Seeing through the crystal ball: predicting the chemistry of ageing wine

Conducting research on the characters that develop in aged wine is not easy. You might trial a new vineyard management treatment or a winemaking additive, conduct the experiment, make and bottle the wine and then have to wait for five years or longer to find out if the treatment has had any effect on the wine's aged characters. This makes it difficult to have agile experimental designs, because you can't adjust plans based on one vintage's results in time for the next vintage. A longer research horizon is needed.

Finding a way to accurately simulate or accelerate a wine's ageing processes is therefore one of the holy grails of wine flavour research. This would allow researchers to predict a wine's future accurately, without having to wait – greatly increasing the amount of research that could be done on the chemistry and sensory characters of aged wines.

Achieving this is not a simple undertaking. Wine contains thousands of different compounds, formed through different pathways and interacting with one another in complex webs of reactions. To understand how even a single wine aroma compound changes during ageing, you need to understand several steps in its life cycle:

- How it is originally formed or released from bound non-volatile and non-aromatic forms
- How it converts into other aromatic compounds through a range of different reactions
- How the final aromatic compounds that are formed eventually degrade.

These steps, and therefore which compounds are most prevalent at any point in time, are influenced by factors including pH and temperature. The rates of different reactions and the overall energy in the system all have an impact. If you then multiply that by all of the different compounds present and think about the fact that many of the chemical reactions going on are interdependent, you can see why accurately accelerating wine ageing is a major challenge.

Investigating aged Riesling character

One AWRI project where considerations of accelerated ageing are particularly relevant is work on the characters that form in aged Riesling wines. This is a collaborative project with Geisenheim University in Germany, through what is known as the BAG Alliance. Experiments are looking at the impact of climatic factors on characters in Riesling, in particular the development of the compound 1,1,6-trimethyl-1,2-dihydronaphthalene (TDN) under a likely warming climate scenario.

TDN is a C_{13}-norisoprenoid that is almost exclusively found in Riesling, with typical aroma descriptors of 'kerosene' and 'petrol' when present at high concentrations. TDN is thought to be biosynthesised from carotenoids, which act to absorb light energy and provide photoprotection to grapes. Bunch exposure has been shown to significantly enhance carotenoid concentrations in grapes, with the consequence that TDN levels also increase. The project aims to identify key timepoints for sun exposure of Riesling grapes, allowing grapegrowers to employ canopy management systems to optimise flavour development and retain aromas typically observed in cooler climates.

Accelerated ageing experiments

As part of this work, experiments were conducted comparing different temperature regimes as possible ways to accelerate ageing and more quickly understand the impact on aged Riesling character. Three of the flavour compounds monitored were geraniol, α-terpineol and TDN. Geraniol is a flavour compound that is released from Riesling grapes during winemaking and contributes to the 'fresh floral' character in young Riesling wines. The compound α-terpineol is formed from geraniol through conversion reactions that occur at different rates depending on the overall conditions. It again contributes to the 'fresh citrus' and 'floral' characters of young Riesling wines. TDN, as discussed above, is associated with aged Riesling characters.

A young Riesling wine that had been in bottle for one year was stored at either 28°C and 40°C, with bottles being removed and analysed after 1 month or 6 months of storage. The concentrations of flavour compounds in these wines were compared with those in the wine when the experiments were started (Figure 1). The changes observed in the wines that had been stored under elevated temperatures were considered with respect to the compositional

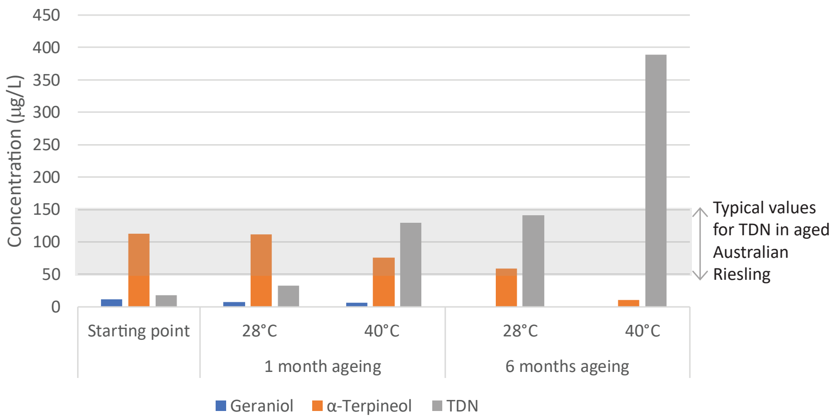

Figure 1. Concentration of key aroma compounds from accelerated ageing experiments, and in the starting Riesling wine, with the grey band showing the typical range of values for TDN in aged Australian Riesling wines (5–10 years).

profiles historically seen in aged Riesling, to give an insight into which method gives results most closely resembling real-world ageing.

After 1 month at 28°C very little change was seen in geraniol and α-terpineol compared with the starting wine, but there was a slight increase in TDN. Storage for the same amount of time at 40°C showed accelerated loss of α-terpineol and increased formation of TDN. By the time these wines had been stored for 6 months, there was no detectable geraniol at either temperature, and the formation of TDN was significantly increased, especially at 40°C. The measured concentration of nearly 400 μg/L of TDN in the wine stored at 40°C is outside the range of what is usually seen in an aged Riesling, which suggests that at this temperature the system has been altered too far to reflect likely ageing outcomes, whereas the 28°C storage shows more realistic numbers. The wines that were aged for 6 months at 28°C will be used in sensory experiments alongside the traditionally aged wines (15°C) to understand if the accelerated ageing produced wines resembling those aged over time without the elevated temperatures. This will provide a basis for future assessment of the traditionally aged Riesling to give further insight into how representative the accelerated ageing was. If successful, this could allow for accelerated ageing of different vineyard or winery treatments, to speed up the timeframe between winemaking and understanding the effect of the treatment on aged Riesling character.

Can the future be predicted?

At present the ability to predict the future for a wine is limited. However, as more is learnt about the pathways for formation of key wine compounds, and more wines are observed over different combinations of time, temperature and pH, the ability to know what is likely to happen will improve. It may never be possible to completely predict the future, but as the accelerated ageing models developed get more accurate, it will become easier to provide answers to research questions in shorter spaces of time…or at least better direct the next research question without having to wait five years for a Riesling to age!

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