CLIMED-FRUIT

Dealcoholisation of wine: adaptation of wine processes to lower alcohol levels associated with rising temperatures

According to the European Environment Agency (EEA), climate change is expected to negatively impact grape growth and wine quality in traditional wine-producing regions of southern Europe by mid-century [1]. Rising temperatures in wine regions, driven by climate change, are accelerating the ripening of grapes and increasing sugar buildup, leading to increased alcohol levels in the wine. This shift affects not only wine balance and typicity but also challenges fermentation and wine marketability. One strategy to mitigate these changes involves implementing agronomic and viticultural practices to reduce the sugar content in grapes, thereby preventing excessive ethanol levels in wine. Another approach focuses on the winemaking process itself, including selecting yeast strains with lower sugar conversion rates or implementing must and wine dealcoholisation processes.

The Mediterranean region is experiencing some of the most intense impacts of climate change on European agriculture, including more frequent extreme heat, droughts, loss of biodiversity and intensifying water needs. This is particularly concerning for perennial fruit crops like grapevines, which cover substantial areas and are increasingly affected by these changes. Farmers are adjusting their practices to cope, but many of these solutions remain confined to specific regions or agricultural sectors. The EU-funded CLIMED-FRUIT [2] project is working to bridge this gap by collecting and sharing innovative, climate-adaptive practices from various sources to enhance resilience and promote effective climate change adaptation and mitigation.

Since the 1980s, alcohol levels in wine have increased by nearly 1% per decade, with an average rise of 2–3% overall. Today, most red wines from the Mediterranean exceed 14% ABV (alcohol by volume), compromising freshness and aromatic complexity [3]. High ethanol levels are often perceived as ‘warmth’ in the mouth and can distort aroma perception by affecting the volatility of key compounds [4]. From a technical standpoint, high alcohol poses challenges in completing fermentation and results in higher taxation in many countries [5]. At the same time, consumer demand for low-alcohol wines is rising, driven by health trends and shifting social norms. In response, the EU introduced two new categories of wines in the Consolidated text of Regulation (EU) No 1308/2013 [6, 7]:

- ‘Dealcoholised wine’: ≤ 0.5% vol.
- ‘Partially dealcoholised wine’: greater than 0.5% vol. and less than 8.5% vol. or 9% vol. (depending on the wine-growing zone)
- In addition, under Regulation (EU) 2019/934, producers are allowed to reduce the alcohol content of wine by up to 20% of the original alcohol content [8].

Methods for producing lower-alcohol wines

- ### Crop management practices

There are various strategies to moderate rising ethanol levels in wine, as well as to produce no- or low-alcohol wines, involving techniques implemented at the pre-fermentation,

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fermentation and post-fermentation stages of wine production. Each strategy differs in terms of dealcoholisation efficiency [9, 10] (Fig. 1). Examples of such strategies include adapting viticultural practices by introducing new grape varieties, altering cultivation methods and relocating vineyards to cooler regions to slow down sugar accumulation in the fruit. Other approaches involve using underripe grapes from cluster thinning or selecting yeast strains that produce less ethanol [11].

Agronomic practices, such as shading and different types of pruning, have been shown to be effective in reducing sugar content in grapes [12]. The reduction of leaf area to fruit mass after fruitset may lead to better synchronisation of sugar and flavour/phenolic ripening [4]. Alternative techniques are trimming the vine canopy to reduce the sugar accumulation in the grapes and foliar application of antitranspirants to reduce photosynthetic capacity [13].

- Oenological practices

Physical methods are widely used and permitted to reduce alcohol content in wines. These kinds of methods are applied during fermentation or in the post-fermentation stage and include membrane-based processes and distillation.

Vacuum evaporation methods are widely used, particularly to produce dealcoholized wines (<0.5% ABV). The spinning cone column (SCC) is one such example: it is a falling film separator consisting of a rotating vertical shaft and vertically stacked cones that rotate alternately and are fixed in place. This technology operates under vacuum conditions at low temperatures (approximately 25–40°C), preserving the wine's delicate aromas and flavours. The process has two steps: first, aroma compounds are separated at ~28–30°C and reduced vacuum pressure (0.04 atm); then, ethanol is distilled and separated at ~38°C. The aroma is then recombined with the dealcoholised wine. Due to its complexity and cost, SCC is best suited to large wineries with specialised facilities [14].

Membrane-based techniques have been developed in the last 15 years and have revolutionised the selective removal of ethanol from wine while preserving the sensory quality. Separation is driven either by pressure (as in reverse osmosis and nanofiltration) or by concentration gradients using a stripping flow (membrane contactors). These methods offer advantages such as energy efficiency, product quality and ease of use, especially for small wineries. However, scaling up can lead to issues such as membrane fouling, variable performance and higher operating costs, making industrial applications more challenging [15].

Distillation helps minimize aromatic losses. To achieve this, it is always carried out under vacuum. This highly efficient technology is widely used in the production of dealcoholized wines.

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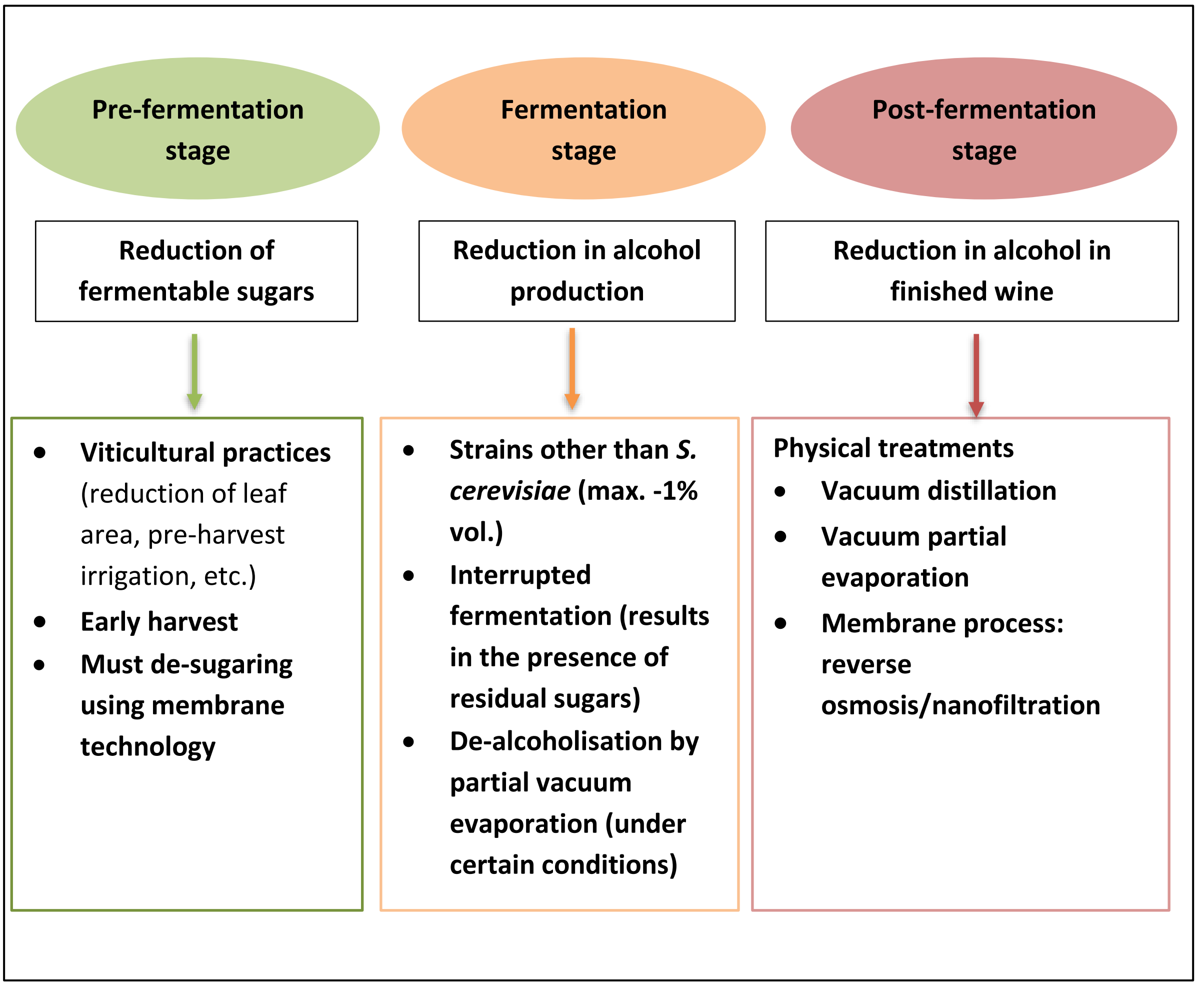

Fig. 1. Authorised methods for alcohol reduction in wine [9, 10]

Reduction of alcohol content at the fermentation stage: example of partial evaporation under vacuum during alcoholic fermentation (AF)

Partial vacuum evaporation of ethanol — currently under review by the **OIV** (International Organisation of Vine and Wine) for use during fermentation (already authorised for finished wine) — involves extracting alcohol through partial vacuum evaporation during alcoholic fermentation. This approach helps preserve and even enhance aromatic compounds, as yeasts continue to generate new aromas after the alcohol evaporation. The French Wine and Vine Institute (IFV) [10] has tested this method on Sauvignon, Grenache Rosé and Syrah musts with promising results (Fig. 2).

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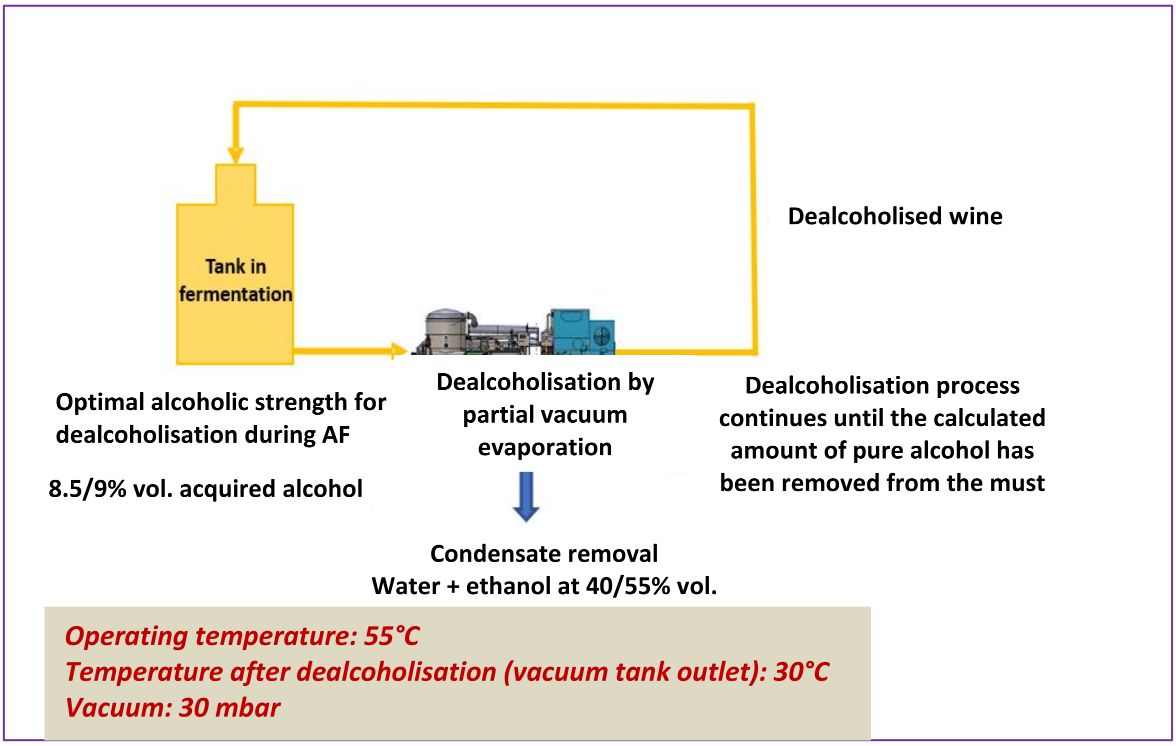

Fig. 2. Partial vacuum evaporation of ethanol from fermenting must [10]

The removal of ethanol from the fermenting must during a single pass through the dealcoholisation equipment ranged from 0.97% and 2.2% v/v. The final ethanol reductions in the wines were: **Sauvignon 1** (11.5% to 9.2% v/v), **Sauvignon 2** (12.8% to 8.7% v/v), **Grenache Rosé** (16.0% to 14.0% and 12.1% v/v), and **Syrah** (14.6% to 13.5% and 11.6% v/v).

In all cases, the dealcoholisation of musts through vacuum evaporation led to a slight increase in total acidity and a drop in pH. The polyphenol concentration also increased, which was attributed to the concentration effect caused by the removal of water and alcohol as condensate. In the Sauvignon, reducing the alcohol during fermentation led to a decrease in thiol compounds, which are essential for the variety's distinctive aroma. However, this loss is partially offset by an increase in other aromatic compounds, indicating a shift rather than a complete loss of aromatic expression. An increased concentration of esters and acetates was observed in the Grenache Rosé and Syrah wines. Additionally, the Grenache Rosé had slightly higher norisoprenoid and terpenol content compared to the control.

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Reducing alcohol levels in the post-fermentation stage: Example of coupling reverse osmosis/nanofiltration with distillation/membrane contactor [10]

Direct distillation is never used to dealcoholize wine under atmospheric pressure due to the high risk of aroma loss; instead, a two-step process is used. First, reverse osmosis (RO) or nanofiltration (NF) removes a permeate containing alcohol, water and small molecules (e.g., acids, potassium). Alcohol is then separated from the permeate via distillation or membrane contactor, and the recovered water is reintroduced into the wine (Fig.3).

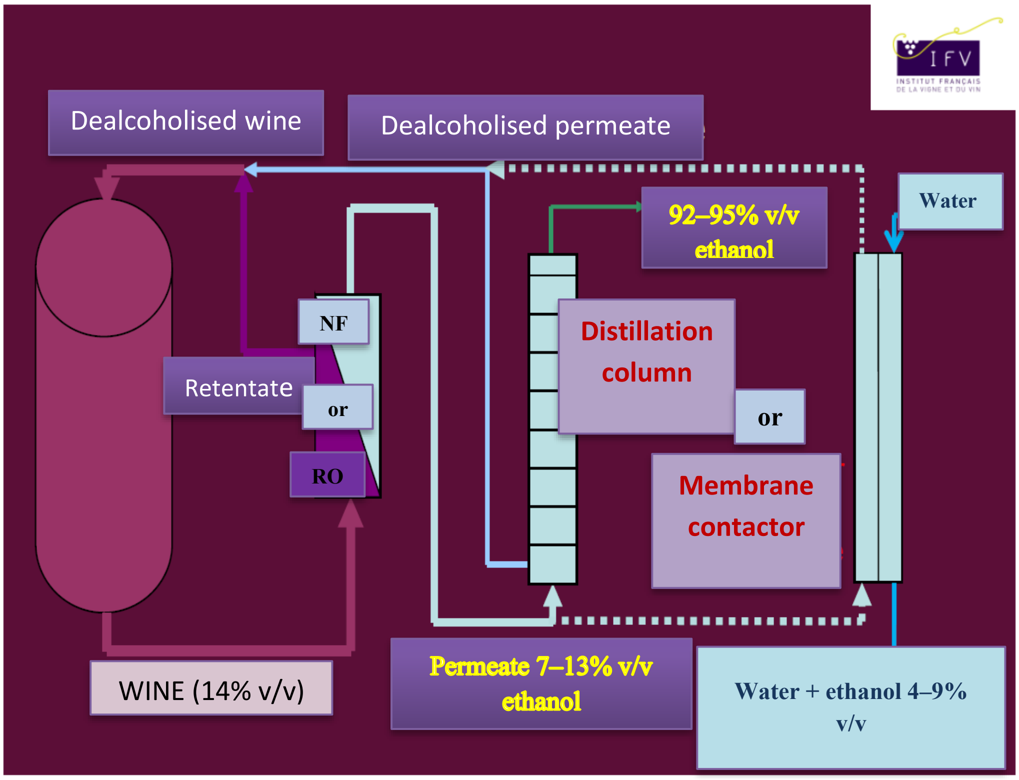

Fig. 3. Nanofiltration (NF) or reverse osmosis (RO) with either distillation or membrane contactor [10]

The process can be conducted continuously (if volumes are large) or in separate locations, RO/NF at the winery and distillation at a distillery. For low-level dealcoholisation, only about 18% of the wine volume needs transporting (for a 2% reduction), keeping costs low. The recovered alcohol is highly concentrated (85–95% vol.) and can be used by the distillery. Volume loss slightly exceeds the ethanol removed (e.g., 1.1% loss for 1% vol. ethanol reduction).

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Conclusion

As Mediterranean wine regions face increasing alcohol levels due to climate change, dealcoholisation has become a key adaptation strategy. However, most current techniques can alter the wine's sensory profile, especially when the alcohol is reduced by more than 1–2% v/v. In almost all cases, this also entails higher production costs due to necessary investments in new grape varieties, double harvesting, applying advanced technologies such as membranes and distillation and loss of wine volume due to dealcoholisation. Balancing quality, authenticity and economic feasibility is now a major challenge for the wine sector, requiring close collaboration between winemakers and researchers.

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