What is flotation, and how does it work?

Flotation is a separation technique which, like cold settling of juice, exploits density differences between solid particles and the surrounding liquid. However, while solids precipitate in cold settling because they are denser than the liquid, the opposite occurs during flotation, with solids rising upward through a buoyancy gained by the adhesion of tiny bubbles of gas.

Flotation via centrifugation was initially employed in the early eighties at Southcorp's Karadoc Winery. In this process, nitrogen gas was injected directly into the centrifuge disc stack (where this facility existed) or directly into the inlet side of the product flow to the centrifuge. The injected nitrogen was then held under pressure, at 3.25 bar, until at the entry point to a flotation tank. Success in this process depends on:

- the head of liquid, in relation to the diameter of the flotation tank;
- providing adequate time for solids to float to the surface of the liquid; and
- holding the gas in solution until just prior to the flotation tank.

After vintage 1993, Southcorp was required to increase its juice clarification capacity, and juice flotation equipment was seen as an alternative to purchasing additional centrifuges. In September 1993, a number of flotation units were viewed in action at various wineries in northern Italy. During the vintage of 1994, the first flotation unit was installed and evaluated at Karadoc winery.

Flotation equipment design

Flotation units are designed to saturate fresh grape juice with gas micro bubbles that adhere to the solid juice particles bringing them to the liquid surface. To clarify juice by flotation, juice is subject to the following treatment stages, as indicated in Figure 1.

- Depectinisation
  Enzyme addition reduces the juice colloidal content and thus reduces the juice viscosity. It is critical to successful flotation.

- Screen filtering
  Juice coming from presses may still contain seeds, skins, and other solid or mucilaginous matter. These particles must therefore be removed by using continuous drum type rotary screens.

- Dosing of clarifying agents
  Clarifying agents surround the solid particles forming a floc. Gelatine and bentonite have the property of replacing the water surrounding the solids, allowing gas bubbles to firmly adhere to the solids formed, thereby allowing the floc to rise easily to the surface. In addition, bentonite will reduce the quantity of proteinaceous substances, polyhydric phenols and oxidase enzymes in the juice.

  Bentonite is the basic clarifying agent for good flotation efficiency. It is possible to treat a juice with bentonite only and obtain good flotation results. Bentonite has the property of surrounding the solid on which the saturation gas micro bubbles have distributed, thus rendering the solid impermeable and therefore suitable for flotation.

  The turbid fraction of the juice is hydrophilic, i.e., it tends to get surrounded with water molecules that prevent air micro bubbles from readily adhering onto the solids surface. Gelatine becomes interposed between the solid and the water, rendering the solid hydrophobic, and helping it to attract air bubbles to its surface. Consequently, a juice subjected to flotation with bentonite only will give a good flota-
tion result but the separation of flocs will not be complete - bentonite/gelatine gives a better result. Typical addition rates are given in Table 1.

The contact time of fining agents is fairly short, approximately 1 hour. The clarifying agents are added in various proportions to 2 litres of juice in a test unit. The test unit is pressurised to 5 bar and agitated vigorously. After two minutes, the juice is pushed under pressure into a measuring cylinder. Within 5–10 minutes, the operator can determine how successful the flotation will be and ascertain the correct addition rate.

Saturation
The juice is saturated with gas under pressure in a special column saturator that ensures maximum gas adsorption. The clarity of the juice is unaffected by the use of air or nitrogen. Hyperoxidation results with the use of air in sulphur dioxide-free juice; this causes polymerisation of phenols which separate from the juice. Gas consumption under a pressure of 5 bars is as in Table 2.

When SO₂ treated juice was used with air as the saturation gas, trials indicated that juice colour was unaffected and that only 1 ppm free SO₂ was lost during the flotation process.

Separation of solids
The final stage is for the juice, that is now under pressure with air or nitrogen, to be fed into a flotation chamber where the micro bubbles raise the solids to the surface. The solids fraction is then continually removed. Lees produced during flotation represent 13–18% of the processed juice, depending on the initial juice solids content. Juice that contains more than 11% suspended solids is difficult to float as flow rates are considerably reduced.

Juice clarity
In the flotation chamber, three phases of juice clarity exist (Figure 2):

• Phase I: Clear juice at the bottom 20–30 cm of the flotation chamber (the greater the depth of clear juice, the more the flow rate can be increased).
• Phase II: Visible floc formation and separation at 50–60 cm of depth in flotation chamber.
• Phase III: 30–40 cm of compact lees below the suction heads.

<table>
<thead>
<tr>
<th>Bivalent (mg/L)</th>
<th>Gelatine (mg/L)</th>
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<tbody>
<tr>
<td>Sultana 500–600 and 100–200</td>
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<td>Chardonnay 900 and 200</td>
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Table 1. Addition rates for clarifying.

<table>
<thead>
<tr>
<th>Flow rate kL/hour</th>
<th>Flotator N² consumption metres²/hour</th>
<th>Centrifuge N² consumption metres³/hour</th>
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</thead>
<tbody>
<tr>
<td>10</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>6</td>
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<tr>
<td>30</td>
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Table 2. Gas consumption by juice under pressure of 5 bars.

Table 3. Comparison of performance of centrifuge and flotation unit.

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- The presence of protective colloids that reduce flotation speed by considerably increasing juice viscosity. The less viscous the juice is, the easier it is to clarify. Depectinisation is therefore essential.
- The density difference between the suspended solids and the juice.
- Low temperature, as this increases the viscosity which reduces the flotation speed. High temperatures facilitate enzyme activity, but high temperatures also reduce the gas solubility.
• The proportion of suspended solids to be removed from the juice.

Comparisons between flotation units and centrifuge/flotation techniques

Results of trials at a flow rate of 25 kl/hour with a Sultana juice that contained 7% suspended solids are presented in Table 3. With the flotation unit, turbidity and percentage yeast removal can be improved by reducing flow rate. A turbidity of 20 NTU has been achieved in Sultana juice, and claims that 86% yeast removal have been achieved have been made for flotation.

Advantages of flotation units over centrifuges
• Higher flow rate for a given capital cost:
  A 25–30 kl/hour Velo flotation unit costs $245,000–250,000; A 24 kl/hour Westfalia SC 150 centrifuge would cost $500,000.
• Potential to protein stabilise juice.
• Less labour intensive.
• Dosing units can be used elsewhere within the winery.
• Better utilisation of working space tanks.
• No dilution of solids (compared with using water displacement on centrifuges).
• Power and maintenance cost savings.
  Power costs per hour: SA 160 = $10.98; Velo Flotation unit = $2.18; annual maintenance and vintage replacements: SA 160 = $35,620; Velo Flotation unit = $4,100

Disadvantages of flotation units
• They generate increased juice lees, requiring greater use of lees recovery filtration equipment (but this is offset by virtually no gross lees post fermentation and less wine stabilising lees).
• A greater juice volume is required to produce stabilised flotation runs; centrifuges are more suited to small batch processing.
• Flotation can only clarify juice; centrifuges can clarify both wine and juice.
• Flotation units occupy more floor area.
• The flotation chamber on a 30 kl/hour machine is 6 metres in diameter itself.

Conclusion

Flotation is a viable alternative to cold setting or centrifugation in medium to large wineries. Additional advantages over cold settling are:
• Immediate juice clarification.
• Energy savings, since refrigeration resources can be employed for ferment control rather than holding juice while settling.
• Fewer process tanks are tied up.
• Cleaner juice.
• Less lees volume.
• Continuous clarification.

References