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# Alcohol reduction in red and white wines by nanofiltration of musts before fermentation

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ABSTRACT

One of the consequences of global warming is the early ripening of grapes which promotes a sugar content increase. Fermentation of their must leads to wines with an alcoholic degree higher than desired. The scope of this study is to select a nanofiltration (NF) technique to reduce the alcohol content of wines approximately 2° by controlling the sugar content of grape must before its fermentation.

For this purpose the performance of single-stage and two-stage NF processes using a spiral wound membrane unit were compared for white must (Spanish *Verdejo*) while for red must (Spanish *Garnacha*) a two-stage procedure was tested. During the single-stage NF intermittent backflush due to the osmotic pressure effect was tested. Results showed that backflushing had an undesirable effect because it increased the flux decay by disturbing the cake stabilization on the membrane. The corresponding wines obtained by adequate mixing of permeated and retained or control musts showed a 1–2° alcohol reduction. Sensory evaluation and principal component analysis (PCA) revealed that there were no significant differences between the control and the filtered wines. Among the processes studied, the best NF technique was the two-stage process without backflush.

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## 1. Introduction

Over the last years, due to global warming, observations from various world winemaking regions have provided evidence of modified vine development and fruit maturation patterns. Among the most important climate change-related effects there is an increased grape sugar concentration that leads to high wine alcohol levels, lower acidities and modification of varietal aroma compounds (Mira de Orduña, 2010). Premature grape harvest and winemaking should affect the final wine quality, because the acidic and phenolic maturity should not be fully achieved (Garcia-Martin et al., 2011) leading to more acid and less colored wines. A commendable oenological practice establishes that the quality of wines depends essentially on the maturity of phenolic components contained in the grape berries. Since phenolic maturity is directly linked to a high sugar concentration, grapes are being picked having high potential alcohol content, up to 17%, with low acidity (Massot et al., 2008).

But in some countries, as USA, wine producers have to struggle with a supplementary tax added to beverages with alcohol content over 14.5%. Moreover, this over maturity leads to difficulties in wine making as some difficulties appear in alcoholic fermentation and in microbiological stabilization. It also causes a gustatory disequilibrium since the strengthening of warm sensation in the mouth could mask the fruity

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**Nomenclature**

| | |
|---|---|
| $C_{0,i}$ | feed concentration of the ith component ($\mathrm{kg\,m^{-3}}$) |
| $C_{m,i}$ | concentration of the ith component on the membrane active layer ($\mathrm{kg\,m^{-3}}$) |
| $C_{p,i}$ | permeate concentration of the ith component ($\mathrm{kg\,m^{-3}}$) |
| $D_i$ | diffusion coefficient of the ith component ($\mathrm{m^2\,s^{-1}}$) |
| $J_v$ | permeate flux per unit of area through the membrane ($\mathrm{m^3\,m^{-2}\,s^{-1}}$) |
| $J_{v,0}$ | permeate flux per unit of area through the membrane at time $t=0$ ($\mathrm{m^3\,m^{-2}\,s^{-1}}$) |
| $K_{m,i}$ | mass transfer coefficient ($\mathrm{m\,s^{-1}}$) of the ith component at impermeable embranes ($\mathrm{m\,s^{-1}}$) |
| $K^s{}_{m,i}$ | mass transfer coefficient of the ith component at semipermeable membranes ($\mathrm{m\,s^{-1}}$) |
| $R_f$ | resistance due to fouling ($\mathrm{m^{-1}}$) |
| $R_i$ | membranes true retention for the ith component |
| $R_m$ | membrane resistance ($\mathrm{m^{-1}}$) |
| *Greeks* | |
| $\Delta\pi$ | osmotic pressure gradient (Pa) |
| $\eta$ | solution viscosity (Pa s) |
| $\eta_f$ | feed viscosity (Pa s) |
| $\upsilon_{\mathrm{eff}}$ | effective velocity ($\mathrm{m\,s^{-1}}$) |
| $\rho_f$ | feed density ($\mathrm{kg\,m^{-3}}$) |

aromas and taste of wine. Meanwhile, consumers show preference and demand wines with less alcohol content (between 9 and 13%), tendency reinforced by the new social trends of limiting alcohol consumption (Labanda et al., 2009; Masson et al., 2008; Massot et al., 2008).

Therefore, in order to produce a full flavored wine, the harvest should be carried out in the optimum ripeness of the fruits and then innovative techniques to control sugars in musts should be applied.

In order to use a mild and highly specific technology, membranes are a good election. Recently, the OIV introduced in the "International Code of Oenological practices" the application of membrane techniques for the treatment of musts and wine in order to enable the selective holding back or passing of some compounds (OIV, 2012).

If the molecular weight of sugars in must is taken into account, nanofiltration (NF) seems to be the most appropriate technique to control their concentration (García-Martín et al., 2009). In our previous work (Salgado et al., 2012), several experiments were performed aiming to select the most appropriate NF membrane for sugar control in grape must. Here, the performance on must NF of 3 flat sheet membranes was compared: NF270 (Dow Filmtec), HL (GE) and SR3 (Koch Membrane System). The results obtained showed that the HL and SR3 membranes were the most appropriate to reduce the content of sugar of red must. Specifically SR3 showed the best passage of sugar and less fouling. As a continuation of the mentioned study, the SR3 membrane was successfully used for sugar control in grape must at a higher scale using a spiral wound module (SWM) (Salgado et al., 2014).

The scope of the present study is to select the most appropriate NF technique to reduce the alcohol content of wines approximately 2° by controlling the sugar content of the grape must before its fermentation. For that purpose the performance of single-stage and two-stage NF processes using a SWM unit were compared. This was tested by treating musts coming from two Spanish varieties of grapes, a white one (*Verdejo*) and a red one (*Garnacha*).

## 2. Theory

When the overall filtration process is taken into account, the permeate flux per unit of membrane area can be written in terms of the applied transmembrane pressure, $\Delta p$, the osmotic pressure gradient, $\Delta\pi$, the viscosity of the solution, $\eta$, and the system resistance. This is the sum of the membrane resistance, $R_m$, plus a series of terms that depend on the fouling caused by the solute and the membrane itself, $R_f$ (Goldsmith, 1971; Jonsson, 1984; Kozinski and Lightfoot, 1971; Wijmans et al., 1984). Thus the permeate flux can be written as

$$Jv = \frac{\Delta p - \Delta\pi}{\eta(R_m + R_f)} \tag{1}$$

The efficiency of a membrane is determined by its true retention R, which is defined as

$$R_i = 1 - \frac{C_{p,i}}{C_{m,i}} \quad (i = 1, 2, \ldots, N) \tag{2}$$

for the ith component present as solute in the feed. Here $C_{m,i}$ is the concentration of the ith component on the membrane active layer and $C_{p,i}$ the permeate concentration of the ith component. One of the methods to calculate the experimentally inaccessible concentration $C_{m,i}$. is the use of the Film Theory of concentration polarization. This model is based on the use of the mass transfer coefficient, $K_{m,i}$, in order to describe the solute transport in the membrane active layer (Kuhn et al., 2010; Prádanos et al., 1994) as

$$C_{m,i} = C_{p,i} + \left(C_{0,i} - C_{p,i}\right) e^{(Jv/K_{m,i})} \tag{3}$$

Here, $J_v$ is the flux through the membrane; $C_{0,i}$ and $K_{m,i}$ are the feed concentration and the mass transfer coefficient of the ith component respectively.

The hydrodynamics and mass transport in a spiral wound module are critically influenced by the presence of the spacer material in the feed channel. The appropriate equations for the spiral wound unit and used in the present study have been explained in detail in our previous work (Salgado et al., 2014) and according to it $K_{m,I}$ can be evaluated as (Koutsou et al., 2009; Schock and Miquel, 1987; Schwinge et al., 2004)

$$K_{m,i} = 0.14 \times D_i^{0.58} \times d_h^{-0.36} \times \upsilon_{eff}^{0.64} \times \rho_f^{0.22} \times \eta_f^{-0.22} \tag{4}$$

where $D_i$ is the diffusion coefficient of the ith component, $d_h$ and $\upsilon_{\mathrm{eff}}$ are the hydraulic diameter and the effective velocity characteristic of the feed channel respectively, and $\eta_f$ and $\rho_f$ stand for the viscosity and density of the feed respectively.

Taking into account that the membrane is semipermeable, the $K_{m,i}$ calculated using Eq. (4), that should be valid for an impenetrable wall, need to be corrected to $K^s_{m,i}$ according to Geraldes & Afonso (Geraldes and Afonso, 2007):

$$K^s_{m,i} = k_{m,i}\left[\left(\frac{Jv}{K_{m,i}}\right) + \left(\frac{Jv/K_{m,i}}{\exp\left\{Jv/K_{m,i} - 1\right\}}\right)\right] \quad \text{for } \frac{Jv}{K_{m,i}} \leq 1 \tag{5}$$

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