ideal clarification.
- ☑ Good quality product for white wine lees.
- ☑ Good quality product for red wine lees post malo.
- ☑ Slow flow rate OK for 5,000 ton Winery.

TWE

9

V15 Barossa Winery Andritz DCF312





Filtering Area 16.4 m2
Nominal Porosity 0.1 um

- For DCN technology skins and seed need to be removed using a brush strainer
- ☑ Andritz system single pass.
- ☒ Alarming and software glitches.
- ☒ Water add during alarm.
- ☒ Feed pump too small
- ☑ Recovery rates compatible with RDV (85% for juice lees, Retentate 70 – 80 % v/v)

TWE

10

V15 Barossa Winery Andritz DCF312



Filtering Area 16.4 m2
Nominal Porosity 0.1 um

- ☑ Good quality product for juice lees although over ideal clarification.
- ☑ Good quality product for white wine lees
- ☒ Poor quality product for young red wine lees as mousy character may develop due to interruption of malo-lactic fermentation
- ☒ Lower than expected flow rates (ave flow rate for juice 525 lph)

11

TWE

Conclusions Rotary Ceramic Cross Flow

- Systems tend to over-alarm. This maybe zealousness to protect ceramic membranes.
- Suitable ability to process both juice and white wine lees.
- Recovery compatible with RDV but quality improved.
- Lower flow rates make this technology more suitable for smaller wineries but not for medium – large wineries.
- No current options for the rotary ceramic flow rates to have flow rates greater than 1 klph.

12

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V16 Decanter Trials Barossa Winery

Model GEA GCF475 decanter



The decanter used for juice lees clarification is a horizontally arranged scroll centrifuge. Solids separation is facilitated as the scroll rotates at slightly higher rpm than the bowl. Clarified juice is exuded *via* a centripetal pump. The solids exit the decanter by gravity *via* a funnel and drops into an auger.

13

TWE

Impetus – Quality

Separating juice from solids quickly.

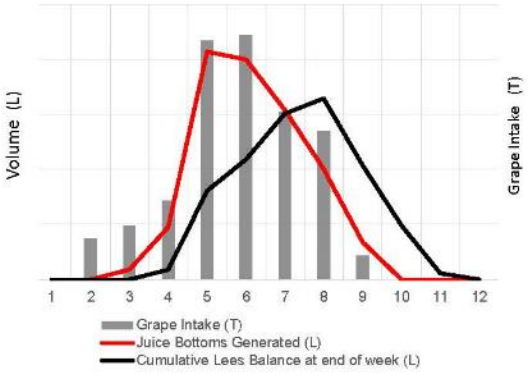
- The longer juice lees remains unclarified, the lower the sensorial quality of wine produced.
- Juice spending extended time on lees risks fermentation on solids and a subsequent quality write down.
- Ideally juice lees should be clarified the day that they are produced.
- Flow rates of 2 – 4 klph required to meet production needs.

14

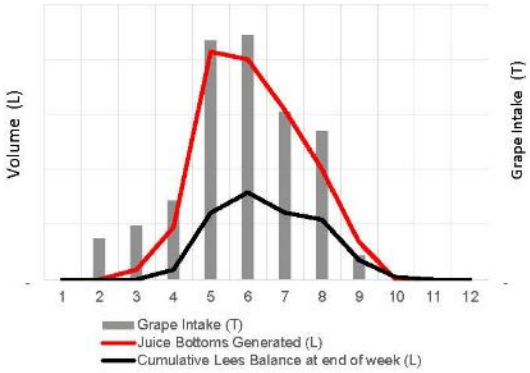
TWE

Juice Throughput

Not ideal - Grape Intake and Lees



Ideal - Grape Intake and Lees



Aim – to process juice in a timely manner. And avoid scenarios where juice spends extended time on lees

15

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Achieving clarification targets





Solid criteria was less than 1.5 % v/v solids.

It took us a while to achieve the desirable solid output level.

16

TWE

Achieving clarification targets



- Solid levels of less then 1.5 % v/v was achieved by finding the right fining agent.
- Inline dosing system was probably not necessary.
- Very thorough mixing of the feed tank to a consistent solid feed considered to be critical to meet performance criteria.
- Static mixer on outlet of feed pump.
- The average flow rate for the decanter was approx. 2350 lph.

17

TWE

Juice Recovery



☑ Over- all recovery of juice across vintage through the decanter was 90 %.

☑ Average solids discharge was measured at 56 % dry solids and had the consistency of toothpaste.

18

TWE

Conclusions Decanter at Barossa Winery

- The decanter can be used to rapidly clarify juice lees
- Choosing the right fining agent and adequate feed tank mixing are the most important factors.
- Better quality juice and higher recoveries were achieved compared to the RDV.
- The decanter does not work for wine lees including bentonite lees and tartrate lees.

TWE

Thank you

Contributors

Vanessa Stockdale

Peter Munro

Luke Skeer

Ben Miller

TWE

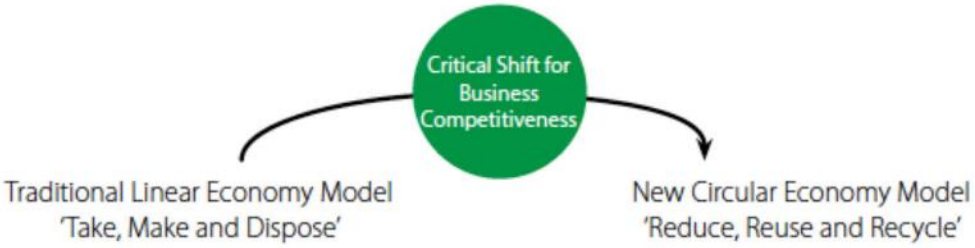
AMS FILTRATION

Sustainability Through Advanced Technology

Sustainability: An Emerging Megatrend

Sustainability is forcing fundamental shifts in how businesses compete

- Planet
- People
- Profit



AMS FILTRATION

History

- AMS Filtration founder, Gilbert Erskine, has worked in the filtration/ separation industry for 30 years
- Gilbert Erskine has provided plant & equipment to the wine industry in Australia
- Membrane technology has been developed and refined over the last 10 to 15 years

AMS FILTRATION

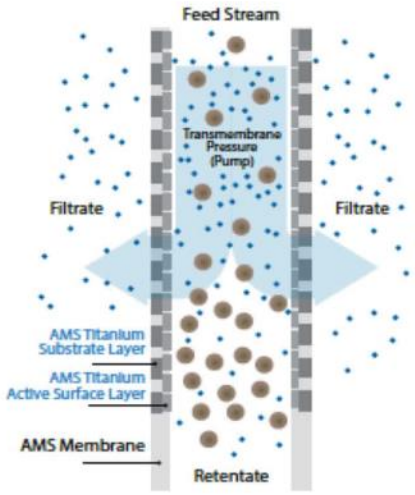
Titanium Properties

- High Strength (Pressure resistant)
- Temperature resistant (melting point of 1725°C)
- Bio Compatible
- Non Corrosive

AMS FILTRATION

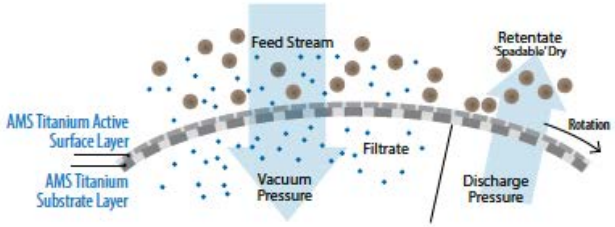
Cross Flow Membrane & Systems

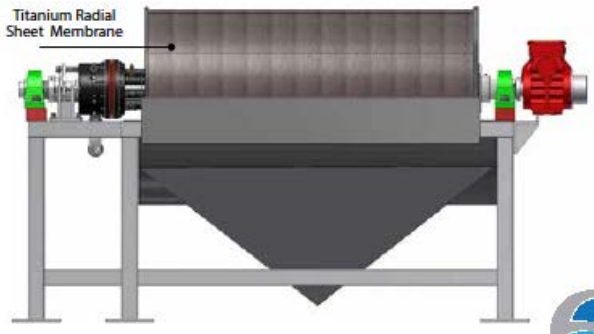




AMS FILTRATION

Rotary Drum Vacuum (RDV)





AMS FILTRATION

Wastewater

- Suspended Solid reduction up to 99%
- BOD reduction up to 94%
- COD reduction up to 92%
- Grease/ Oil reduction up to 99%

AMS FILTRATION

Thank you!

AMS FILTRATION

8. Appendix B – Intellectual property

No explicit intellectual property needing to be protected.

9. Appendix C – Staff

Project Supervisor: Vincent O'Brien,
Chief Investigator: Simon Nordestgaard
Project Engineer: Tadro Abbott

10. Appendix D – Additional data

Table D.1: Winery juice lees sample data

Winery	Process	Sampling location	Variety/detail	Wet solids content (v/v)	Dry solids content (w/w)	Static yield stress (Pa)	Dynamic yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)
A	Settling	Settling tank - Bottom valve (pre-rack)	Gewurztraminer - Free-run	27%	7.0%	<0.5	0.3	5.8
A	Settling	Settling tank - Bottom valve (pre-rack)	Gewurztraminer - Pressings	30%	7.2%	<0.5	0.4	6.5
A	Settling	Settling tank - Bottom valve (pre-rack)	Gordo (with Na/Ca bentonite)	31%	10%	<0.5	0.3	5.3
A	Settling	Settling tank - Bottom valve (pre-rack)	Gordo (with Na/Ca bentonite)	31%	9.0%	<0.5	0.3	5.2
B	Centrifugation	Desludge outlet	Chardonnay - Free-run	37%	17%	2	0.8	17
B	Centrifugation	Desludge tank inlet	Chardonnay - Pressings	15%	1.6%	0.6	0.6	6
B	Settling after centrifugation	Lees tank (agitated) - sample tap	Gordo - Free-run	7%	0.9%	<0.5	0.1	2.7
B	Settling after centrifugation	Lees tank (agitated) - sample tap	Gordo - Free-run/Pressings	10%	1.4%	<0.5	0	3
B	Settling after centrifugation	Lees tank (agitated) - sample tap	Colombard - Pressings	16%	1.8%	<0.5	0.1	3.3
B	Settling after centrifugation	Lees tank (agitated) - sample tap	Sauvignon Blanc - Free-run/Pressings	9%	1.0%	<0.5	0.02	2.7
B	Settling after centrifugation	Lees tank (agitated) - sample tap	Chardonnay - Free-run/Pressings	10%	1.1%	n.m.	0	3
B	Settling after centrifugation	Lees tank (agitated) - sample tap	Chardonnay - Free-run/Pressings	8%	0.8%	<0.5	0.1	3.3
B	Settling after centrifugation	Settling tank - Bottom valve (pre-rack)	Chardonnay - Free-run/Pressings	30%	3.2%	0.6	0.4	7.5
B	Flotation	Lees tank - Bottom valve	Chardonnay	34%	8.6%	2.5	0.8	17
C	Centrifugation	Desludge outlet	Chardonnay - Pressings	27%	9.1%	0.6	0.45	7.5
C	Centrifugation	Desludge outlet	Chardonnay - Free-run	72%	27%	9.1	5	42
C	Centrifugation	Desludge outlet	Riesling - Free-run	76%	17%	17.5	12	63
C	Flotation after centrifugation	Buffer tank door	Chardonnay - Pressings	n.m.	5.0%	n.m.	5	25
C	Centrifugation & Flotation	Feed to RVDF	Semillon/Riesling	24%	5%	<0.5	0.2	6.8

Table D.2: Winery white ferment lees sample data

Winery	Process	Sampling location	Variety/detail	Wet solids content (v/v)	Dry solids content (w/w)	Static yield stress (Pa)	Dynamic yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)
A	Settling	Sampled by winery post-racking (asked for thickest lees)	Fiano (with Na/Ca bentonite)	55%	13%	1.1	0.8	14
A	Settling	Sampled by winery post-racking (asked for thickest lees)	Vermentino	67%	29%	<0.5	0	37
A	Settling	Sampled by winery post-racking (asked for thickest lees)	Chardonnay (with Na/Ca bentonite)	40%	10%	0.7	0.4	8.2
A	Settling	Sampled by winery post-racking (asked for thickest lees)	Chardonnay (with Na/Ca bentonite)	51%	18%	2.2	1.5	23
A	Settling	Sampled by winery post-racking (asked for thickest lees)	Chardonnay	39%	18%	1	0.7	26
B	Settling	Settling tank - Bottom valve (pre-rack)	Chenin Blanc	51%	15%	<0.5	0.3	14
B	Settling	Sampled by winery post-racking (asked for thickest lees)	Chardonnay	55%	21%	<0.5	0.3	14

Table D.3: Winery red ferment lees sample data

Winery	Process	Sampling location	Variety/detail	Wet solids content (v/v)	Dry solids content (w/w)	Static yield stress (Pa)	Dynamic yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)
A	Centrifugation	Desludge outlet	Cabernet Sauvignon	90%	29%	25	25	279
B	Settling	Lees tank (agitated) - racking valve	75% P. Verdot + Shiraz, Cab, Merlot	47%	16%	28	22	132
B	Settling	Settling tank - door (starting to pump lees away)	Shiraz	45%	14%	37	42	142
B	Settling	Settling tank - door (0.4 m lees remaining)	Shiraz	57%	21%	100	105	256
B	Settling	Settling tank - door (0.2 m lees remaining)	Shiraz	47%	18%	128	n.m.	n.m.
B	Settling	Settling tank - door	Cabernet Sauvignon	38%	12%	15	25	73
B	Settling	Settling tank - door (starting to pump lees away)	Merlot	56%	18%	54	n.m.	n.m.
B	Settling	Settling tank - door (0.2 lees remaining)	Merlot	57%	16%	44	n.m.	n.m.
B	Settling	Settling tank - door (starting to pump lees away)	Cabernet Sauvignon	61%	20%	71	n.m.	n.m.
B	Settling	Settling tank - door (chips on tank floor)	Cabernet Sauvignon	n.m.	33%	297	n.m.	n.m.
B	Settling	Settling tank - door (sludge on top of chips)	Cabernet Sauvignon	60%	19%	64	55	206
B	Settling	Lees tank (agitated) - sample tap	Red	40%	14%	12	13	92
B	Settling	Lees tank (agitated) - sample tap	Red	54%	17%	73.5	65	247
B	Settling	Settling tank - door	Shiraz (malo lees)	49%	17%	26	22	97

Table D.4: Winery wine bentonite lees sample data

Winery	Process	Sampling location	Variety/detail	Wet solids content (v/v)	Dry solids content (w/w)	Static yield stress (Pa)	Dynamic yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)
A	Settling	Settling tank - Bottom valve (pre-rack)	Rosé (Na/Ca bentonite)	28%	10%	0.9	0.55	7.2
B	Settling	Sampled by winery post-racking (asked for thickest lees)	Chardonnay (Na bentonite)	22%	3.50%	1.1	0.3	5.6

Table D.5: Uncategorised winery lees sample data

Winery	Process	Sampling location	Variety/detail	Wet solids content (v/v)	Dry solids content (w/w)	Static yield stress (Pa)	Dynamic yield stress (Pa)	Viscosity @ 500 1/s (mPa.s)
B	Settling	Lees tank (agitated) - sample tap	Sweet white wine	28%	6%	1.1	1	14
B	Settling	Settling tank - Bottom valve (post-rack)	Port (Na bentonite)	60%	4.4%	2.6	2.2	13
B	Centrifugation	Mixed desludge tank (not agitated)	White/Rosé ferment	80%	25%	6.3	4	83

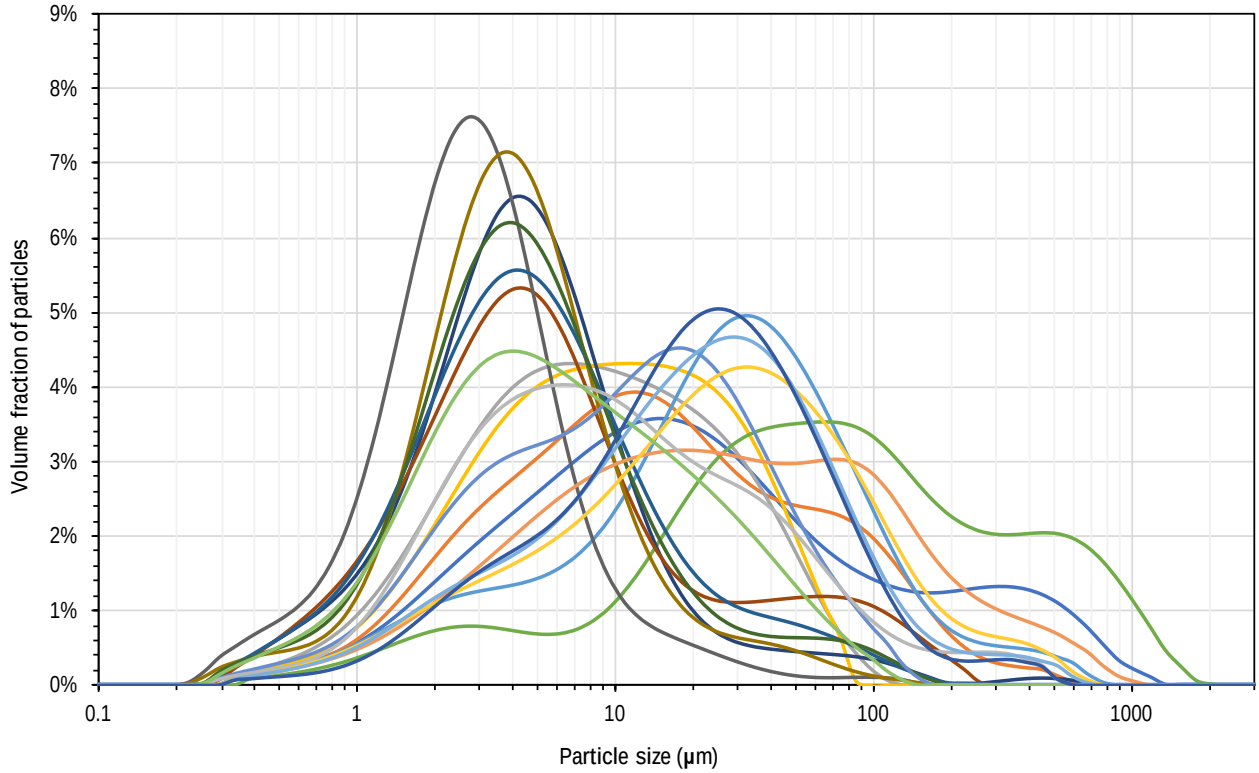


Figure D.1: Particle size distribution of juice lees samples

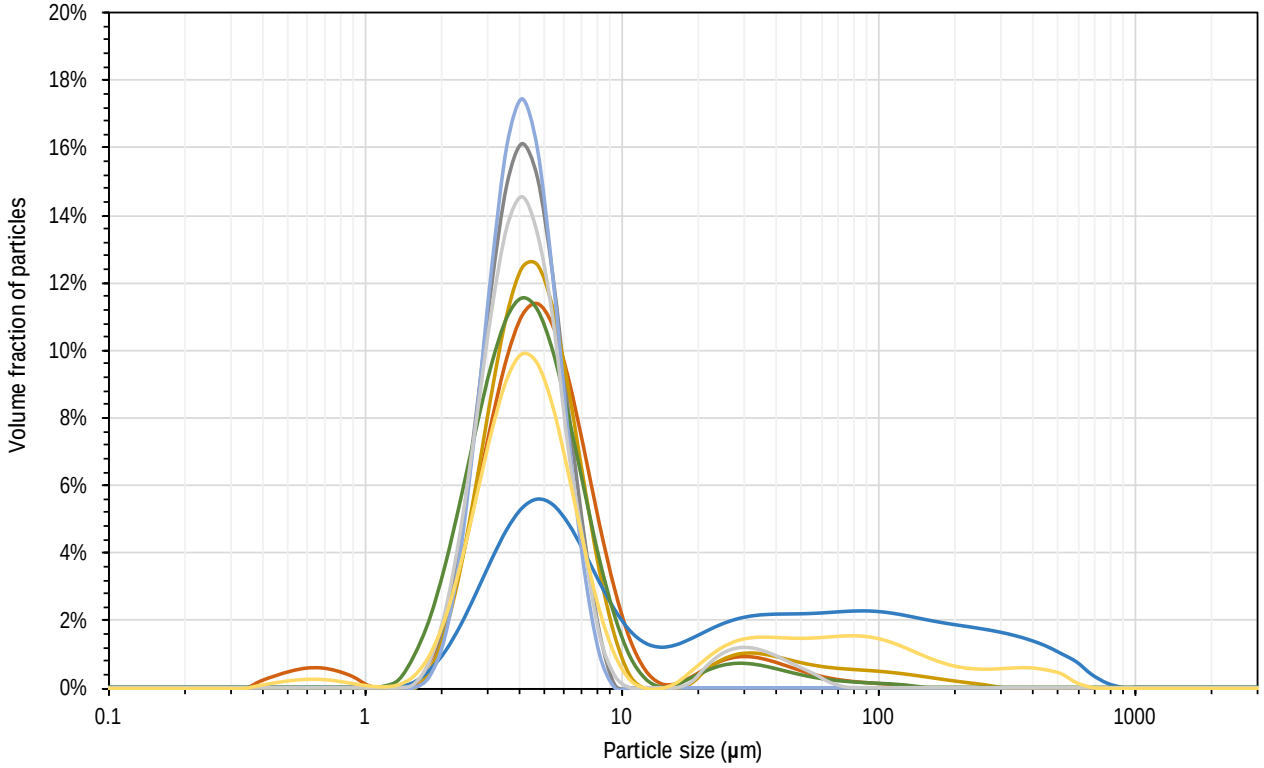


Figure D.2: Particle size distribution of white ferment lees samples

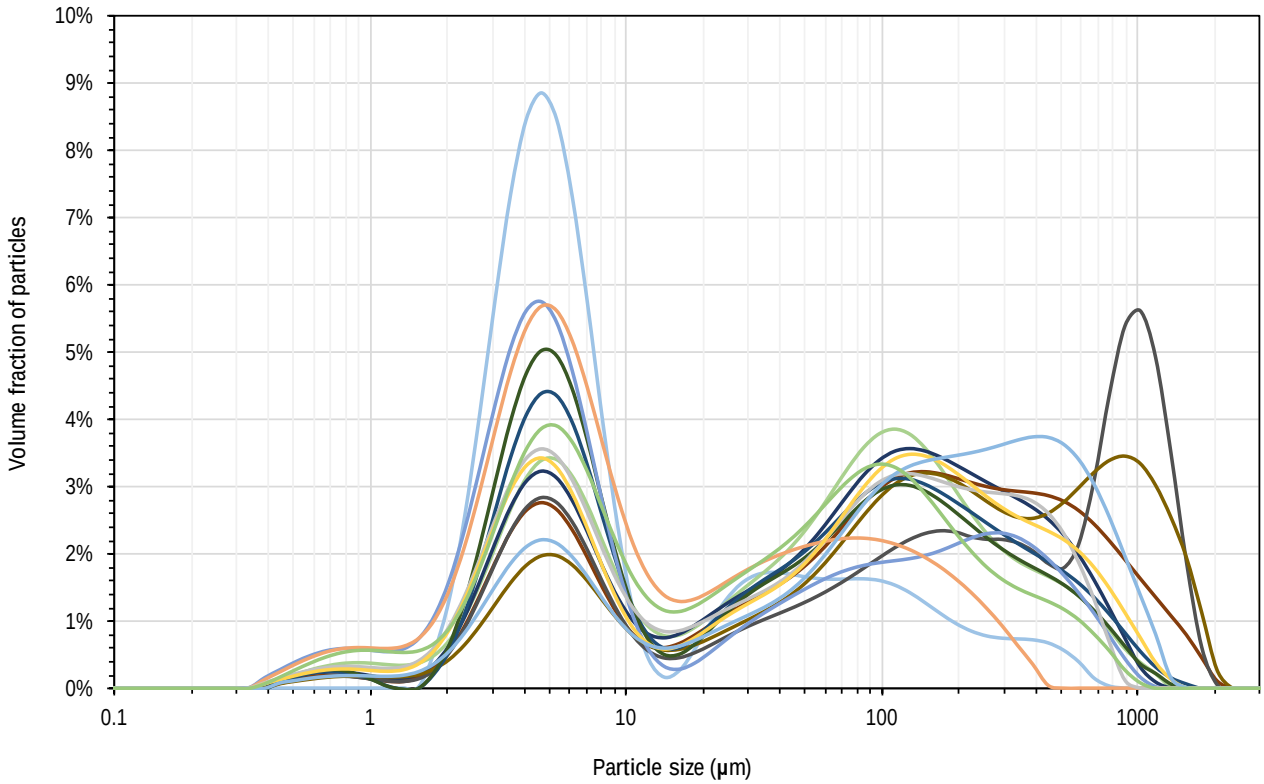


Figure D.3: Particle size distribution of red ferment lees samples