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Title: **"A review of the effect of winemaking techniques on phenolic extraction in red wines"**

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This is an excellent review on the effects of different winery practices on the extraction of phenolic compounds during red winemaking. The article looks at many studies, and does a great job at separating what works sometimes and on some varieties from what works most of the times. Here are the highlights.

- In a study on Pinot noir, **fermentation temperature** had little effect on the extraction of wine anthocyanins, known to reach a maximum early in fermentation. But increasing fermentation temperature from 20 to 30°C did increase the levels of polymeric pigments.

- **Higher SO2** levels in the must increased phenolic extraction early in the fermentation in a cold soak trial, but there was little difference in phenolic content in the finished wines.

- **Cold soak** (low temperature extraction in the absence of alcohol) produced little difference in anthocyanin and tannin levels, or sometimes, produced even less anthocyanins, color intensity, and flavonols than non cold-soaked wines (Pinot noir). The authors point out that, even in cases where cold soak was able to increase anthocyanins, a long-term impact on color would not be expected since the polymeric pigments needed to stabilize them would not have been affected.

- **Freezing the must** before fermentation breaks cell membranes and seems to be an effective technique for releasing anthocyanins. Interestingly, when dry ice was used to freeze the must, several studies reported a two-fold increase in both anthocyanins and tannins, in all Merlot, Cabernet sauvignon and Cabernet franc. This had the added benefit of protecting the berries from oxygen before fermentation.

- **Heating the must** (thermovinification) damages the cell membranes, releasing anthocyanins, but since there is no alcohol, tannin extraction is not increased. When thermovinification (heating juice with skins, pressing, letting juice cool down, then fermenting off-skins) was compared to traditional fermention on the skins, the result was that thermovinification lead to improved color, but phenolic extraction was much lower. This difference in color was highest early on (3X), and then decreased rapidly, even though still remained 1.5X that of the control (Pinot noir). For the technique to be effective, it is important that the skins be in contact with the juice during or after the heating, so the compounds released have a chance to get dissolved.

- Regarding the effect of **carbonic maceration** (partial fermentation in a carbon dioxide atmosphere due to the activity of berry glycolytic enzymes), conflicting results were found in different countries, depending on varieties. It seems that the overall positive or negative effect is going to depend on which varieties are present.

• **Juice runoff** (bleeding or "saignée") increased both anthocyanins and tannins in the resultant wines. If extraction of these compounds were strictly dependent upon solubility, we would expect the opposite effect, since there is less liquid to dissolve the phenols. So extraction of phenolics is not strictly solubility limited. In both Malbec and Pinot noir, wines with saignée had more tannin, more polymeric pigment, and more color than the control wines. In another study with Syrah, this was true early on, but after six months, the differences had almost disappeared. This has triggered questions about the long-term effects of saignée, still unanswered.

• **Pectolytic enzymes** were able to increase wine color and total phenols at the end of fermentation for a number of varieties, according to early reports. In two separate studies in Pinot noir and Cabernet sauvignon, respectively, the enzyme treatment increased tannins and polymeric pigments, but there was no change, or even a decrease, in anthocyanins. It is believed that this was due to the formation of polymeric pigments at the expense of anthocyanins. In most of the studies reviewed, pectinase did not seem to increase anthocyanin, but it did increase extraction of other phenols, like tannins. The purity of the pectolytic enzyme preparation is important, since the presence of ß-glucosidase impurities can convert anthocyanins to aglycones, resulting in a color loss.

• The extraction effectiveness of **pump-overs, punch downs, and rack & returns** ("delestage") seems to be very variety-dependent. Pump-overs tend to increase extraction as compared to punch-downs. But in Pinot noir, this was reversed. Another example of how variable the effects are: with Negramano and Primitivo, pump-overs allowed greater extraction than punch-downs, but in the same study with Sangiovese there was little difference. Rack & returns (pumping all the juice from the skins into a separate tank, then pumping the juice back over the skins) behaved closer to pump-overs, rather than punch-downs, in terms of extraction.

• **Extended maceration** tended to increase tannin, but not anthocyanin. This is because anthocyanins peak on days 4 and 5 of skin contact, with little gain after day 10.

• The **yeast strain** used did not seem to be relevant in terms of extraction level. Besides, most studies failed to check if their fermentations were indeed pure and attributable to the strain that was inoculated, rather than a contamination. In general, we know that lees adsorb anthocyanins. Macromolecules released by yeast autolysis bind to phenols in a similar way that a fining protein would. Also, addition of mannoproteins from certain yeast led to more anthocyanin-tannin combinations, and decreased astringency.

• In summary, a review of the literature showed that several winemaking techniques were effective in increasing phenolic extraction. These included *increased fermentation temperature*, *must freezing*, *must heating*, *juice run-off*, *pectolytic enzymes* and *extended maceration*. Sulfur dioxide and cold-soak were not effective. Rack and return, pump overs, punch downs and carbonic maceration had mixed results depending on the variety.

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