Ethanol Removal from Wine: Making More with Less

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Alcohol Levels Going Up

- **Australia**
  - Red wines: 12.4% (1984) to 14.4% (2008)
  - White wines: 12.5% (1985) to 12.9% (2008)

Why Remove Alcohol?

- Wine style
- Health – disease, injury
- Social impacts – drink driving, violence
- Financial impacts – some jurisdictions tax according to alcohol content
- Pressure to reduce alcohol consumption
Overview

• Commercial ethanol removal techniques
  – SPP versus membrane

• Compositional analysis of wines

• Sensory comparisons
Spinning Cone

System Design

**Stripping column**
- Vacuum
- Low temperature
- High solids ok
  - Juice conc.
  - De-sulfuring

Vertical Column
Central rotating shaft
Normal Speed 350 rpm
Wine & Stripping Flow

Down stationary cone under gravity

Up rotating cone under centrifugal force

Stripping Vapour (Reinjected Wine)
Alcohol removal in 2 stages

De-aromatisation: 0.04 atm/26-28°C
Ethanol base with aroma ~ 1% vol

Dealcoholisation: 36-38°C
Product strength > 50% v/v
<table>
<thead>
<tr>
<th>Process</th>
<th>Approx. size</th>
<th>Separation Mechanism</th>
<th>Driving Force</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanofiltration</td>
<td>0.5 – 5.0 nm</td>
<td>Sieving &amp; charge effects</td>
<td>Pressure</td>
<td>Juice sugar removal</td>
</tr>
<tr>
<td>Reverse Osmosis</td>
<td>0.1 -1.0 nm</td>
<td>Semi-permeable membrane</td>
<td>Trans membrane pressure</td>
<td>Ethanol removal</td>
</tr>
<tr>
<td>Osmotic distillation (perstraction, membrane</td>
<td>0.03 – 0.5 um</td>
<td>Volatilisation &amp; permeation</td>
<td>Vapour pressure gradient</td>
<td>Ethanol removal, aroma, water</td>
</tr>
<tr>
<td>Pervaporation</td>
<td>Non-porous</td>
<td>Partial vaporization</td>
<td>Partial pressure differential</td>
<td>Ethanol removal, aroma, water</td>
</tr>
</tbody>
</table>
# Reverse Osmosis

## Nominal molecular weight cut off

<table>
<thead>
<tr>
<th>Component</th>
<th>Molecular Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>18</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>44</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>44</td>
</tr>
<tr>
<td>Ethanol</td>
<td>46</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>60</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>88</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>90 “tight” RO↑</td>
</tr>
<tr>
<td>Malic acid</td>
<td>134</td>
</tr>
<tr>
<td>Tartaric acid</td>
<td>150</td>
</tr>
<tr>
<td>Volatile phenols</td>
<td>120-150 “loose” RO↑</td>
</tr>
<tr>
<td>Glucose / Fructose</td>
<td>180</td>
</tr>
<tr>
<td>Flavonoids</td>
<td>&gt;300</td>
</tr>
</tbody>
</table>

## Aroma compound loss
Osmotic Distillation

- Also known as
  - Isothermal membrane distillation
  - Evaporative perstraction
  - Membrane contactor

[Diagram showing the process of Osmotic Distillation]

- Higher temp. favours ethanol permeation
- Degassed water
- Operation at 40°C
- Polypropylene
- polyvinylidene fluoride
- Or permeate from RO
- High ethanol permeate
- Stripping phase (low ethanol)
- Reduced ethanol retentate
- High ethanol wine
Alcohol Adjustment (AA) Process

- Combination of two processes:
- Reverse Osmosis and Evaporative Perstraction
<table>
<thead>
<tr>
<th></th>
<th>Membrane (RO + Perstraction)</th>
<th>Spinning Cone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wine requirements</td>
<td>Heat &amp; cold stable Pectin &amp; glucan free NTU &lt; 50</td>
<td>Unstable wines ok High solids ok</td>
</tr>
<tr>
<td>Number of passes</td>
<td>Multiple</td>
<td>Two (Flavour, ethanol)</td>
</tr>
<tr>
<td>Strip ethanol conc.</td>
<td>&lt;10% v/v (batch)</td>
<td>&gt; 50% v/v (65% typical)</td>
</tr>
<tr>
<td>Potential ethanol removal/pass</td>
<td>0.7 – 1.5% v/v</td>
<td>0.5 – 15% v/v</td>
</tr>
<tr>
<td>Residence time</td>
<td>Minutes</td>
<td>10-20 seconds per pass</td>
</tr>
<tr>
<td>Process time</td>
<td>Hours/days</td>
<td>Hours</td>
</tr>
<tr>
<td>Flavour Impact</td>
<td>Some compounds pass through membranes</td>
<td>Recovered aroma in 1% vol added back to BW</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>20-22°C (RO) ~40°C (Perstraction)</td>
<td>~28°C (flavour) ~36°C (ethanol)</td>
</tr>
<tr>
<td>Water removal</td>
<td>High – but reclaimed</td>
<td>Negligible</td>
</tr>
<tr>
<td>Water consumption</td>
<td>Moderate (Perstraction)</td>
<td>Minor</td>
</tr>
<tr>
<td>Consumables</td>
<td>Membranes</td>
<td>N/A</td>
</tr>
<tr>
<td>Capital</td>
<td>$$</td>
<td>$$</td>
</tr>
</tbody>
</table>
Memstar ‘Mini’
Wine must be **VERY** clean
Temperature 18-20°C (tank cooling)
Permeate rate ~ 60 L/hour
Strip water ~ 180 L/hr

Approx 40 hours to reduce 2% v/v in 10kL
Experiment 1 - Alcohol Adjustment

- Varieties
  - Chardonnay 12.2%
  - Sauvignon Blanc 9.9%
  - Shiraz 13.7%

- Adjusted to:
  - 10% alcohol
  - 8% alcohol
  - 5% alcohol
Ethanol Content During Operation

![Graph showing the ethanol content over time for different wines: Shiraz, Chardonnay, and Sauvignon Blanc. Each wine has a corresponding line and scatter points representing the ethanol content at various time intervals.]
Rate of Ethanol Reduction

Shiraz  
Chardonnay  
Sauvignon Blanc

Ethanol Reduction Rate (% v/v/hr)  
Time (hrs)
Ethanol conc. in strip water
Sauvignon Blanc Headspace Composition

Change in Headspace Concentration Compared to Original Wine (%)

- Decanoic acid
- Octanoic acid
- Propanoic acid
- (z)-3-hexenol
- 3-methyl-1-butanol
- Beta-phenyl ethanol

Sauvignon Blanc 5 %
Sauvignon Blanc 8 %
Sauvignon Blanc Headspace Composition

![Graph showing the change in Headspace Concentration Compared to Original Wine (%)]

- Beta-phenyl ethyl acetate
- Ethyl butyrate
- Ethyl decanoate
- Ethyl hexanoate
- Ethyl octanoate
- Ethyl-2-methyl butyrate
- Ethyl-3-methyl butyrate
- Ethyl-s-lactate
- Isoamyl acetate

Compared to Original Wine (%): Sauvignon Blanc 5 %, Sauvignon Blanc 8 %
<table>
<thead>
<tr>
<th></th>
<th>Chardonnay</th>
<th>Shiraz</th>
<th>Sauvignon Blanc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5%</td>
<td>8%</td>
<td>5%</td>
</tr>
<tr>
<td>Acid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decanoic acid</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Octanoic acid</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Propanoic acid</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Alcohol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(z)-3-hexenol</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>3-methyl-1-butanol</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Beta-phenyl ethanol</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Ester</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta-phenyl ethyl acetate</td>
<td>-</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Ethyl butyrate</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ethyl decanoate</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ethyl-s-lactate</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Isoamyl acetate</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

Change 0-25%: - or +  25-50%: -- or ++  >50%: --- or +++
Change with Alcohol Concentration

• Decreasing alcohol concentration
  – Volatile HS conc. generally **decreased**
  – All esters decreased
  – Only a few exceptions (e.g. β-phenyl ethanol, propanoic acid)

• Alcohol Re-adjustment studies
  – Generally reduced conc. of all cmps
    • Reduced β-phenyl ethanol, propanoic acid

• Liquid Conc.
  – Generally **reduced** conc.
Experiment 2 - Alcohol Adjustment

• Shiraz
  – ‘Mature Fruit’ 12.2%
  – ‘Post Mature’ 14.0%

• Adjusted to:
  – 10% alcohol
  – 8.0% alcohol

Initial Alcohol

Blended to: 10%
Rank sum pref. (lowest = most preferred)

**Mature**
- Wine and Viti. students
  - Original 12%
  - Reduced 10%
  - Blended 10%
  - Reduced 8%

**Post-Mature**
- Original 14%
- Reduced 10%
- Blended 10%
- Reduced 8%

Legend:
- b
- bc
- b
- e
- bc
- cd
- a
- e

Notes:
- “Wine and Viti. students” likely refers to a group or study population.
- The chart indicates a preference ranking with specific values for each category.
Degree of grape berry ripeness will influence the perception of reduced alcoholic wines.

### Difference Testing

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Comparison</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% Mature Fruit</td>
<td>10% Post Mature Fruit</td>
<td>NS</td>
</tr>
<tr>
<td>10% Mature Fruit</td>
<td>10% Blended Mature Fruit</td>
<td>NS</td>
</tr>
<tr>
<td>10% Post Mature Fruit</td>
<td>10% Blended Post Mature Fruit</td>
<td>NS</td>
</tr>
<tr>
<td>8% Mature Fruit</td>
<td>8% Post Mature Fruit</td>
<td>Significant</td>
</tr>
</tbody>
</table>
An Integrated Approach Required

- Vineyard Decisions
- Blending Decisions
- Alcohol Reduction Technology
- Fermentation Decisions

Lower Alcohol Wine
Acknowledgements

• Grape Growers and Wine makers of Australia
  – Through their investment body the Australian Grape and Wine Authority

• Charles Sturt University &
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