Industrial Applicability of Modelling Polyphenol Extraction during Red Wine Fermentation

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Phenolic compounds are important contributors to red wine quality, due to their influence on mouthfeel, colour and ageing potential. They can be found in the grape berry skins and seeds and are extracted during fermentative maceration. Grape composition can vary between vintages and there is no set production and monitoring procedure to guarantee consistent product quality. Predictive extraction models can potentially address such constraints when implemented into the process control systems of commercial wine production, ultimately leading to improved automation and reliability

Objectives/Aims

Our previous models[1] were based on laboratory-scale extractions and have focused on malvidin-3-glucoside (M3G). Therefore, the first objective of this project was to adapt and validate these predictive models for industry-scale wine production.

Methods and Design

The mechanistic model of M3G extraction[1] describes the process as a multiphase mass transfer, Figure 1, starting with the diffusion of the dissolved M3G in the solid phase to the solid-liquid boundary layer *(1)*, then the mass transfer from the boundary to the liquid bulk *(2)*.

$$(1-\varepsilon)\frac{dc_\beta}{dt} = k_{c\beta}a\left(c_{\beta i} - c_\beta\right) \qquad (1) \qquad \varepsilon\frac{dc_\gamma}{dt} = k_{c\gamma}a\left(c_{\gamma i} - c_\gamma\right) \qquad (2)$$

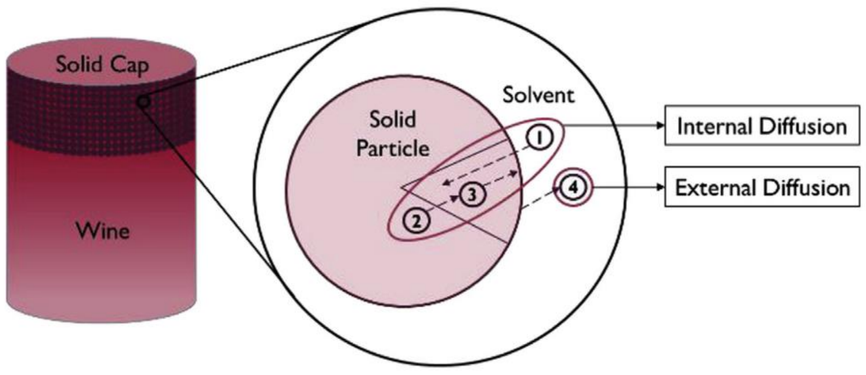

Figure 1: The four steps of phenolic extraction during fermentation. Step 1: Internal solvent diffusion into the grape solid. Step 2: Solute dissolution into this solvent. Step 3: Diffusion of the dissolved solute to the grape surface. Step 4: Diffusion of the dissolved solute to the surrounding solvent.[2]

Fermentation samples from three different varieties in five 180 t fermenters were collected from a commercial winery. Samples were taken after pump over cycle to represent a well mixed system and analysed by HPLC to quantify monomeric anthocyanins using M3G as an external standard.

Parameters of the system used by the model to predict the anthocyanin extraction are:

- cap management procedures
- sugar concentration
- fermentation temperature
- alcohol content

This prediction was then compared to the actual M3G content of the samples collected throughout fermentation for future simulation improvement.

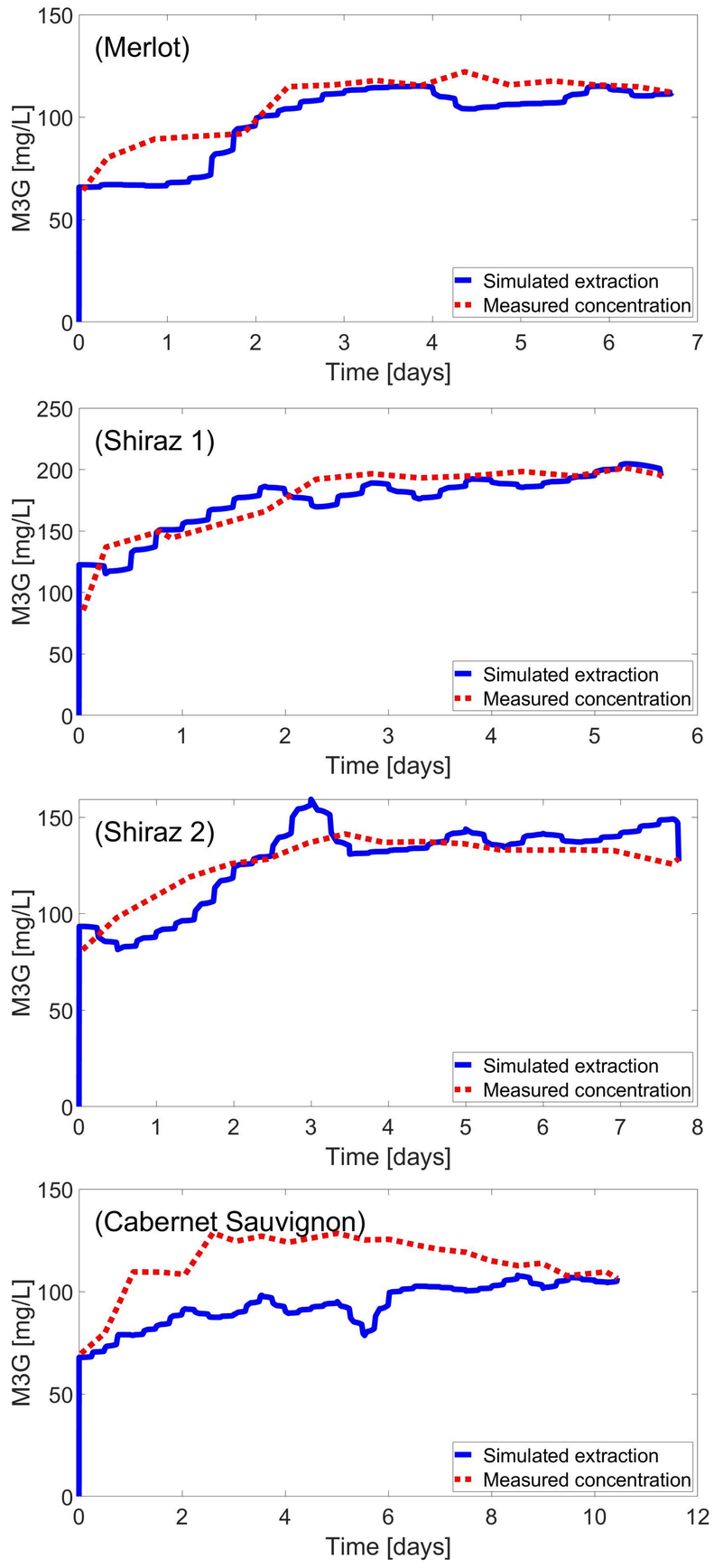

Figure 2: Simulated extractions and measured concentrations for malvidin-3-glucoside for different varieties in 180 t fermenters.

Key Preliminary Findings

As seen in Figure 2, the model can predict the initial M3G concentration purely on the sugar and alcohol values. The model also predicts the extraction trends for some varieties (Shiraz and Merlot R^2>0.77) well, however the fit for Cabernet Sauvignon grapes suggests the need for further model customisation to address varietal variability. Model optimisation to account for fermenter geometry and cap management configuration will further improve simulation predictive performance from that shown in Figure 2.

Industry Significance

Such models together with real-time data acquisition during fermentation will help future development of automatic process control systems for optimised extraction through temperature control and cap management. Overall, this approach will facilitate:

- efficient production
- decreased production costs
- consistent colour and tannin profile
- improved wine quality

References:
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[2]Setford, P. C., Jeffery, D. W., Grbin, P. R., & Muhlack, R. A. (2017). Factors affecting extraction and evolution of phenolic compounds during red wine maceration and the role of process modelling. Trends in Food Science and Technology, 69, 106–117.

FOR MORE INFORMATION

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