The effects of elevated storage temperature on wine composition

The AWRI recently published a review article on the effects of elevated storage temperature on wine composition (Scrimgeour et al. 2015). This article summarises the key points from that review.

Temperature plays a significant role in the winemaking process and, as such, efforts are made to control its impact at all stages of production. Once a wine has been bottled, it is at risk from many factors during transportation and storage. Elevated temperatures experienced through the supply chain can accelerate wine development and reduce shelf life. These changes may go unnoticed until the wine reaches the consumer.

The chemical changes that are produced by elevated temperatures are generally more prominent in white wines than in red wines. The most noticeable effects are a loss of 'fruity' aroma compounds, premature browning, loss of sulfur dioxide (SO_2) and the presence of negative attributes generated through oxidation reactions. The chemistry involved in heat-affected red wines is generally more complex and can affect colour, flavour, mouth-feel and aroma characteristics.

The role of preservatives in protecting wine

Changes in the chemical and sensory properties of a wine are a consequence of a range of complex chemical reactions. The extent and speed of these reactions are strongly influenced by wine composition and temperature. A commonly employed rule of thumb is that reaction rates double for every 10°C increase in temperature. However, this depends on the specific reaction, the temperatures involved and the activation energy required to produce the reaction.

Sulfur dioxide (SO_2) is the most common additive used for wine preservation, with free SO_2 concentration often used as a marker for shelf life. SO_2 inhibits the growth of microorganisms and protects wine against the effects of oxidative reactions. The concentration of free SO_2 typically declines during storage and bottle ageing, with the speed of loss accelerated by elevated temperatures.

SO_2 exists in three free forms in wine in equilibrium: molecular SO_2, bisulfite (HSO_3^-) and sulfite (SO_3^{2-}). The bisulfite form is always predominant and it is this form that reacts with the by-products of wine oxidation processes, causing the overall concentration of SO_2 to decrease with time. Temperature influences both the SO_2 equilibrium in wine and the kinetics of those oxidative reactions.

Boulton et al. (1996) report useful data on the influence of temperature on oxidation-related reaction rates. These can be used to estimate the consequences of elevated temperature exposure, for example, when a refrigeration plant has failed or an uninsulated container has been held up by customs at an overseas port. Of course, actual rates will differ, depending on the wine variety and style, along with the concentration of phenols, transition metals, alcohol, dissolved oxygen, ionic strength, and wine pH.

The effects of elevated temperature on wine

Flavour and aroma are arguably the most important contributors to perceived wine quality. Unfortunately, the compounds that contribute most significantly to these attributes are the ones that tend to be affected most noticeably by elevated temperatures. During storage, the volatile composition of wine changes due to a diverse range of reactions taking place, in particular ester hydrolysis/esterification reactions. Changes in ester composition occur during normal bottle ageing, with the reaction rate appearing to increase with storage temperature and with wine pH.

It is evident from a number of heat impact studies that there is a significant loss of esters responsible for fruit-related attributes and a premature increase in compounds that contribute to aged characters (such as TDN in Riesling) when white wines are exposed to elevated temperatures. Acetates are hydrolysed more quickly than the ethyl esters of short chain fatty acids which, as a result, leads to loss of fruitiness in young white wines.

Temperature also affects the concentration of compounds that contribute to the varietal character of wines, such as methoxypyrazines, monoterpenes, norisoprenoids and thiols. One study showed that the concentration of varietal thiols 3-mercaptohexanol (3-MH) and 3-mercaptohexylacetate (3-MHA) in Sauvignon Blanc decreased after storage at elevated temperatures. Another study reported precursor hydrolysis as a contributor to changes in Chardonnay and Semillon wine aroma brought about by heat treatment, resulting in changes to ester composition and in norisoprenoid concentration. Substantial changes in the aroma profile of red wines have also been reported, with a significanrt proportion of the volatile compounds affected directly by elevated temperature.

While volatile compounds are important for aroma perception, non-volatile compounds play an important role in the palate and flavour characteristics of a wine and, in many cases, these can be equally sensitive to the impacts of temperature. The group of non-volatile compounds most sensitive to heat is polyphenols, which are responsible for red wine colour (anthocyanins) and mouth-feel (flavan-3-ols, tannins and phenolic acids). The polyphenols most sensitive to temperature effects are the flavanols and anthocyanins. The most common effect on non-volatile compounds from elevated temperature exposure in red wines is a decrease in anthocyanin concentration and a corresponding increase in tannin-bound anthocyanins (polymeric pigments). This process is typically associated with conversion of unstable (and SO_2 bleachable) colour components in red wine to more stable (and non-SO_2 bleachable) forms. Heat exposure results in a colour change from purple to red/orange and essentially mimics (in an accelerated manner) the red wine ageing process.

Many studies have observed that the extent of the effects caused by elevated temperature in red wines is very much dependent on the wine type (variety), even more so than with white wines. This is due to the more complex chemical composition found in red wines, in particular the phenolic profile and different reactivities of the phenolic species present.

Tannins are important for their impact on mouth-feel, especially in red wines. The concentration of tannins in red wines appears to decrease with increasing temperature exposure. This is consistent with the faster formation of polymeric pigments commonly seen with elevated temperature, as well as changes in colour and phenolic composition, which affect the measured tannin concentration.

One of the most obvious effects of elevated temperatures on white wines is the formation of brown pigments, commonly referred to as browning. Browning in white wines is commonly attributed to the mechanisms involved with the oxidation of polyphenols and many studies have shown that the formation of quinones is a significant driver in the browning process.

Summary

It is clear that elevated temperatures accelerate the ageing process wines typically experience over time. The chemical profile of wine can change significantly with different storage temperatures, indicating that the reaction mechanisms involved are highly sensitive to temperature. The sensitivity of any given wine to a certain temperature, however, is very much dependent on its winemaking history and composition. It is not currently possible to define a specific temperature, or time at a given temperature, at which a particular wine will begin to show deleterious effects.

The most common and noticeable impacts on wines that have been subjected to high temperatures are the loss of sulfur dioxide, an increase in browning, loss of desirable 'fruity'/'floral' characters and the development of undesirable aroma attributes. Red wines also experience a reduction in the concentration of anthocyanins and an increase in polymeric pigments.

Further research is needed to develop practical tools for the wine industry to be able to predict the effects of temperature exposure on a specific wine.

References

Boulton, R.B., Singleton, V.L., Bisson, L.F. Kunkee, R.E. (1996) Principles and practices of winemaking. New York: Chapman and Hall.

Scrimgeour, N., Nordestgaard, S., Lloyd, N.D.R., Wilkes, E.N. (2015) Exploring the effect of elevated storage temperature on wine composition. Aust. J. Grape Wine Res. 21 (S1): 713–722.

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