BIOPROCESS SYSTEMS ENGINEERING (BSE) APPLIED TO THE PRODUCTION OF BIOETHANOL FROM SUGARCANE BAGASSE

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a)
b)
c)

Figure 1. From micro scale to plant-wide optimization: (a) Cellulase-production fungus culture on bagasse substrate. (b) Lab scale bioreactor operating with immobilized pool of cellulolitic enzymes. (c) Biorefinery flowsheet: EMSO graphical user interface.

The consolidation of the industrial production of 2G bioethanol will depend on a combination of economical criteria, process robustness and compliance to environmental and sustainability restrictions. In this scenario the optimization of this complex, interconnected process ideally must be pursued ever since its early stages of development, aiming at costs reduction, negative overall CO_2 balance, cutback of water usage and of effluent emissions and so forth. Fine-tuned processes, operating at (near-) optimum conditions will have a significant competitive advantage.

This project focused on the rational application of (Bio-)Process Systems Engineering (BSE) techniques to the process for production of 2G bioethanol from an important lignocellulosic material in the Brazilian scenario, sugarcane bagasse (and leaves). In other words, the same approach that allowed oil refineries to achieve a high productivity is herein applied to biorefineries.

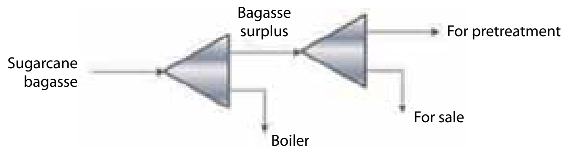
The validation of BSE tools for assessing different routes for bioethanol, however, must be based on real data. With this purpose, this project joined efforts of a group of researchers from the Chemical Engineering Department of UFSCar and from EMBRAPA. A biochemical route for production of ethanol from sugarcane bagasse was our selected case study, encompassing different technologies: *in-situ* production of cellulases in triphasic reactors; feedstock pre-treatment; intensification of the processing of the C5 fraction (from xylooligosaccharides to ethanol, within a nonconventional bioreactor); application of advanced control techniques for optimization of the C6 enzymatic hydrolysis reactor were some of the topics of the project.

A global view is necessary to integrate these processes from the early stage of development, including the analysis of their techno-economic feasibility. Particularly, the competition for the use of sugarcane bagasse and leaves, between bioelectricity (cogeneration) and 2G ethanol, was thoroughly addressed. The free software EMSO (http://vrtech.com.br/rps/emso.html) was the computational environment for the simulations.

Therefore, this project aimed simultaneously at providing the necessary software and at researching new feasible routes for bioethanol which, in addition to their intrinsic value, were employed for validation of the methodology.

SUMMARY OF RESULTS TO DATE AND PERSPECTIVES

This project included the Laboratory for Development and Automation of Bioprocesses (LaDABio), the Laboratory of Enzymatic Process Engineering (LabEnz) and the Biochemical Engineering Group, all from the Department of Chemical Engineering of the Federal University of São Carlos (DEQ/UFSCar) and the Bioprocess Group of the EMBRAPA Agriculture Instrumentation unit, in São Carlos. Cooperation with other groups was also promoted, from Brazil: PEQ/COPPE/UFRJ, DEQ/UFRGS; and from abroad: Purdue University (USA), DTU and KU (Denmark), UMinho (Portugal), ICP-CSIC (Spain). The results are available through research papers, and one filed patent. With respect to transfer of technology for industry, this project induced a partnership of UFSCar with Petrobras (CENPES), which is presently supporting the continuation of the studies, using EMSO as the computational environment for simulation and optimization of a 1G-2G ethanol biorefinery.



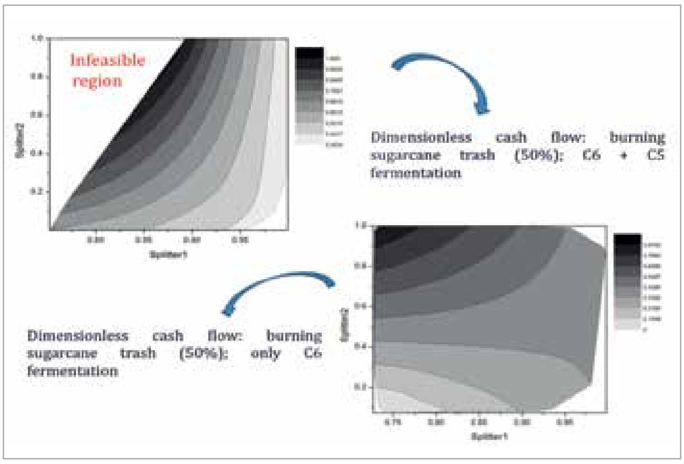


Figure 2. Furlan et al. Assessing the production of first and second generation bioethanol from sugarcane through the integration of global optimization and process detailed modeling. Computers & Chemical Engineering, 2012.

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