# Applications of flash détente for red wine style differentiation

*By Richard Ntuli[1,2], Yaelle Saltman[2], Ravi Ponangi[1], David Jeffery[2], Keren Bindon[3] and Kerry Wilkinson[2]*

**Two separate studies were carried out at E & J Gallo Winery in California to determine the potential use of flash détente to differentiate red wine styles. The studies focussed on Cabernet Sauvignon and Merlot.**

## IN BRIEF

- **The effect of flash détente and fermentation temperature, grape solids and the use of oak and oenotannin for wine colour stabilisation were studied.**
- **Flash détente mitigated the intensity of green, savoury and dusty sensory attributes.**
- **Temperature and solids content affected the composition and sensory profiles of FD wines.**
- **Fermenting with no or low grape solids enhanced red fruit and confectionery aromas.**
- **Dark fruit attributes were enhanced when fermenting with oak chips, but tannin had little impact.**
- **Flash détente wines were clearly differentiated from wines made via traditional maceration.**

## INTRODUCTION

Recent advances in technology, for example flash détente (FD), have led to the development of new approaches to red wine production. FD involves heating grape must to ~85°C, followed by vacuum treatment to boil or 'flash' off the water present in grape tissues. This results in cellular damage that aids extraction of key grape constituents into juice. Consequently, FD technology offers the opportunity to reconfigure the red winemaking process by separating colour and phenolic extraction from fermentation. The potential use of FD for red wine style differentiation has not been fully explored and was therefore the focus of the studies outlined in this article.

## METHODS

Two separate studies involving flash détente treatment of grapes were undertaken. The first study compared the composition and sensory profiles of wines made from FD-treated Cabernet Sauvignon musts fermented at 16, 24 or 34°C, with or without the inclusion of grape solids, to a control wine made using traditional red winemaking practices. In the second study, FD-treated Merlot musts were either fermented with grape solids for 1, 2 or 5 days (before pressing), or pressed immediately and the resulting juice fermented with or without the addition of oak chips or oenological tannin. The composition and sensory profiles of the resulting wines were again compared to a control wine made via traditional maceration. Compositional analyses comprised basic wine chemistry (total soluble solids, TSS), pH, titratable acidity (TA), free and total sulfur dioxide, alcohol, and residual sugars), as well as total phenolics, polysaccharides, anthocyanins and volatile compounds, measured according to published methods described previously (Ntuli *et al*. 2021). Wine sensory profiles were determined by a trained panel using descriptive analysis.

## IMPACT OF FERMENTATION TEMPERATURE AND SOLIDS ON RED WINE COMPOSITION AND SENSORY PROFILES

This study shed light on how fermentation temperature and fine grape solids content can be manipulated to target specific styles of red wine made without prolonged skin contact (i.e. 'off-skins') by fermenting juice derived from FD-treated must. Fermentation temperature and suspended solids affected wine colour, phenolics, polysaccharides and aroma composition. Higher fermentation temperature increased fermentation kinetics, producing wines with lower alcohol content, higher titratable acidity, volatile acidity, glycerol and red colour (A520) (Table 1). Fermentation temperature was negatively correlated with monomeric flavan-3-ol and anthocyanin concentrations in finished wines due to a greater conversion to derived pigments at higher fermentation temperatures while having no effect on tannin concentration (Table 1).

The suspended solids present in 'off-skin' red fermentations were found to have a major effect on wine chemical and sensory profiles, likely due to grape solids being a rich source of lipids and phytosterols (Casalta *et al.* 2016). A higher concentration of suspended solids produced wines with lower ethanol concentration, possibly due to stripping resulting from carbon dioxide nucleation on sludge particles (Casalta *et al*. 2016), higher malic acid and red colour, and lower volatile acidity while having no effect on tannin. However, colour intensity measured one year after bottling showed no significant difference between the treatments.

FD ferments all had significantly lower lactic acid and volatile acidity compared to traditional maceration controls, possibly due to the inactivation of native lactic acid and acetic acid bacteria due to thermal treatment. In addition, they had significantly higher caftaric acid concentration while most had elevated quercetin glycosides compared to traditional maceration controls likely due to heat inactivation of polyphenol oxidase preventing the enzymatic oxidation of caftaric acid and higher quercetin glycosides extraction from flash détente treatment, respectively. Control wine had significantly higher polysaccharide concentrations compared to FD wines due

[1]E & J Gallo Winery, Modesto, California, United States of America
[2]Department of Wine Science, The University of Adelaide, Urrbrae, South Australia
[3]The Australian Wine Research Institute, Urrbrae, South Australia

to increased extraction from prolonged skin contact.

Low fermentation temperature and suspended solids content increased the concentration of ethyl esters (ethyl butanoate, hexanoate, octanoate and decanoate), while high fermentation temperature and suspended solids content increased fusel alcohols. In liquid phase FD fermentations, lower suspended solids gave higher concentrations of isoamyl acetate, isobutyl acetate and ethyl acetate.

An evaluation of odour activity values (OAVs) in this study highlighted the critical contribution of esters such as ethyl octanoate, ethyl hexanoate and isoamyl acetate in defining the flavour profile of red wines made via liquid phase fermentation of FD treated must, whereas fusel alcohols were shown to play a lesser role. High temperatures also increased linalool concentrations, which were unaffected by solids content.

Classic maceration (i.e. the control) gave wine with low ethyl ester concentrations similar to FD wine fermented at 32°C with 3.5% suspended solids, likely due to the comparable fermentation temperature and high concentration of suspended solids. The control also had the highest concentrations of 1-hexanol and fusel alcohols, and low concentrations of isoamyl acetate and total esters. Isoamyl alcohol was found to increase with fermentation temperature and/or grape solids, together with active amyl alcohol, isobutyl alcohol, 2-phenylethanol and total fusel alcohols.

The sensory profiles of wines made via 'off-skins' fermentations, with or without the removal of suspended solids, were clearly distinguishable from one another, and from the control wine made via classic maceration. Sensory analysis showed that removing grape solids from FD-derived Cabernet Sauvignon juice prior to fermentation led to wines with increased red fruit (raspberry and strawberry) and confectionery (candied fruit) attributes, while fermenting on 3.5% grape solids enhanced dark fruit (blueberry and plum jam) notes (Figure 1, see page 22). These results were consistent with the observed increase in total esters in response to the decrease in suspended solids during fermentation. PLSR analysis (data not shown) revealed that the increase in dark fruit attributes and decrease in red fruit and confection attributes with higher levels of grape solids were attributable to the loss of ethyl esters, and increased 2-phenyl ethanol together with higher alcohols, namely isoamyl alcohol, methanol and total fusel alcohols.

**Table 1. Selected compositional data for Cabernet Sauvignon wines produced from flash détente derived musts fermented at 16, 24 or 34 °C, with or without grape solids, or from traditional maceration (control).**

| | Control | 16 °C ± solids | | 24 °C ± solids | | *34 °C ± solids* | |
|---|---|---|---|---|---|---|---|
| | | LTLS | LTHS | MTLS | MTHS | HTLS | HTHS |
| Ethanol (% abv) | 13.4 d | 14.2 a | 14.0 b | 13.9 b | 13.6 c | 13.7 c | 13.4 d |
| TA (g/L) | 6.2 ab | 4.9 e | 5.7 cd | 5.5 d | 6.6 a | 5.7 cd | 6.0 bc |
| VA (g/L) | 0.26 a | 0.11 cd | 0.08 d | 0.18 b | 0.12 cd | 0.18 b | 0.13 c |
| Lactic acid (mg/L) | 123.5 a | 71.5 b | 68.5 b | 60.0 b | 60.5 b | 61.0 b | 56.0 b |
| Glycerol (g/L) | 10.4 ab | 6.1 b | 7.1 b | 7.9 b | 14.1 a | 9.6 ab | 10.6 ab |
| Wine colour (A520) | 1.71 b | 1.41 b | 1.68 b | 1.49 b | 2.44 a | 2.12 ab | 2.03 ab |
| Caftaric acid (mg/L) | 9.50 b | 25.5 a | 24.5 a | 27.0 a | 26.5 a | 26.5 a | 24.0 a |
| Ethyl butanoate (µg/L) | 211 d | 854 a | 581 b | 412 c | 274 cd | 304 cd | 184 d |
| Ethyl hexanoate (µg/L) | 338 d | 870 a | 624 b | 617 b | 473 c | 420 c | 305 d |
| Ethyl octanoate (µg/L) | 543 d | 1,778 a | 1,177 b | 1,298 b | 892 c | 996 c | 590 d |
| Isoamyl acetate (µg/L) | 4,037 d | 7,056 bc | 5,077 cd | 7,436 ab | 6,569 bc | 9,437 a | 7,623 ab |
| 1-Hexanol (µg/L) | 1,912 a | 200 b | 324 b | 180 b | 346 b | 169 b | 216 b |
| Isoamyl alcohol (mg/L) | 337 a | 101 e | 207 c | 148 d | 264 b | 200 c | 265 b |

Values are means of two replicates. Different letters (within rows) indicate statistical significance ($P < 0.05$). LT, MT, HT = low, medium and high fermentation temperatures; LS, HS = low (< 0.5%) and high (3.5%) suspended grape solids.

Ratings for dried fruit aroma and flavour, alcohol heat and acidity were not significantly different amongst Cabernet Sauvignon wines. Increased concentrations of isoamyl acetate were observed in some FD wines, but the banana characters often imparted by this ester were not perceived by the sensory panel. Given banana characters are considered detrimental to red wine quality, excessive isoamyl acetate concentrations might need to be mitigated, e.g. via low fermentation temperatures and/or must oxygen treatments (Cejudo-Bastante *et al*. 2011, Du Toit *et al*. 2017, Rihak *et al*. 2022). Traditional maceration gave significantly less intense red fruit and confectionery aromas and flavours, and more intense green and savoury notes compared to the FD treatments, irrespective of grape solids content. Although the control wine had higher grape-derived polysaccharides, which was expected to increase body or fullness based on studies in model wines (Vidal *et al*. 2004), no significant textural differences were detected amongst wines.

This study focussed on the effects of grape solids and fermentation temperature, without any oxygen supplementation, but commercial winemaking often employs macro-oxygenation during fermentation as standard practice. Future research should therefore investigate the combined effect of macro-oxygenation and removal vs. supplementation of fine grape solids on the composition and sensory profiles of red wines made from FD-treated must. Future work could also consider liquid phase red fermentations with higher concentrations of suspended solids to help define a cut-off point beyond which wine quality is negatively impacted. While in white winemaking it is recommended that suspended solids remain within 50-150 NTU (Casalta *et al*. 2016) during fermentation (to ensure an adequate supply of lipids to yeast, thereby preventing the development of off-odours), no guidance or recommendation is similarly available for liquid phase red fermentations.

## IMPACT OF SKIN CONTACT TIME DURING FERMENTATION OF FLASH DÉTENTE TREATED MUST ON RED WINE COMPOSITION AND SENSORY PROFILES

The second study compared the outcomes of FD-treated must fermented with different levels of skin contact, ranging from juice with no grape solids to 'on-skins' fermentations, for which pressing occurred after 1, 2 and

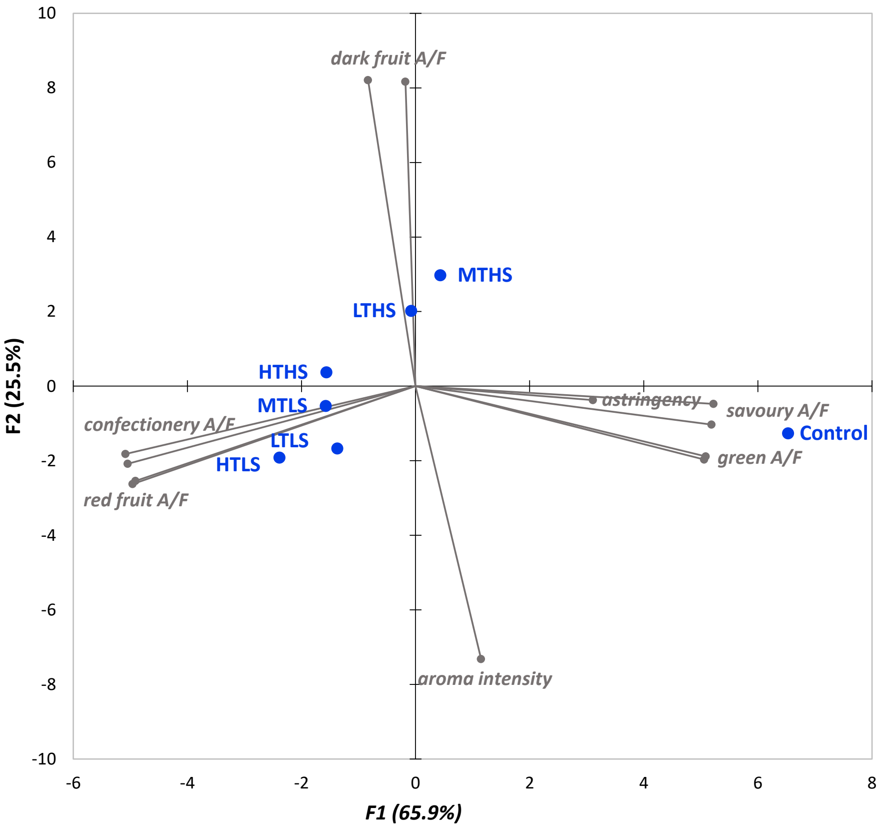


**Figure 1. Principal component analysis biplot of sensory attributes with statistically significant ratings for Cabernet Sauvignon wines made via traditional maceration (Control) vs. fermentation of flash détente derived juice (at different temperatures, with and without suspended solids). A = aroma attribute; F = flavour attributes; LT, MT, HT = low, medium and high fermentation temperatures; LS, HS = low (< 0.5%) and high (3.5%) suspended grape solids.**

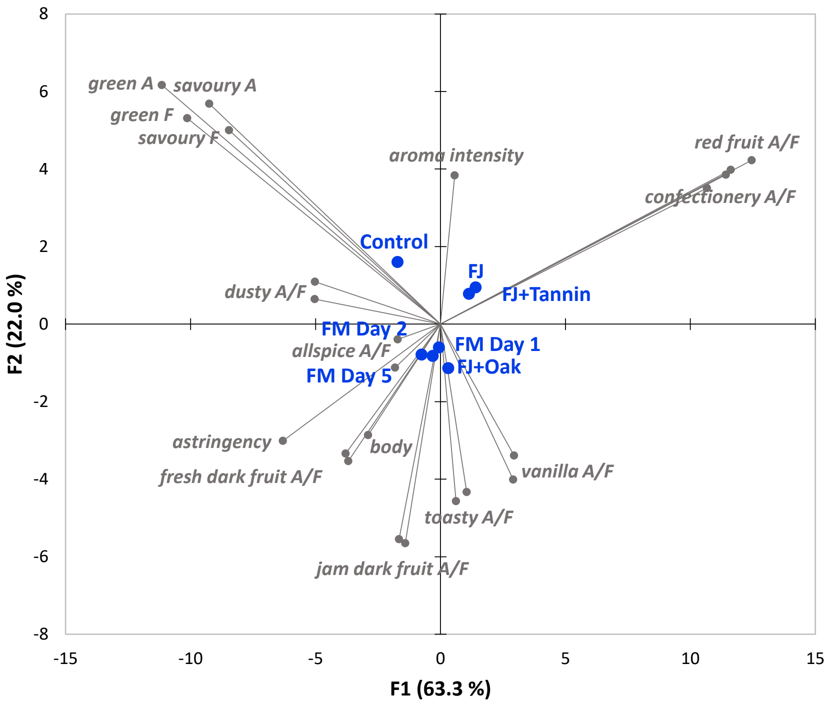


**Figure 2. Principal component analysis biplot of sensory attributes with statistically significant ratings for Merlot wines made via traditional maceration (Control) vs. fermentation of flash détente derived juice (FJ, with and without oak and tannin additions) or must (FM, with 1, 2 or 5 days of skin contact before pressing). A = aroma attribute; F = flavour attributes.**

5 days of skin contact, i.e. at 17, 7 and 0°Brix, respectively.

The presence of suspended grape solids during fermentation influenced the chemical and sensory profiles of Merlot wines. Compositional differences included malic acid, TA, glycerol, caftaric acid, malvidin-3-glucoside, quercetin glycosides, proanthocyanidins, polysaccharides and colour intensity (Table 2, see page 24). As expected, wines made from FD-treated musts that were fermented 'off-skins' had less phenolic extraction than wines corresponding to 'on-skins' fermentations. Tannin composition in the control wine was similar to that in the FJ (juice) treatments, having higher trihydroxylation and lower galloylation than FM (must) treatments. Control and FM wines had significantly higher concentrations of polysaccharides compared to FJ wines, with prolonged skin contact during fermentation notably increasing total polysaccharide concentrations (Table 2).

Having no suspended grape solids contact during fermentation had a greater impact on wine volatile composition and flavour profiles than skin contact time, which mainly impacted phenolic extraction and mouthfeel attributes. The FJ wine series had ~60% higher concentrations of ethyl esters compared with FM treatments that had some contact with solids during fermentation (Table 2). In contrast, skin contact time during fermentation of flash-treated musts had no significant effect on wine ester concentrations. The FJ wine series had significantly higher concentrations of ethyl butanoate, ethyl decanoate, ethyl hexanoate, ethyl octanoate, isoamyl acetate, isobutyl acetate and ethyl acetate than wines from treatments that involved skin contact during fermentation (i.e., control and FM wines). The high odour activity value (OAV) calculated for these esters suggest the presence or absence of grape-derived solids would likely influence wine sensory profiles.

As seen with Cabernet Sauvignon, fermentation of FD-derived juice without grape solids increased concentrations of esters, β-damascenone and linalool and decreased concentrations of fusel alcohols and 1-hexanol compared to traditional maceration ferments. 'Off-skins' fermentations (with no suspended solids) produced wines that were characterised by enhanced red fruit and confectionery attributes (Figure 2) which were attributed to the combination of increased ester formation and increased extraction of β-damascenone and linalool from must, as well as decreased fusel alcohol formation, as seen with Cabernet Sauvignon. 'On-skins' fermentation of FD-treated must gave wines with higher intensity ratings for dark fruit, body and astringency compared to 'off-skins' fermentations. FD wines received significantly lower green, savoury and dusty ratings compared to the control wine. The higher green attribute rating in the control wine may be attributable to higher concentrations of $C_6$ compounds in this wine. FD-treated 'off-skins' fermentations were perceived to have less body and astringency. The fuller body of wines from 'on-skins' fermentations was potentially due to enhanced tannin and polysaccharide extraction during fermentations involving longer skin contact times.

PLSR analysis showed that higher concentrations of most ethyl and acetate esters, as well as linalool and β-damascenone, and lower levels of higher alcohols were associated with red fruit and confectionery attributes. Conversely, elevated levels of higher alcohols and lower levels of esters, linalool and β-damascenone were associated with dark fruit attributes (fresh and jam). Wines with higher levels of dark fruit attributes (fresh and jam) were also associated with increased concentrations of various phenolic measures associated with astringency and colour.

The effect of pre-fermentation removal of fine suspended solids from classic maceration red fermentations or flash détente treated red must fermented on skins warrants further investigation. Based on findings reported here, such fermentations could potentially enhance fruit aroma and flavour intensity, while also improving mouthfeel properties, thereby creating wines of greater sensory appeal. Pre-fermentation removal of fine suspended solids could be achieved by centrifuging juice once the cap has formed during cold maceration. Centrifuged juice would then be returned to the fermenter prior to inoculation and primary fermentation.

**IMPACT OF OAK OR OENOLOGICAL TANNIN ADDITION ON COLOUR STABILITY OF FLASH DÉTENTE-DERIVED WINES**

One of the key challenges with 'off-skins' red wine production is colour loss during fermentation. For 'on-skins' fermentations, colour loss is mitigated by continuous anthocyanin extraction from skins. Pre-fermentation addition of oenological tannins or toasted oak chips were investigated as methods for stabilising the colour of red wines made from FD-derived Merlot juice. Despite vendor claims advocating the colour stabilisation benefits of oenotannins, there is little evidence confirming the composition and colour stabilisation properties of the diverse range of commercial tannins used by the wine industry. Results from this study suggest pre-fermentation addition of oenological tannin or toasted oak chips did not improve wine colour stability. The oenotannin used comprised 50% total tannin on a dry mass basis, while the composition of the remaining material was unknown. Without a standard oenotannin definition (or standardised preparation methods), it is not surprising that findings differ among studies evaluating the colour stabilisation effects of tannins (Chen *et al*. 2016, Ghanem *et al*. 2017, Vignault *et al*. 2019).

The addition of 0.4g/L of oenological tannin to 'off-skins' fermentations did not affect the enhanced red fruit and confectionery ratings of

**Table 2. Selected compositional data for Merlot wines produced from flash détente derived juice (FJ, with and without oak and tannin additions) or must (FM, with 1, 2 or 5 days of skin contact before pressing), or from traditional maceration (control).**

| | Control | FD must fermentation | | | FD juice fermentation | | |
|---|---|---|---|---|---|---|---|
| | | FM (1 day) | FM (2 day) | FM (5 day) | FJ | FJ+Oak | FJ+Tannin |
| Ethanol (% abv) | 13.9 | 14.2 | 14.0 | 13.9 | 13.9 | 14.0 | 13.9 |
| TA (g/L) | 7.1 b | 7.4 a | 7.1 ab | 7.1 ab | 6.5 c | 6.6 c | 6.6 c |
| VA (g.L) | 3.0 a | 1.9 bc | 2.0 bc | 1.5 c | 1.9 bc | 2.0 b | 2.1 b |
| Glycerol (g/L) | 9.5 a | 9.7 a | 9.5 a | 9.7 a | 8.0 b | 8.0 b | 8.3 b |
| Wine colour (A520) | 3.11 bcd | 6.21 a | 6.62 a | 6.33 a | 3.99 bc | 4.06 bc | 4.25 b |
| Malvidin-3-O-glucoside (mg/L) | 70.0 c | 82.0 ab | 91.0 a | 83.0 ab | 82.0 ab | 82.0 ab | 80.5 b |
| Quercetin glycosides (mg/L) | 13.0 e | 27.5 ab | 29.0 a | 26.0 bc | 24.0 cd | 24.5 cd | 23.0 d |
| Proanthocyanidins (mg/L) | 151.5 b | 197.5 ab | 277.0 a | 256.0 a | 118.5 b | 152.0 b | 140.0 b |
| Tri-OH (%) | 19.3 ab | 16.7 cd | 17.4 bcd | 15.2 d | 18.4 abc | 18.4 abc | 20.0 a |
| Galloylation (%) | 4.20 c | 5.46 bc | 6.90 ab | 8.48 a | 3.74 c | 4.26 c | 4.00 c |
| Total polysaccharides (mg/L) | 165.0 ab | 144.7 b | 177.5 ab | 211.8 a | 82.8 c | 85.4 c | 85.0 c |
| Ethyl butanoate (µg/L) | 268.0 b | 298.0 b | 324.5 b | 268.5 b | 371.0 ab | 529.0 a | 526.5 a |
| Ethyl hexanoate (µg/L) | 317.0 b | 375.5 b | 354.0 b | 362.0 b | 454.5 a | 455.5 a | 458.5 a |
| Ethyl octanoate (µg/L) | 537 b | 680 b | 665 b | 569 b | 1096 a | 1231 a | 1166 a |
| Isoamyl acetate (µg/L) | 97.0 b | 6151 ab | 7528 ab | 4300 bc | 7768 a | 8429 a | 8830 a |
| β-Damascenone (µg/L) | 1.85 b | 2.45 a | 2.35 ab | 1.90 b | 2.45 a | 2.35 ab | 2.50 a |
| Linalool (µg/L) | 6.0 c | 11.0 ab | 9.5 abc | 8.0 bc | 11.0 ab | 13.0 a | 12.5 a |
| Isoamyl alcohol (mg/L) | 296 a | 284 a | 273 a | 273 a | 159 b | 159 b | 175 b |

Values are means of two replicates. Different letters (within rows) indicate statistical significance ($P < 0.05$). Oak = addition of 4.0 g/L of medium toasted oak chips. Tannin = addition of 0.4 mg/L of oenological tannin.

these wines, whereas fermentation with 4g/L of toasted oak chips decreased the perception of these attributes, instead enhancing the intensity of jam, dark fruit, toasty, vanilla and allspice attributes.

## CONCLUSIONS

This research demonstrates how conditions such as temperature, the percentage of suspended grape solids and the duration of skin contact time during fermentation of FD-derived juice or must can be manipulated to create differentiated styles of red wine, whilst improving the efficiency of red winemaking by overcoming the need for prolonged skin contact (and associated cap management) during fermentation. Following FD, fermentations can be performed either 'on-skins' or 'off-skins' at different temperatures with different concentrations of suspended solids, with or without oak additions, to achieve a diverse range of wine styles that can either become stand-alone wines or be used as blending components for targeted wine style attainment.

The contribution of esters such as ethyl octanoate, ethyl hexanoate and isoamyl acetate to the flavour profile of red wines made via liquid phase fermentation of FD-treated must was demonstrated via descriptive analysis. The sensory profiles of FD wines were clearly distinguishable from those of the control wines made via traditional maceration. The addition of toasted oak chips prior to fermentation of FD-derived juice yielded wine with perceivable oak characters, but neither oak nor tannin additions improved the short- or long-term colour stability of wines. FD nevertheless offers innovative winemakers new approaches for creating novel wine styles, including lighter-bodied, fruit-driven red wines with less apparent 'green' notes via liquid phase fermentations under non-traditional conditions.

## ACKNOWLEDGEMENTS

The authors thank the E & J Gallo Winery for supporting this research, Stella Kassara from the Australian Wine Research Institute for wine tannins and polysaccharide analysis, and the sensory panellists who evaluated the wines.

## REFERENCES

Casalta, E.; Vernhet, A.; Sablayrolles, J.M.; Tesniere, C. and Salmon, J.M. (2016) Review: Characterization and role of grape solids during alcoholic fermentation under enological conditions. American Journal of Enology and Viticulture 67:133-138.

Cejudo-Bastante, M.J.; Hermosín-Gutiérrez, I. and Pérez-Coello, M.S. (2011) Micro-oxygenation and oak chip treatments of red wines: Effects on colour-related phenolics, volatile composition and sensory characteristics. Part II: Merlot wines. Food Chemistry 124:738-748.

Chen, K.; Escott, C.; Loira, I.; Fresno, J.M.D.; Morata, A.; Tesfaye, W.; Calderon, F.; Benito, S. and Suarez-Lepe, J.A. (2016). The effects of pre-fermentative addition of oenological tannins on wine components and sensorial qualities of red wine. Molecules 21:1-17.

Du Toit, W.J.; Marais, J.; Pretorius, I.S. and Du Toit, M. (2017) Oxgen in must and wine: A review. South African Journal of Enology and Viticulture 27:76-94.

Ghanem, C.; Taillandier, P.; Rizk, M.; Rizk, Z.; Nehme, N.; Souchard, J.P. and El Rayess, Y. (2017) Analysis of the impact of fining agents types, oenological tannins and mannoproteins and their concentrations on the phenolic composition of red wine. LWT - Food Science and Technology 83:101-109.

Ntuli, R.G.; Saltman, Y.; Ponangi, R.; Jeffery, D.W.; Bindon, K. and Wilkinson, K.L. (2022) Impact of fermentation temperature and grape solids content on the chemical composition and sensory profiles of Cabernet Sauvignon wines made from flash détente treated must fermented off-skins. Food Chemistry 369:1-13.

Rihak, Z.; Prusova, B.; Kumsta, M. and Baron, M. (2022) Effect of must hyperoxygenation on sensory expression and chemical composition of the resulting wines. Molecules 27:235.

Vidal, S.; Francis, L.; Williams, P.; Kwiatkowski, M.; Gawel, R.; Cheynier, V. and Waters, E. (2004). The mouth-feel properties of polysaccharides and anthocyanins in a wine like medium. Food Chemistry 85:519-525.

Vignault, A.; Gombau, J.; Pascual, O.; Jourdes, M.; Moine, V.; Canals, J.M.; Zamora, F. and Teissedre, P. (2019) Copigmentation of malvidin-3-O-monoglucoside by oenological tannins: Incidence on wine model color in function of botanical origin, pH and ethanol content. Molecules 24:1448. WVJ