The effects of fermentation temperature on the composition of red wines

This article concludes a series examining red and white winemaking techniques included in the AWRI's winemaking treatment trials. In these trials, several wines were made from a single batch of grapes, with one winemaking variable being changed in each of the wines. Four trials were conducted, commencing with Pinot Noir in 2016, and followed by Shiraz, Cabernet Sauvignon and Chardonnay in subsequent vintages. The wines made were presented to winemakers in tastings held around Australia.

In the red wine trials, particularly those using Shiraz and Cabernet Sauvignon, the wine produced with an increased fermentation temperature compared to the control was almost always the preferred wine in the tastings. This article explores how changes in such a small and simple to manage winemaking variable can result in large differences in wine composition and sensory properties.

Effects of fermentation temperature on red wine phenolics

The contributions of grape-derived phenolics to the colour, tannin concentration, mouthfeel, overall quality and ageing potential of red wines have been established by numerous studies. While the initial concentration of phenolic compounds in grapes has some relationship to the final phenolic composition of wine, fermentation temperature and the extent and duration of cap management have been shown to strongly determine phenolic extraction during winemaking and the phenolic composition of wines over time.

The earliest structured studies on the effects of winemaking treatments on the extraction of phenolics during red winemaking were conducted at the University of California, Davis, in the early 1950s (Amerine 1954, 1955, Amerine and Ough 1957), with studies which specifically examined the effects of temperature appearing in the early 1960s (Ough and Amerine 1960, Ough and Amerine 1961a, b). Among other things, this work established that higher fermentation temperature resulted in greater extraction of colour and tannin in Pinot Noir, Grenache, Cabernet Sauvignon and Valdepenas (Tempranillo), and that pumping over was more effective than plunging for increasing wine colour. However, Casassa and Harbertson (2014) report that Eugene Hilgard, also working at the University of California, established in 1887 that the maximum extraction of colour occurred before that of tannins, and that maximum colour was obtained earlier at higher temperatures.

Not all phenolics are extracted at the same rate during fermentation, and it has been shown that while the rate of extraction of some compounds is increased with increasing fermentation temperature, the final concentrations may be unaffected. Lerno et al. (2015) found that in 120-litre Cabernet Sauvignon fermentations increased fermentation temperature increased the rate of extraction but not the final concentration for skin-derived phenolics, whereas for seed-derived phenolics both the rate and final concentration increased. They also concluded that the must temperature was more important than the cap temperature in determining the extraction of phenolics.

Effects of fermentation temperature on non-phenolic composition of red wines

Fermentation temperature has also been shown to affect other non-phenolic wine components. For example, Rollero et al. (2015) examined the effect of temperatures of 20°C to 28°C on the final concentration of several yeast-synthesised volatile and non-volatile components using a synthetic grape juice. This work found that while increased evaporation caused by increased temperature accounted for an accumulation of some esters (i.e. a concentrating effect presumably due to the preferential evaporation of other components such as water and ethanol), the formation of isoamyl acetate ('fruity', 'banana', 'pear') and ethyl octanoate ('dark cherry', 'red cherry') was positively independently correlated with increasing temperature. The production of succinic acid, glycerol and the higher alcohol isobutanol (flavour and aroma contribution unelucidated) was also positively correlated with temperature, but this was not the case for other higher alcohols. Several studies have reported lower concentrations of ethanol and certain volatile compounds with increasing temperature, which is largely attributed to increased volatilisation. Small increases in wine pH have also been reported, presumably due to increased extraction of potassium from grape skins at higher temperature.

Little sensory data is present in the published studies on fermentation temperature. However, Reynolds et al. (2001), working with Shiraz in the cool-climate Okanagan Valley and Niagara Peninsula in Canada, reported that increasing fermentation temperature from 15°C to 30°C resulted in increased 'blackcurrant' flavour and reduced 'herbaceous' flavour, with Girard et al. (1977) also reporting increased 'currant' flavour and aroma in Pinot Noir wines when fermentation temperature was increased from 20°C to 30°C.

What effects of higher fermentation temperature were seen in the AWRI red winemaking treatment trials?

Data on the changes in wine phenolics between two fermentation temperatures for Pinot Noir, Shiraz and Cabernet Sauvignon wines are provided in Table 1. For all three varieties, total phenolics, total anthocyanins, tannin and non-bleachable pigments increased with increased fermentation temperatures. The percentage increases for Pinot Noir were less than for Shiraz and Cabernet Sauvignon, which might be accounted for by a lower initial concentration of phenolic compounds in the grapes and the smaller difference in fermentation temperatures. Nonetheless, marked increases in tannins (33.5%) and non-bleachable pigments (16.7%) were seen in the Pinot Noir wines, with a mean increase in fermentation temperature of only approximately 3°C.

The largest changes in phenolic composition were seen in the Shiraz wines, with total phenolics increasing by 42%, total anthocyanins by 34%, tannins by 107% and non-bleachable pigments by 36%, when the mean fermentation temperature was increased from approximately 25°C to 33.5°C. It is noteworthy that the control fermentation temperature of 25°C is commonly employed by many of the Australian wine producers who responded to a survey of winemaking practices, which was conducted when determining the treatments to be included in the trials.

Table 1. Comparison of phenolic composition of Pinot Noir, Shiraz and Cabernet Sauvignon wines fermented at different temperatures in AWRI fermentation treatment trials

Pinot Noir (2016)			
Phenolic measure	**Control ferment 24–26°C, 10-day ferment**	**Warm ferment 24–32°C, 7-day ferment [a]**	**% increase**
Total phenolics (AU)	22	23	4.5%
Total anthocyanins (mg/L)	115	121	5.2%
Tannin (mg/L)	480	641	33.5%
Non-bleachable pigments (AU)	0.36	0.42	16.7%
Shiraz (2017)			
Phenolic measure	**Control ferment 24–26°C, 12-day ferment**	**Warm ferment 32–35°C, 10-day ferment [b]**	**% increase**
Total phenolics (AU)	31	44	41.9%
Total anthocyanins (mg/L)	415	556	34.0%
Tannin (mg/L)	576	1192	106.9%
Non-bleachable pigments (AU)	1.35	1.83	35.6%
Cabernet Sauvignon (2018)			
Phenolic measure	**Control ferment 24–26°C, 14-day ferment**	**Warm ferment 32–34°C, 10 day ferment [c]**	**% increase**
Total phenolics (AU)	44	55	25.0%
Total anthocyanins (mg/L)	476	508	6.7%
Tannin (mg/L)	1,336	2,167	62.2%
Non-bleachable pigments (AU)	2.7	3.7	37.0%

[a] One additional pump-over was performed each day compared to the control, so that both the control and warm ferment received approximately the same amount of pumping over in total.
[b, c] Additional plunging was performed so that both the control and warm ferment received approximately the same amount of plunging overall.

In general, the increases in wine phenolics seen in these three sets of wines are larger than those reported in many studies, and this is especially the case if one considers the fermentation temperature differences between this and other studies. Most studies compared fermentation temperatures of 15°C and/or 20°C, to 30°C, whereas for the current Pinot Noir, Shiraz and Cabernet Sauvignon wines, the mean temperature of the control ferments was 25°C, with mean fermentation temperature being increased by 3°C, 8.5°C and 8°C, respectively, for the three varieties. One possible explanation of the large differences seen with the current study might be that the starting concentration of phenolics in the grapes was higher than for grapes used in other studies, but it is not possible to be definitive on this point.

Practical considerations and potential risks

Increased fermentation temperature increases the rate of fermentation, thereby further increasing temperature in a positive feedback loop. The larger the ferment, the greater the amount of heat produced, with the highest temperature in any red fermentation likely to be at the base of the cap in the centre of the fermenter.

Consequently, there is a greater risk of fermentations becoming uncontrollable or 'bolting' at higher temperature if insufficient cooling capacity is available, of if the fermentations are not actively cooled, and this can result in markedly undesirable sensory characters. Active cooling may include cooling jackets on fermenters or cooling plates placed in the fermentation, although these may only result in localised cooling. Pumping the fermenting liquid though a heat exchanger and distributing the cooled liquid over the cap is the most effective way of cooling a ferment.

The passive dissipation of heat during fermentation will be chiefly influenced by the ambient temperature, the material the fermenter is made from, the presence of insulation and the surface area to volume ratio of the fermenter. Proportionally more heat will be lost as the surface area to volume ratio increases, and passive heat dissipation will be negligible from concrete or wooden fermenters compared to uninsulated stainless steel fermenters.

It should also be remembered that while cap management techniques such as pumping over, rack-and-return and, to a lesser degree, plunging may help to dissipate heat, they also introduce oxygen which may stimulate yeast and contribute to an increased fermentation rate.

Conclusion

Increases in red wine phenolics, particularly colour, are generally associated with increased wine quality, and as has been discussed in other articles in this series, several techniques can be employed to increase red wine phenolics. These include pre-ferment cold maceration, post-ferment extended maceration and saigneé. While each of those treatments will confer different sensory properties, if the winemaker's primary aim is to increase the concentrations of total phenolics, total anthocyanins, tannin and non-bleachable pigment, increasing fermentation temperature to between 30°C and 32°C is a simple, relatively low risk and cost-effective method of achieving that aim compared to other methods.

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