Metabolic modelling and control of wine-making

Keywords : Ethanol fermentation; Metabolic engineering; Control.

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***Abstract** – This research activity deals with the study of wine making. More precisely, metabolic engineering is considered to better understand the production of the organoleptic properties of the wine. Further, a controller has been designed and implemented for a multi-stage reactor for which each reactor corresponds to a specific physiological state of the yeast during wine making.*

During the alcoholic fermentation, sugar is converted to ethanol and carbon dioxide, but many other compounds are removed from the must and a large set of by-products are formed that affect the sensorial properties of the wine. Optimising the control of alcoholic fermentations for wine-making is a difficult challenge. Unlike some other kinds of industrial fermentations, such fermentations do not aim to maximise the concentration or yield of a defined metabolite, or the productivity of the process. In wine-making, the main objective is to optimise product quality, which is very difficult to quantify. From now on quality marker molecules are identified and could - partly - describe the major organoleptic qualities or defaults. They are issued from complex and numerous metabolic pathways inside the yeast cell and the metabolic engineering could be used for this modelling. The analysis considers Metabolic Flux Analysis (MFA) and first results identify 79 intracellular reactions with 70 internal metabolites and 9 external metabolites [1]. The objective is to reduce substantially the reaction network and to come up a reduced number of macroscopic reactions that can be validated on experimental data (including data of amino-acids and sulfur compounds that intervene in the organoleptic properties of the wine).

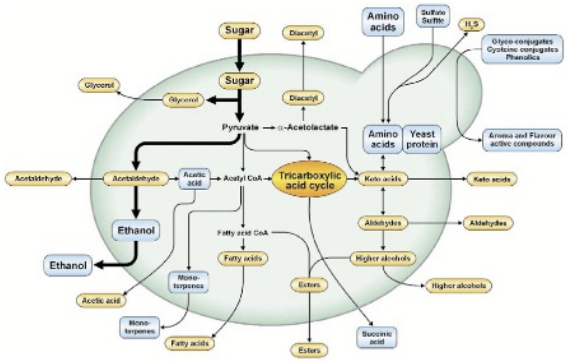

Figure 1: Schematic view of the yeast metabolism.

In parallel to the metabolic engineering modelling, an experimental setup has been designed with the objective to better characterize the physiological state of the yeast at different stages of the ethanolic fermentation (run in batch conditions). It is based on the concept well-known in chemical engineering of the time-space equivalence that allows to transpose batch reactor operation into steady-state plug-flow reactor operation. The SPO (Sciences pour l'oenologie) of the INRA in Montpellier has been setting up a cascade of four reactors that approximates the behaviour of the plug flow reactor in an optimised way. The main advantage of this configuration is to have, in stable conditions, different physiological states of the yeast in each reactor corresponding to key transient states of the batch fermentation.

The main challenge is to design and implement a control scheme

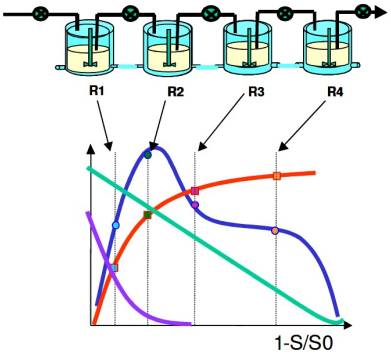

Figure 2: Equivalence Batch - Plug Flow.

that allows to reach each of these physiological state and to maintain them in stable conditions, with major constraints of the feed flow rates. Such control law have been analyzed and implemented on the SPO experimental setup. This study has received the Application Paper Prize at the IFAC World Congress in 2014.

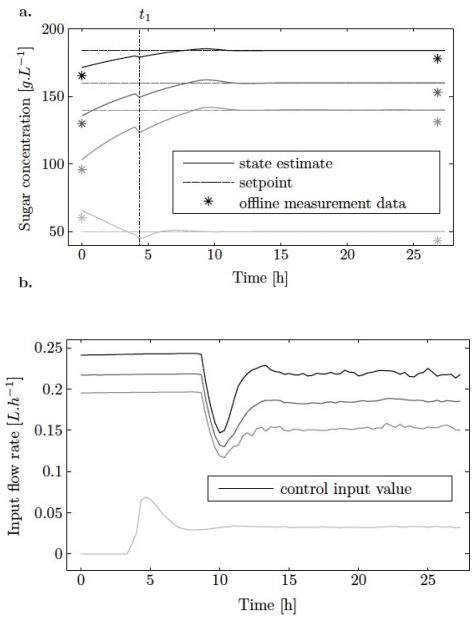

Figure 3: Control results.

References

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