18-080 Comparing reverse osmosis and chaptalization in Chardonnay

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Abstract

In Virginia, wet vintages like 2003, 2011 and 2018 as well as more frequent fall rains and occasional hurricanes sometimes lead winemakers to pick grapes with lower potential alcohol than desired. The 2018 in Virginia included high amounts of rainfall, providing an opportunity to test the use of juice RO as a means of increasing potential alcohol and combatting dilution of flavor and body. Chardonnay juice was treated with either chaptalization or reverse osmosis to the same target Brix prior to fermentation. Chemical and sensory outcomes were evaluated 6 months after completion of primary fermentation. Reverse osmosis led to higher TA, higher pH and slightly higher volatile acidity in the finished wine. There were no significant differences in perception of aroma or flavor concentration in a paired difference test. Descriptors for intensity and volume were also scored the same by a sensory panel.

Introduction

In Virginia, wet vintages like 2003, 2011 and 2018 as well as more frequent fall rains and occasional hurricanes sometimes lead winemakers to pick grapes with lower potential alcohol than desired. Winemakers are then left with the decision of whether to intervene to augment the potential alcohol or not intervene and make a lower alcohol wine.

Several options for increasing sugar include chaptalization, addition of juice concentrate and reverse osmosis of juice to remove water. Chaptalization adds only sugar and does not address concerns about flavor dilution, though chaptalization alone has been shown to increase sensory perception of ripeness (Sherman et al 2017). Adding concentrate brings concerns such as the potential for *Zygosaccharomyces* infection and the addition of phenolics disproportionate to the treated juice (Jackson 2014). Juice concentrate addition is not allowed for wines entered in the Virginia Governor's Cup unless the concentrate is produced from Virginia fruit (J. Rose, personal communication). Reverse osmosis of juice to remove water not only increases potential alcohol but also concentrates flavor and structure that may be diluted in wet vintages while maintaining the terroir and appellation of the fruit.

Reverse osmosis of juice has been utilized in Europe in wet years since the 1980's to "squeeze" the rain out of the juice to obtain flavor concentration and alcohol balance. This technique has been utilized in Bordeaux, Burgundy, Tuscany, Piedmont of Italy, and is used frequently in cool climate regions such as Germany (Goode 2014). EU regulations allow RO of juice but limit must concentration to 20% of the volume of the juice.

Reverse osmosis works by using pressure to force molecules across a membrane against a concentration gradient. Osmosis is the movement of water in response to a chemical gradient by diffusion. Water moves by osmosis from areas of low solutes to areas of high solutes, which lowers the gradient between areas. Solutes are separated by a semipermeable membrane will pass through that membrane until differences are evened out on either side. If the membrane does not permit some materials to pass, for example, only small molecules can fit though the pores in the membrane, the remaining molecules will maintain a gradient, and water will move the opposite direction to even it out (Jackson 2014).

During wine filtration, there is a gradient of materials maintained on the retaining side of the membrane, creating osmotic pressure for water to move to the retaining side. Reverse osmosis filtration exerts physical pressure to overcome the osmotic pressure (Jackson 2014). Wine contains many large molecules that are retained by the filter, which leads to fouling of the membrane. Fouling is partially offset in reverse osmosis by the design of the filters which contain long tubes with high amounts of surface area for filtration and the flow of the wine in turbulent cross-flow currents (Smith 2014, Goode 2014).

Reverse osmosis membranes are not absolute filters, but rather layered web-like frameworks through which molecules must find their way through the "torturous path" (Ghosh et al 2015). Reverse osmosis membranes have a pore size rating of 80 Daltons which means that molecules of 80 Daltons will pass through the membrane 50% of the time. Water has a pore size of 18 Daltons and passes easily through RO membranes while most other constituents of juice, including sugar and molecules that contribute to flavor are larger than this (Smith 2014). Most flavor molecules are still bound to sugars at the juice stage and are more likely to be retained in the juice during reverse osmoisis. Once cleaved/released during fermentation, these molecules are smaller, so larger pore sizes can be used for reverse osmosis of juice than for wine without losing flavor.

Complications of juice RO

There are several complicating factors when performing reverse osmosis on juice. Due to very small pore sizes, reverse osmosis filters clog quickly with particulates, so juice must be clarified to less than 200 NTU prior to filtration. Clarification is a normal step in white winemaking. However, for red wines, juice must be bled off the skins and clarified prior to RO, then returned to the must after treatment (Goode 2014). Even in clarified juice, pectin and pulp can clog the membranes. To increase the overall surface area for filtration, long tubes are needed, but the cross section of the tubes must be fatter than with wine filtration (Smith 2017).

High pressure is needed to raise Brix levels of juice. Sugar is a solute that exerts osmotic pressure. Two bars of osmotic pressure are added to the juice for each degree of Brix. As the juice is concentrated, additional pressure is needed to maintain reasonable flux rates on the filter. Figure 1 (from Duitschaever et al 1991) demonstrates the slowing flux rates for juice at ascending degrees of sugar. This same graph applies as juice is concentrated unless additional pressure is added throughout the filtration run. For example, at 21 Brix, 40 bar of pressure is needed simply to maintain the gradient. This leads to the need for high pressures to accomplish concentration (Smith 2017).

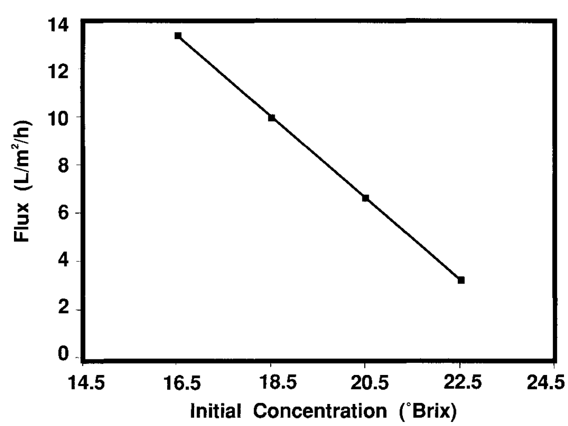

Fig. 1. Influence of the initial concentration of soluble solids in Riesling must on the flux when increasing the soluble solids by 2° Brix. Volume treated 60 L.

Flux = 40.79 - 1.67 (°Brix)

Operating conditions: Temperature of the must before treatment, 6°C; temperature of the must after treatment 26°C; pressure, 40 bar; processing mode, recirculation; coolant, water at 15°C.

High pressure flow also means high amounts of friction and heating. Heat increases permeability of the membrane which means the potential loss of flavor, and can also lead to cooked flavors. At high levels, heat can damage the membrane of the filter (Ferrarini et al 2001). To counter the buildup of heat, juice must stay cold during operation. For the RO unit used in this study, the product of temperature x pressure could not exceed 1350. As wine heated up during treatment, after a period of time allowable pressure is too low to accomplish further concentration, thus limiting operations (M. McGeary, personal communication).

RO vs. Chaptalization or Addition of Concentrate

Reverse osmosis has a greater impact on the chemistry of the wine than chaptalization alone. In a study comparing musts and wines made with chaptalization verses RO to the same I 20 L fermentations, Duitschaever et al (1991) found that reverse osmosis increased must TA by 25-28% with 4°Brix increase while there was no change in TA due to chaptalization to the same sugar target. Tartaric and malic acid increased with reverse osmosis (30 and 38%, respectively). There were no significant changes in pH with either treatment. These differences persisted in wine, where the TA from RO wines were higher than that from chaptalization, though the tartaric acid mostly dropped out during cold stabilization. pH of the wine remained the same for both treatments. Volatile acidity was also higher in RO wines than chaptalized wine. In a study comparing wines made by concentrating juice with reverse osmosis to those made with the addition of juice concentrate, Pati (2014) found an increase in TA (5-7%), color (6-8%) and total phenol content with membranes that were not found in wines with addition of juice concentrate. Once again there was no change in pH with any treatment. Sensory analysis of these wines showed wines made with reverse osmosis of juice had better color; taste and odor were mixed results.

The 2018 in Virginia included high amounts of rainfall, providing an opportunity to test the use of juice RO. In the present study, Chardonnay juice was treated with either chaptalization or reverse osmosis to the same target Brix prior to fermentation. Chemical and sensory outcomes were evaluated 6 months after completion of primary fermentation.

Procedure

After harvest, grapes were refrigerated overnight then whole cluster pressed with addition of 28 ppm SO_2 and 1-2 ml/1000 kg Lafasse XL Press. Juice was cold settled until clear (<200 NTU), then juice for the control was transferred to two barrels for chaptalization while juice for the treatment was transferred to tank for reverse osmosis.

Reverse osmosis treatment was carried out using a Bucher Vaslin Flavy ML Osmoser Machine. The machine was run between 60-90 bar of pressure and wine at a range of 5-25°C with a maximum pressure x temperature of 1350. For example, if the wine was at 20°C the maximum pressure would be 67.5 bar (1350 = 20 x 67.5) so as not to damage the membrane. Treatment began with juice at 5°C running at 88-90. As the juice heated up during processing, at 15°C the operator would lower the pressure to maintain pressure x temperature less than 1350. Lower than 67.5 bar, the rate of RO was slower than was useful for processing. The machine operated at 150 L/hour initially but slowed to 20 L/hour when at lower pressure. Eleven percent of the volume of the juice was removed. After reverse osmosis, juice was transferred to two barrels for fermentation. There were two barrels of control and two barrels of treatment. After transfer to barrel, 2 g/L tartaric acid and 0.75 g/L malic acid were added. Control barrels also received 20 g/L sugar to the same potential alcohol target as the juice that received reverse osmosis. Juice was inoculated with an ambient fermentation starter raised in the vineyard. All barrels were inoculated from the same well-mixed keg. Brix and temperature were monitored daily during active brix depletion. Malic acid depletion was monitored using enzymatic analysis after brix depletion was complete. The control wine completed malolactic fermentation and was treated with SO_2 on 3/4/19/. The reverse osmosis wine completed malolactic fermentation and was treated with SO_2 on 4/9/19.

Sensory analysis was completed by a panel of 27 wine producers. Wines were presented blind in randomly numbered glasses. Panelists were presented with two wines, one of each type, and asked to identify the wine with the most concentration of aroma and flavor (a paired difference test). They were then asked to score each wine on a scale of 0 to 10 for aromatic intensity and palate volume. Panelists were also given open ended questions to describe the wines. After revealing which wines were which and discussing the volume loss associated with reverse osmosis, respondents who chose the wine produced from juice treated with RO were asked if they thought the difference in the wine was worth the cost of volume loss.

Results

Juice chemistry before and after reverse osmosis is shown in Table 1. Reverse osmosis raised the sugar by 1.7 Brix or 1 degree of potential alcohol. pH did not change. TA appeared to go down with reverse osmosis. This is an unusual result.

Table 1: Juice chemistry before and after reverse osmosis

	Brix	pH	TA (g/L)
Control (before)	19.8	3.66	6.84
RO	21.5	3.67	6.4

Fermentation kinetics for all 4 barrels are shown in Figure 1. Fermentations were largely consistent among barrels with RO 1 showing a slightly faster fermentation. Finished wine chemistry of all 4 barrels is shown in Table 2. All barrels had RS < 1 and MA <0.15 (data not shown). Differences in ethanol concentration are consistent with differences in starting density (caused by slightly different results from chaptalization and RO). Increased TA in wine treated with RO is expected due to the concentrating effect of this treatment. Higher pH is unusual in the literature. In this case, higher pH may be due to higher potassium with RO concentration, leading to loss of acid through tartaric precipitation. Wines treated with RO resulted in slightly higher volatile acidity. This may be due to a longer malolactic fermentation in these barrels, or concentration of acetic acid at the juice stage. Duitschaever et al (1991) also found higher VA in wines subjected to RO than those that were chaptalized.

In a paired difference test of concentration, 12 respondents chose the control wine while 14 respondents chose the treatment (reverse osmosis) wine, indicating the wines were not significantly different ($Z=0.19$, $p=0.42$). There were no significant differences in scores for aromatic intensity ($F=0.79$, $p=0.38$) or palate volume ($F=0.01$, $p=0.94$). Open ended questions did not reveal any consistent trends. Of respondents who chose the wine produced from juice treated with reverse osmosis, 6 felt the volume loss associated with this treatment was worth the cost while 4 felt it was not (4 did not comment).

Figure 1: Fermentation kinetics for replicate barrels of chaptalized and RO treated Chardonnay

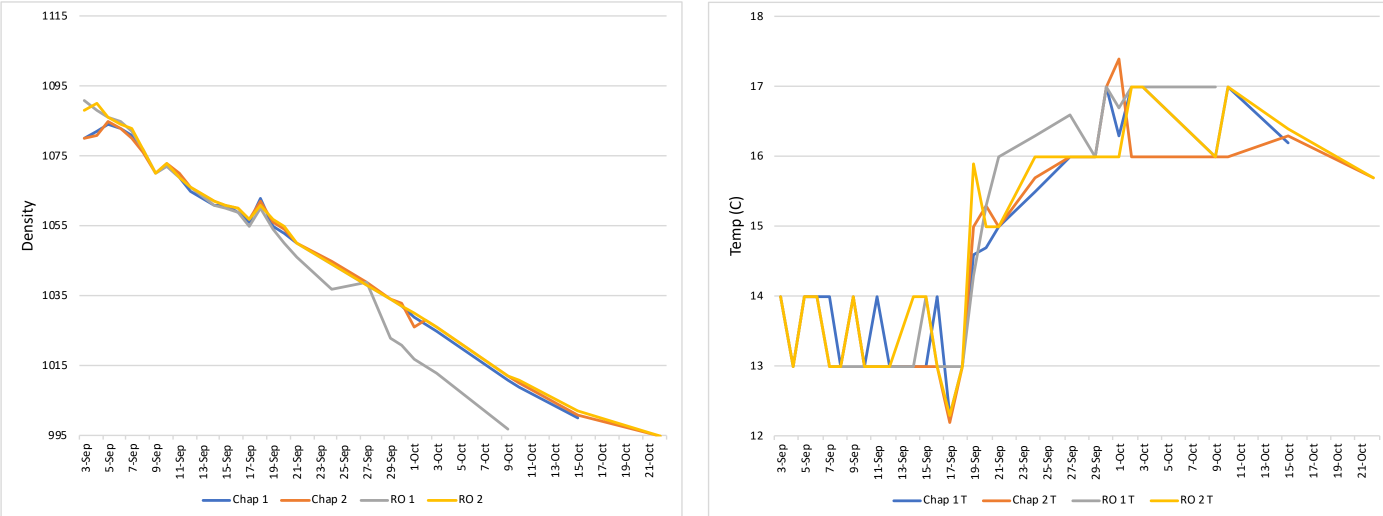

Table 2: Finished wine chemistry for replicate barrels of chaptalized and RO treated Chardonnay

	VA (g/L)	Ethanol (%)	pH	TA (g/L)
Chaptalized 1	0.49	12.92	3.61	4.65
Chaptalized 2	0.48	12.99	3.62	4.68
RO 1	0.56	13.29	3.7	4.74
RO 2	0.59	13.26	3.67	4.81

Conclusions

- Reverse osmosis of juice includes a commitment of money (to purchase the equipment) and time during harvest.
- The change in Brix is more difficult to control than with chaptalization, as seen in different alcohol concentrations between wines.
- Reverse osmosis of juice led to higher volatile acidity in the wine. This is consistent with at least one other study of juice concentration with reverse osmosis (Duitschaever et al 1991).
- There was no significant difference in sensory attributes between wines produced from chaptalized juice and juice that was treated with reverse osmosis.

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