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

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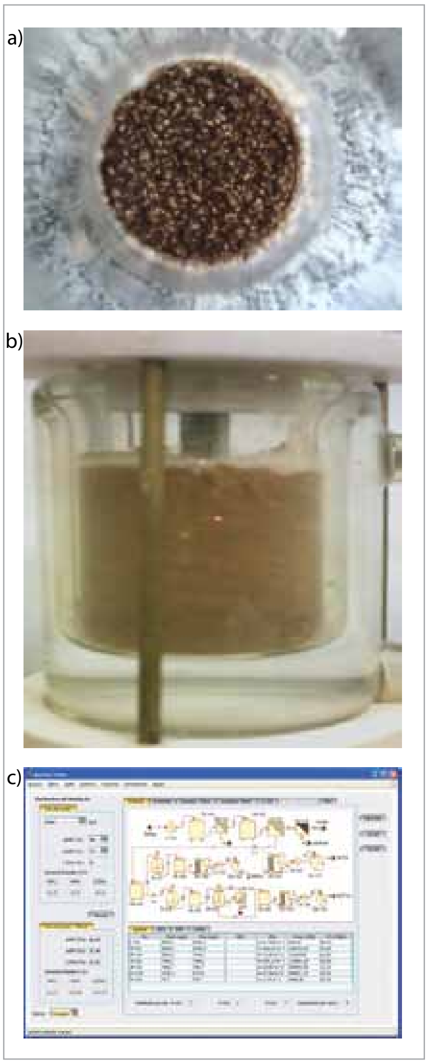

Figure1. From micro scale to plant-wide optimization: (a) Cellulase-production fungus on bagasse substrate. (b) Lab scale bioreactor operating with immobilized pool of cellulolitic enzymes. (c) Biorefinery flowsheet: graphical user interface of the simulation toolbox of the web application

The industrial production of biofuels, understood as fuels produced from biological feedstock, is presently at what can be called a technological crossroad, and a hard competition among different technologies is in course. The winners will be defined by 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 focuses on the rational application of (Bio-)Process Systems Engineering (BSE) techniques to the process for production of bioethanol from an important lignocellulosic material in the Brazilian scenario, sugarcane bagasse. 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 joins efforts of a group of researchers from the Chemical Engineering Department of UFSCar and from Brazilian Agricultural Research Corporation (EMBRAPA Agriculture Instrumentation). A biochemical route for production of ethanol from sugarcane bagasse is our selected case study, encompassing different technologies, some of them still exploratory: *in situ* production of cellulases in triphasic reactors; feedstock pre-treatment; enzymatic production of pentoses (and their transformation) and of hexoses via a non-conventional process using immobilized enzymes, combined with simultaneous (SSF) or consecutive fermentation (CSF), using *S. cerevisiae* in conventional and non-conventional bioreactors. A global view is necessary to integrate these processes from the early stage of development. Therefore, this project aims simultaneously at providing the necessary software and at researching new feasible routes for bioethanol which, in addition to their intrinsic value, will be employed for validation of the methodology.

SUMMARY OF RESULTS TO DATE AND PERSPECTIVES

This project is implementing the necessary software while researching new feasible routes for bioethanol which, in addition to their intrinsic value, will be the case study for validation of the methodology. It is important to notice that the proposed computational applicative, within a web-based environment, may serve as a support tool for other projects within the BIOEN program. It includes 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 is also evolving (including PEQ/COPPE/UFRJ and DEQ/UFRGS). The project research lines are:

- Development, implementation and validation of a user-friendly integrated computational environment, enabling simulation, optimization, economic evaluation, CO_2 and water usage assessment, analysis of kinetic data.
- Cultivation of microorganisms from EMBRAPA bank (*Aspergillus sp.*), for the production of cellulases and xylanases, using non-conventional triphasic reactors.
- Physical-chemical pre-treatment of bagasse and characterization of the resulting biomass: Production of substrates for fermentation of hexoses and of pentoses.
- Determination of (sub-)optimal bioreactor operational conditions for fermentation of hexoses using free and immobilized enzymes.
- Assessment of the production of ethanol from hemicellulose using free and immobilized enzymes.

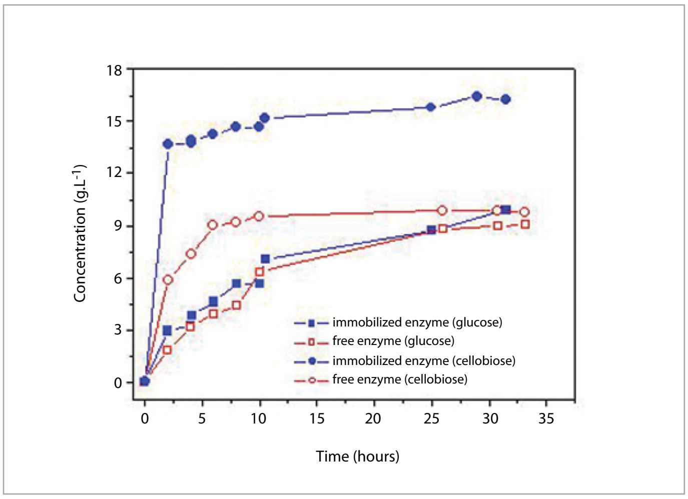

Figure 2. Assessing the performance of immobilization of cellulases. Immobilized enzyme load: 15 $U_{FP}.g^{-1}$ $_{cellulignin}$. Free enzyme load: 5 $U_{FP}.g^{-1}$ $_{cellulignin}$. All assays: 47ºC 0-10h and 37ºC until 10-33h, pH 5.0

MAIN PUBLICATIONS

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