Pre-fermentation heating of red grapes: A useful tool to manage compressed vintages?

Fermentation

Pre-fermentation heating of red grapes can greatly speed up the extraction of skin colour, meaning less time required on skins and less demand on expensive red fermenters. It can also be used to denature laccase, remove 'green' aromas, and produce different red wine styles. While rarely used in Australia, pre-fermentation heating is quite common in France, Germany, and other countries for commercial red wine production. Many process variations exist (see summary). **Simon Nordestgaard**, from The Australian Wine Research Institute, reports.

HEATING GRAPES to enhance extraction of colour from skins is not new. Considerable research was performed on the topic from the early 20th century (see for example Bioletti 1906, Figure 1), but it was not widely adopted commercially until the 60s and 70s.

Poor vintages in France in the 1960s created interest in finding better ways of managing laccase, and equipment was developed that allowed large tonnages to be quickly and cheaply processed. This was true thermovinification - short maceration times and liquid phase fermentations.

There was interest in the topic in Australia as well at that time. For example, there were two presentations on thermovinification at the 1973 Australian Wine Industry Technical Conference and in the same year AWRI researcher Bryce Rankine described in an article that "heat extraction of color (sic) from red grapes prior to fermentation is one of the most important recent developments in Australian winemaking" (Rankine 1973). The subsequent extent of its use in Australia is not clear, but it seems likely that it was not widespread given the near absence of pre-fermentation heating from modern Australian wine production. However, developments have continued to the present day in Europe, particularly in France.

SENSORY CHARACTERISTICS

Wines produced with true thermovinification often have poor colour stability and little structure. While coloured anthocyanins are extracted very quickly at high temperature, tannins take longer to extract and after less than an hour of hot maceration they are not at sufficient levels to stabilise anthocyanins or provide much structure.

AT A GLANCE

Summary of different pre-fermentation heating processes

Thermovinification: Heating to ~70°C for less than one hour followed by liquid-phase fermentation (i.e. pressing is performed before fermentation, as for a white wine).

Pre-fermentation hot maceration (MPC): Heating to ~70°C for a longer period (up to ~15 hours) followed by solid- and/or liquid-phase fermentation.

Short-time-high-temperature treatment with warm maceration (KZHE): Heating to ~85°C for ~2 minutes, cooling to ~45°C (by pre-heating incoming grapes) and holding for ~6-10 hours before liquid-phase fermentation.

Flash détente: Heating to ~85°C for a short time then exposure to a vacuum that vaporises a portion of the grapes, cooling the remainder and weakening skin cell walls. Solid and/or liquid-phase fermentation follows.

Thermo détente: Heating to ~75°C then pressurisation using compressed gas and release. Pre-fermentation maceration, and solid- and/or liquid-phase fermentation follows.

The process definitions above are based on those used in France, except for KZHE, which is a German process. The term 'thermovinification' is used by some as a catch-all for all pre-fermentation heating techniques, but this article uses the term as defined above.

There are options to try to address these issues including the use of a longer period of pre-fermentation hot/warm maceration, some period of fermentation on skins and the use of techniques like flash détente.

A summary of typical sensory characteristics associated with different pre-fermentation heating techniques currently used in France is presented in Table 1 (although outcomes of course vary with grape variety and process specifics).

Pre-fermentation heat treatments using short contact times coupled with liquid-phase fermentations have a reputation for producing wines with a generic 'fruity ester' profile. Sometimes they are described by French winemakers as 'banana yoghurt' (Geffroy et al. 2015).

This profile can reportedly be modulated (if desired) by varying juice clarification levels and fermentation temperature. Wines fermented from juice with initial turbidities less than 100 NTU tend to be more estery, while wines with turbidities greater than 400 NTU tend to have more weight. Juice clarity can be altered by choosing between rotary drum vacuum filtration, flotation, centrifugation or no clarification at all prior to fermentation. Lower fermentation temperatures (18°C) favour ester production, while higher fermentation temperatures (23°C) favour a riper fruit profile. (IFV c. 2013).

Wines produced with pre-fermentation heating techniques do not need to be used pure and are often blended, bringing different sensory characteristics.

TEMPERATURES AND HEATING

The higher the temperature used for heating, the faster the rate of anthocyanin extraction; however long periods over 80°C may result in 'cooked' flavours (Rankine 1973). If grapes are affected by bunch rots the speed with which grapes are heated is critical since while laccase is denatured quickly over 70°C, its activity actually peaks around 30-50°C.

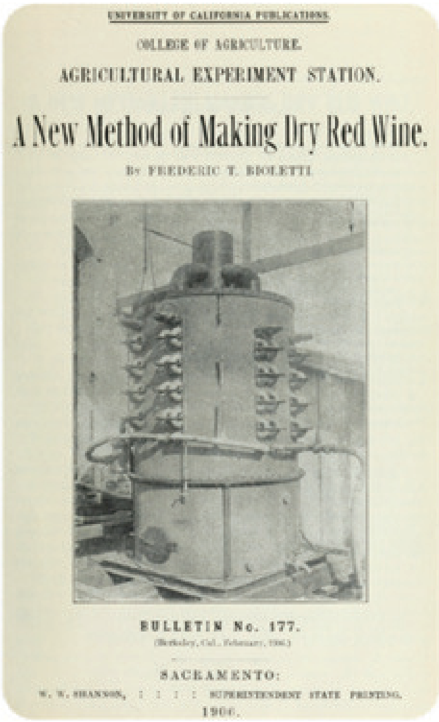
UNIVERSITY OF CALIFORNIA PUBLICATIONS.
COLLEGE OF AGRICULTURE.
AGRICULTURAL EXPERIMENT STATION.
A New Method of Making Dry Red Wine.
By FREDERIC T. BIOLETTI.
BULLETIN No. 177.
(Berkeley, Cal., February, 1906.)
SACRAMENTO:
W. W. SHANNON, : : : : SUPERINTENDENT STATE PRINTING.
1906.

Figure 1. Cover of Bioletti's 1906 report showing the French Gomot juice heater used in his work to extract colour with heat in California

Scraped-surface, immersion and tube-in-tube heat exchangers are commonly used for heating. Scraped-surface heat exchangers (Figure 2) have a rotating shaft with elements that help improve heat transfer to the grape must.


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Table 1. Typical sensory outcomes for different pre-fermentation heat treatments (adapted from the website of the South-West section of the French Institute of Wine and Vine, IFV c. 2013)

Treatment		Aroma	Palate	Comments
Thermovinification		• Fresh fruit • Estery	• Little body • Unstable colour (tannin addition helps)	• Weak concentration • Used in blends to add fruitiness • Suitable for grapes with green or neutral aromas
Pre-fermentation hot maceration (MPC)	***Liquid-phase fermentation*** (i.e. pressed off skins prior to fermentation)	• Riper fruit • Decreased green aromas	• Balance approaching a classic red	• Used pure or in blends with thermovinified or classically made wines • Useful for underripe grapes
	Solid-phase fermentation (i.e. fermented on skins)	• Very ripe fruit (jammy) • Decreased green aromas but some still present	• Wealth of tannin and sweetness • Hard tannins, rarely dry	• Needs ageing (micro-oxygenation or wood) • Used in blends with MPC or thermovinified wines
Flash-détente	***Liquid-phase fermentation*** (i.e. pressed off skins prior to fermentation)	• Fruity to estery • Reductive and green if juice poorly clarified	• Balanced wine • Green tannins if insufficient phenolic maturity	• Used pure • Not very suitable for underripe grapes
	Solid-phase fermentation (i.e. fermented on skins)	• No estery notes • Ripe fruit characters if good grape maturity • Green characters if average or insufficient grape maturity	• Richness and sweetness of ripe grapes • Aggressive tannins with under-ripe grapes	• Used in blends • Not very suitable for underripe grapes (aggressive tannins)

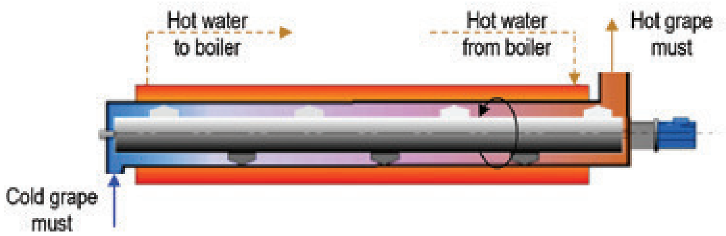

Figure 2. Schematic of scraped-surface heat exchanger

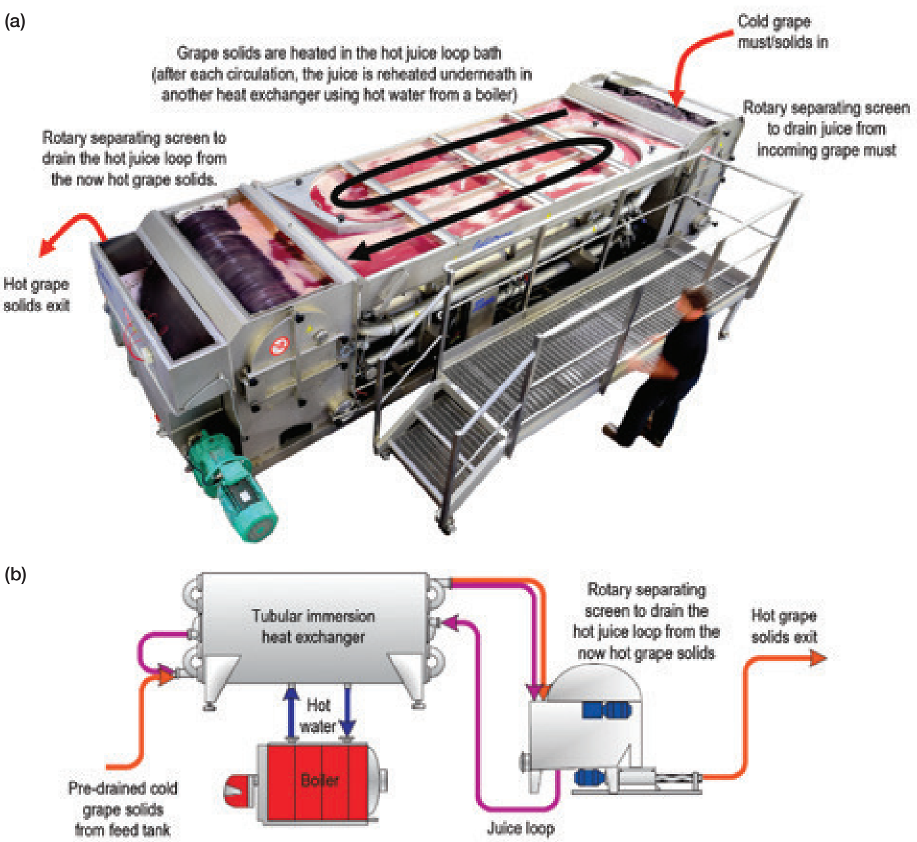

Figure 3. Modern immersion heat exchange systems from (a) Pera-Pellenc and (b) Della Toffola

They were initially introduced in this application by Gasquet in the 1960s and are now sold by Pera-Pellenc, Bucher-Vaslin and others. Immersion heat exchangers heat pre-drained grape solids in a recirculating bath of hot juice. They were introduced in this application by IMECA in the 1960s and modern versions are now sold by Pera-Pellenc and Della Toffola (Figure 3).

An advantage of scraped-surface exchangers is that they require little supervision and can handle a moderate degree of pre-draining without blocking. An advantage of immersion baths is that they can handle as much pre-draining as desired since solid material is being conveyed by a separate juice loop. Tube-in-tube heat exchangers are the simplest and cheapest of the heat exchangers used for pre-fermentation heating but grape must cannot be significantly pre-drained or tubes may block. Considerable pre-draining is very useful in wineries that make a lot of rosé. It is also beneficial in terms of energy savings since it minimises the quantity of material that needs to be heated and cooled.

Some German producers use a different approach to save energy. In their short-time high-temperature (KZHE) process (Maurer 1974, Schmidt 2013) they continuously recover heat. Well-mixed grape must without any pre-draining is heated to ~85°C for ~2 minutes before being cooled to ~45°C (by pre-heating incoming grape must) and held for ~6-10 hours before a liquid-phase fermentation. The exchange between hot and cold grape must would be problematic in a normal tube-in-tube exchanger because the outer tube would be liable to block. To avoid this issue, heat exchange is sometimes performed via an intermediate water loop that circulates in the outer tube of two tube-in-tube exchangers. Alternatively, heat exchange is performed by direct heat exchange between hot and cold must using spiral heat exchangers or a heat exchanger with a section of parallel rectangular channels (Becker Tanks, Figure 4). The KZHE process is clever because the short-time at ~85°C is enough to denature any laccase that would otherwise be active during the ~6-10 hour holding period. Enzymes added during the holding period to enhance pressing and clarification are also highly active at ~45°C.

The techniques above are used in a continuous single pass in larger facilities. An alternative used in some smaller wineries is to heat while recirculating on a tank via a tube-in-tube heat exchanger. This results in a slower and often heterogeneous temperature rise and is therefore not suitable for laccase-affected grapes. Heat is usually provided to exchangers in the form of hot water, glycol or steam from a separate boiler, but packaged systems are available that incorporate both the heat source and heat exchanger in a single unit such as the AP3M Thermopack (Figure 5). This device uses an oil burner mounted centrally inside a cylinder to heat a water jacket. The tube within which the grape must flows runs back and forth in this jacket. Clauger (Figure 6) has also released a very small capacity packaged system that heats glycol using a heat pump instead of a burner.

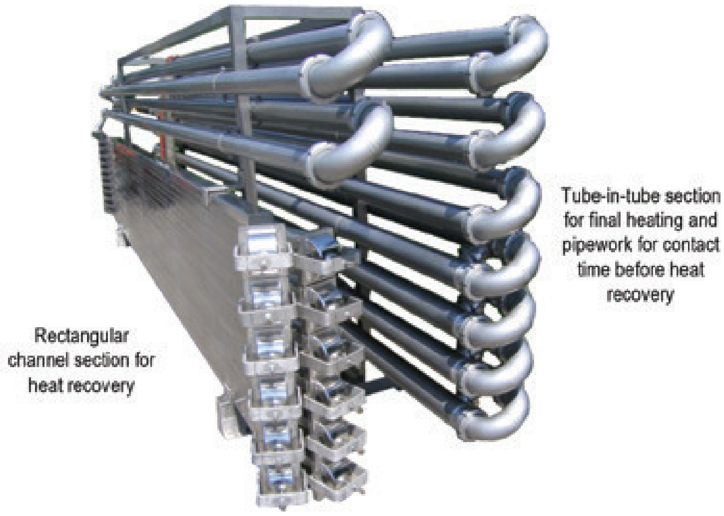

Figure 4. Becker 2-stage heat exchanger with rectangular channel section for heat recovery between hot and cold grape must

COOLING

After a period of heating, the grape must or juice needs to be cooled prior to fermentation. Where a purely liquid-phase fermentation is performed, cooling could be performed before or after draining/pressing. Where some period of solid-phase fermentation (on skins) is desired, cooling must be performed with solids present.

Figure 5. AP3M Thermopack packaged heating system

Figure 6. Clauger heat pump based packaged heating/cooling system

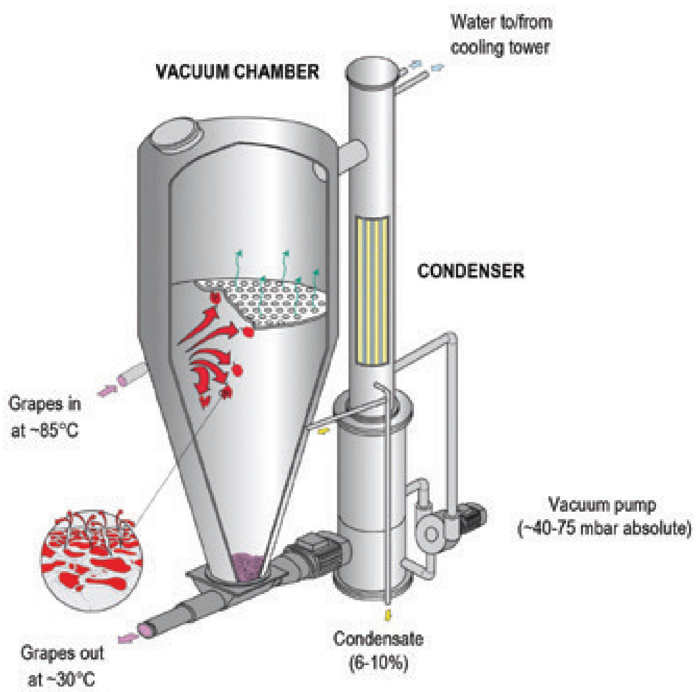

Figure 7. Flash détente vacuum chamber

Similar heat exchange equipment can be used for cooling as for heating.

Generally, it is most energy efficient to cool with as much evaporative cooling as possible followed by refrigerative cooling as needed – i.e. first cooling by exchange with water from a cooling tower, then by exchange with water/brine/glycol from a refrigeration system down to the fermentation temperature. Hot grape must/juice is even passed directly through a special cooling tower in some French configurations with the cooling occurring by direct evaporation of some of the juice.

Flash détente, which is usually talked about with respect to its extractive effects, is also a means of rapidly cooling grape must by partial vaporisation.

SUPPLEMENTARY EXTRACTIVE TECHNIQUES – FLASH AND THERMO DÉTENTE

In the flash détente process, grape must is heated to ~85°C for a short time before being introduced to a vacuum chamber (Figure 7). In the vacuum chamber, the grape must boiling point is lower than at atmospheric pressure, so a portion of the grape must boils instantly - some from inside skin cells, weakening the skin cell walls and enhancing extractability in subsequent processes. The vapour is condensed and this condensate can be kept separate or added back as desired (sometimes after treatment with activated carbon).

The flash détente process was originally patented in 1993 by INRA, the French National Institute for Agricultural Research. In 2011, INRA and Pera-Pellenc patented a modified 'half' flash détente process. In this process a weaker vacuum is employed such that grape must is only cooled to ~50°C instead of the usual ~30°C. Enzymes are added and several hours of skin contact are provided prior to warm pressing and liquid-phase vinification. Like the German KZHE technique, this process has the advantage that the short period of time at ~85°C is enough to denature any laccase, meaning that oxidation is not such an issue during the warm maceration at ~50°C during which time the added enzymes are near their optimum activity. The enzymatic maceration may even be performed while filling a large membrane press, avoiding the use of a separate maceration tank.

In addition to the use of the full or half-flash process, sensory outcomes with flash détente can be modulated by the use of different periods of solid- and liquid-phase fermentation, different fermentation temperatures and different clarification levels for liquid-phase fermentations.

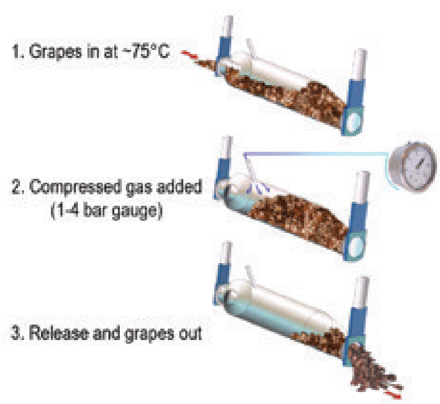

Figure 8. Thermo détente pressure bottle

Flash détente style equipment is offered by Pera-Pellenc, Della Toffola and TMCI Padovan.

Another supplementary extraction technique is the thermo détente process from Brunet Ertia (now also sold by Bucher-Vaslin as Extractys). In this process, hot grapes are pressurised in bottles using compressed gas and this pressure is then released (Figure 8). Two bottles are used alternately to make the process semi-continuous. There is no flash vaporisation, but there is some smaller effect on extractability. Thermo détente is cheaper than flash détente and is marketed as something that can be easily retrofitted to existing thermovinification installations.

REMOVAL OF METHOXYPYRAZINES, C_6 COMPOUNDS AND SMOKE TAINT

Pre-fermentation heat treatment can also remove 'green' aromas. Figure 9 presents results from three studies illustrating the removal of 3-isobutyl-2-methoxypyrazine (IBMP), a compound associated with 'green capsicum', 'herbaceous' and 'tomato leaf' aromas. IBMP has a boiling point of 50°C at atmospheric pressure (Roujou de Boubée 2003) and it is clear from Figure 9 that pre-fermentation heating reduces IBMP levels in wine.

Flash détente appears to be particularly effective (the IBMP is collected in the condensate). C_6 compounds that can also be responsible for 'green' aromas are also reportedly lower in hot extracted grapes. Heat denatures enzymes associated with the production of C_6 compounds (Fischer et al. 2000). Flash détente has also been suggested as a possible treatment for smoke-affected grapes. Dobson (2015) compared the flash détente treatment of smoke-affected Pinot Noir grapes with traditional processing, followed by fermentation conducted on skins in both cases.

Nine months post-fermentation, the guaiacol concentration in the flash-détente treated wine was 5.3 µg/L compared with 14.9 µg/L for the control and the 4-methylguaiacol concentration was <1 µg/L compared with 2.5 µg/L for the control. Conceivably the result could have been even more dramatic if flash détente had been coupled with a liquid-phase instead of a solid-phase fermentation because there would have been less skin extraction. In evaluating smoke taint treatments it is important to remember that compounds responsible for smoke taint are mainly present as non-volatile precursors, so if a treatment only removes the free smoke taint compounds, there is a risk that smoke taint can re-emerge when the precursors hydroylse during ageing (Fudge et al. 2011). Nevertheless, the results from this study are promising, and warrant further investigations of flash détente as a treatment for smoke-affected grapes.

COSTS

Capital costs for heating equipment vary considerably with process choice. ▸

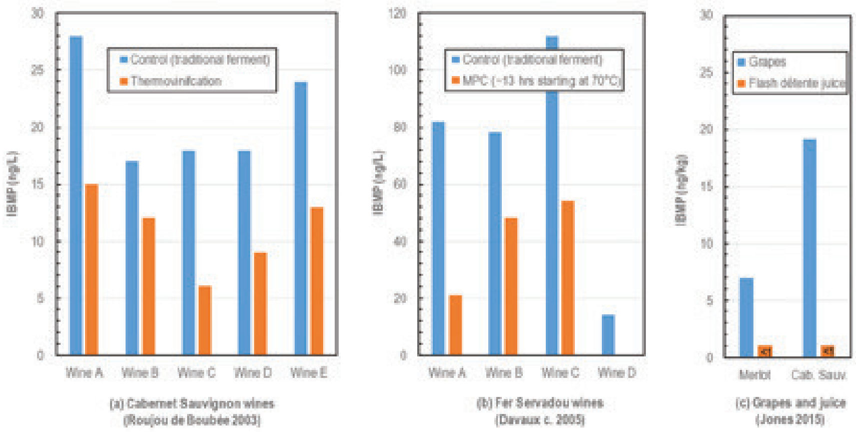

Figure 9. Changes in pyrazine levels following pre-fermentation heat treatment (data sources shown in brackets)

At the lower priced/lower throughput end of the market, a Thermopack packaged heating system offered by AP3M capable of processing around 10 tonnes/hr costs in the order of $50,000. AP3M also offers a packaged cooling system incorporating evaporative and refrigerative cooling which would cost a further $50,000.

At the high throughput end, a scraped-surface or immersion heat exchanger capable of processing around 30 tonnes/hr costs in the order of $300,000. If a flash détente vacuum chamber is to be used this would likely add a further $300,000.

This excludes all other major capital equipment and peripherals that would be required including boilers, cooling towers and storage tanks, which would add considerably to the cost. A process like flash détente does add a major expense, but provides more flexibility than heating alone.

Irrespective of the equipment used there will be some utility costs associated with heating and cooling. These costs are estimated to be in the order of 1 cent per 750 mL bottle for large wineries*.

For Australian wineries to adopt pre-fermentation heat treatment, the capital costs would have to be justified. One potential justification relevant to compressed vintages is savings from avoiding purchases of red fermenters through reductions in skin contact time.

(* Assumed 1 kg of grapes is needed to produce 1 bottle of wine and the specific heat capacity of grapes is 4 kJ/kg/°C. Assumed grapes are heated from 15 to 70°C with a net grape heating efficiency of 60% from a natural gas-fired boiler and that natural gas costs 2 cents/MJ. Assumed grapes are cooled evaporatively to 35°C with a coefficient of performance (COP) of 10 and then refrigeratively to 20°C with a COP of 2, and that electricity costs 18 cents/kWh.)

CONCLUSIONS

This article summarises some of the existing knowledge on pre-fermentation heat treatment, principally based on the French literature. In Australia, there is currently little experience using these techniques and it would be advantageous to build knowledge on them through research and practice. Wines produced with some pre-fermentation heat treatment techniques have been criticised for 'estery' sensory characteristics and there is merit in more research to better

understand how these and other aroma effects can be modulated. The potential application of pre-fermentation heat treatment techniques like flash détente to smoke-taint remediation is another area that would benefit from further research.

Pre-fermentation heating will never replace traditional red wine fermentations. However, it could be a very useful tool for some larger wineries to process part of their grape intake and help manage compressed vintages.

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Disclaimer

Readers should undertake their own specific investigations before purchasing equipment or making major process changes. This article should not be interpreted as an endorsement of any of the products described.

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