Post-doctoral position in automatic control – 18 months - 2022-2023

# Control of the aroma synthesis during wine fermentation process

## Context

Alcoholic fermentation is a crucial step in wine making. Generally performed in a batch reactor[1], it consists mainly of the bioconversion of sugar (from the grapes) into ethanol and $CO_2$. It is the yeasts that carry out this conversion, from which they draw energy for their growth. They therefore play a central role, which explains the importance of studying them to control fermentation.

During the bioconversion of sugar to ethanol, other metabolites (glycerol, organic acids, aroma compounds, etc.) are also synthesized, some of which contribute to the aromatic profile of wine. Among them are esters - and higher alcohols to a lesser extent - which contribute to the fruity aroma of wines (Torrea et al. 2011). As foreign consumers are increasingly attracted to these aromas, there is a willingness of the French winemakers to implement strategies that increase the ester concentration of wines to maintain their export market share. More generally, the challenge is to control the synthesis of aromas during fermentation in order to obtain a target aromatic profile and thus produce personalized wines that meet the different tastes of consumers.

Until now, industrial practices have been essentially dictated by practical considerations of cellar management (Sablayrolles et al. 1996). The objective is generally to accelerate fermentation, i.e., to speed up the conversion of residual sugar, which is slower at the end of fermentation (when ethanol stress is maximal for the yeasts). To achieve this objective, two practices are commonly used: the addition of nitrogen at the beginning or during fermentation, and the anisothermal fermentation management, which generally consists of increasing the temperature at the end of the process.

Yet it has been shown that these practices also influence the final aroma content of the wine, and in different ways depending on the considered aroma (Mouret et al. 2014, Rollero et al. 2015). By modifying the amount of nitrogen added, the timing of the addition, and the anisothermal temperature profile, we can therefore hope to be able to control aroma synthesis and reach a predefined aroma target.

This is the objective of the ANR project STARWINE (STrategies for the real-time control of ARoma production during WINE fermentation) in which this post-doctoral position is part.

## Objectives

The objective of the post-doctoral fellowship is to design a strategy for real-time control of the wine aroma profile based on a model composed of ordinary differential equations that is being developed in the STARWINE project.

The control inputs are: (1) amount of nitrogen to be added (at a given time) and (2) temperature throughout the fermentation. The available real-time measurements are: (1) quantity of released $CO_2$, (2) temperature and (3) aroma concentration. We will focus here on a single aroma, the isoamyl acetate, whose response to nitrogen addition and temperature variation is quite strong (according to preliminary experiments done in the STARWINE project). The objective is to achieve a given concentration of this aroma at the end of fermentation.

The control strategy will be composed of different steps:

- a one-time addition of a variable amount of nitrogen (open-loop control) at an instant chosen from the experiments
- a continuous modification of the temperature (closed loop control), after the addition of nitrogen.

1 A batch reactor is a closed reactor, also called "discontinuous" reactor in which there is no inlet or outlet, and whose volume remains constant over time.

## Work program :

1. **Bibliographic work and familiarization with available data and models**
   A calibration step of the model parameters could be done if needed.
2. **Off-line optimization**
   First, we will perform an off-line optimization to determine the amount of nitrogen to add and the temperature profile to follow to reach the set point (target value to be reached in isoamyl acetate). In a second step, we will add in the optimization criterion an energy consumption term to be minimized.
3. **Real-time control (closed loop) of aroma concentration through temperature management**
   In a second step, once the value of the amount of nitrogen to be added is fixed, we will design a closed-loop temperature control law, which will guarantee that the targeted aroma concentration will be effectively reached after the addition of nitrogen, despite the uncertainties on the model and the measurement noise. This control law will consist in adjusting in real time the temperature profile according to the on-line measurement of the aroma content and $CO_2$. It will be tested and validated in simulation.
4. **Test and validation on the real process**
   The control strategy will finally be applied and tested on the real process located in the Experimental Unit of Pech Rouge, in Gruissan.

## References

To become familiar with the subject, the candidate may refer to the articles given below, some of which deal with the modeling and/or control of alcoholic fermentation.


Casenave, C., Dochain, D., Harmand, J., Perez, M., Rapaport, A., & Sablayrolles, J. M. (2014). Control of a Multi-Stage Continuous Fermentor for the study of the wine fermentation. *IFAC Proceedings Volumes*, *47*(3), 6192-6197.

Casenave, C., Perez, M., Dochain, D., Harmand, J., Rapaport, A., & Sablayrolles, J. M. (2019). Antiwindup Input–Output linearization strategy for the control of a multistage continuous fermenter with input constraints. *IEEE Transactions on Control Systems Technology*, *28*(3), 766-775.

David, R., Dochain, D., Mouret, J. R., Wouwer, A. V., & Sablayrolles, J. M. (2014). Nitrogen-backboned modeling of wine-making in standard and nitrogen-added fermentations. *Bioprocess and biosystems engineering*, *37*(1), 5-16.

Malherbe, S., Fromion, V., Hilgert, N., & Sablayrolles, J. M. (2004). Modeling the effects of assimilable nitrogen and temperature on fermentation kinetics in enological conditions. *Biotechnology and bioengineering*, *86*(3), 261-272.

Mouret, J. R., Farines, V., Sablayrolles, J. M., & Trelea, I. C. (2015). Prediction of the production kinetics of the main fermentative aromas in winemaking fermentations. *Biochemical Engineering Journal*, *103*, 211-218.

Mouret, J. R., Camarasa, C., Angenieux, M., Aguera, E., Perez, M., Farines, V., & Sablayrolles, J. M. (2014). Kinetic analysis and gas–liquid balances of the production of fermentative aromas during winemaking fermentations: effect of assimilable nitrogen and temperature. *Food research international*, *62*, 1-10.

Rollero, S., Bloem, A., Camarasa, C., Sanchez, I., Ortiz-Julien, A., Sablayrolles, J. M., ... & Mouret, J. R. (2015). Combined effects of nutrients and temperature on the production of fermentative aromas by Saccharomyces cerevisiae during wine fermentation. *Applied microbiology and biotechnology*, *99*(5), 2291-2304.

Sablayrolles, J. M., Dubois, C., Manginot, C., Roustan, J. L., & Barre, P. (1996). Effectiveness of combined ammoniacal nitrogen and oxygen additions for completion of sluggish and stuck wine fermentations. *Journal of fermentation and bioengineering*, *82*(4), 377-381

Torrea, D., Varela, C., Ugliano, M., Ancin-Azpilicueta, C., Francis, I. L., & Henschke, P. A. (2011). Comparison of inorganic and organic nitrogen supplementation of grape juice–Effect on volatile composition and aroma profile of a Chardonnay wine fermented with Saccharomyces cerevisiae yeast. *Food chemistry*, *127*(3), 1072-1083.


## Required skills

The candidate must have a Ph.D thesis in the field of automatic control. The research that would be conducted being applied, a taste for applications is required. Candidates with a rather theoretical profile and without experience in applications are however welcome, provided they show a strong motivation. The candidate should have programming skills (matlab in particular). A taste for multidisciplinary work and teamwork will be appreciated, since the candidate will be required to discuss with researchers in oenology of the UMR SPO (Sciences for Oenology).

## Terms of the contract

The post-doctoral work will be supervised by Céline Casenave, INRAE researcher (National Research Institute for Agriculture, Food and the Environment) in the UMR MISTEA (Mathematics Informatics and STatistics for the Environment and Agronomy).
The candidate will be hosted in the UMR MISTEA premises, on the Gaillarde campus of Montpellier SupAgro - 2 place Pierre Viala, 34090 Montpellier.
The duration of the contract is 18 months and may start as early as February 2022 depending on the availability of the candidate. The salary will depend on the candidate's experience and will be between 2300€ and 2700€ gross per month.

## Contact :

Applications should be sent by email to Céline Casenave at celine.casenave@inrae.fr and should include a detailed CV, a letter of motivation and one or two letters of recommendation or 1 or 2 names of referees.