Monitoring of alcoholic fermentation: development of an applicable in-line system

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Alcoholic fermentation plays a crucial role in the winemaking process. In addition to producing ethanol, it results in the formation of various secondary metabolites that significantly influence the wine's characteristics. Proper management of alcoholic fermentation ensures it occurs over a sufficient duration, promoting the release of varietal aromas and the development of fermentative aromas. Preventing stuck fermentation is essential, as it can degrade the wine and lead to the formation of unwanted aromas. Generally, in-line process monitoring, enabled by sensors, facilitates prompt interventions, helping to avoid the emergence of defects. Today, a wide range of sensors is used throughout the wine production process, from monitoring grape ripening to bottling (Thanasi et al., 2022). However, the adoption of sensors becomes viable when their cost is competitive, making them a sustainable tool for wineries.

The aim of this research was to develop a low-cost prototype for monitoring the fermentation process using VIS/NIR optical sensors. The prototype is equipped with sensors that operate in the wavelength range of 340 to 1050 nm, which are readily available on the market. Some parts of the prototype were created using 3D printing. The prototype was tested for monitoring fermentation at both (i) the laboratory scale (microvinifications) and (ii) the industrial scale. For the industrial scale, three types of must were used (white, red, and rosé), sourced from three different batches of grapes, for a total of nine fermentation processes monitored. Samples were collected daily to measure sugar concentration through enzymatic analysis and for optical analysis. The enzymatic analysis results served as reference parameters for developing predictive models using chemometric analysis, specifically partial least squares (PLS) regression.

The models developed on the laboratory scale (internally validated via cross-validation) demonstrated the device's ability to capture, both directly and indirectly, the chemical information related to the sugar concentration in the analyzed must samples. Preliminary results from monitoring fermentation on an industrial scale indicate a strong correlation between the sugar concentrations determined by optical and enzymatic analyses, similar to the laboratory scale findings.

Thus, the prototype provides a foundation for developing an effective and cost-efficient instrument that, when combined with widely used temperature and carbon dioxide sensors, could optimize fermentation monitoring and processes.

Keywords: alcoholic fermentation, sugars, VIS/NIR sensor, modelling, precision oenology

References:

Thanasi, V., Catarino, S., & Ricardo-da-Silva, J. M. (2022). Fourier transform infrared spectroscopy in monitoring the wine production. Ciência e Técnica Vitivinícola. https://doi.org/10.1051/ctv/ctv2022370179