AN INTEGRATED PROCESS FOR TOTAL BIOETHANOL PRODUCTION AND ZERO CO_2 EMISSION

Rubens Maciel Filho
Faculty of Chemical Engineering / University of Campinas (UNICAMP)
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co-PIs: Aline Carvalho da Costa, Carlos Eduardo Vaz Rossell, Dejanira de Franceschi de Angelis, Francisco Maugeri Filho, Maria Isabel Rodrigues, Maria Regina Wolf Maciel

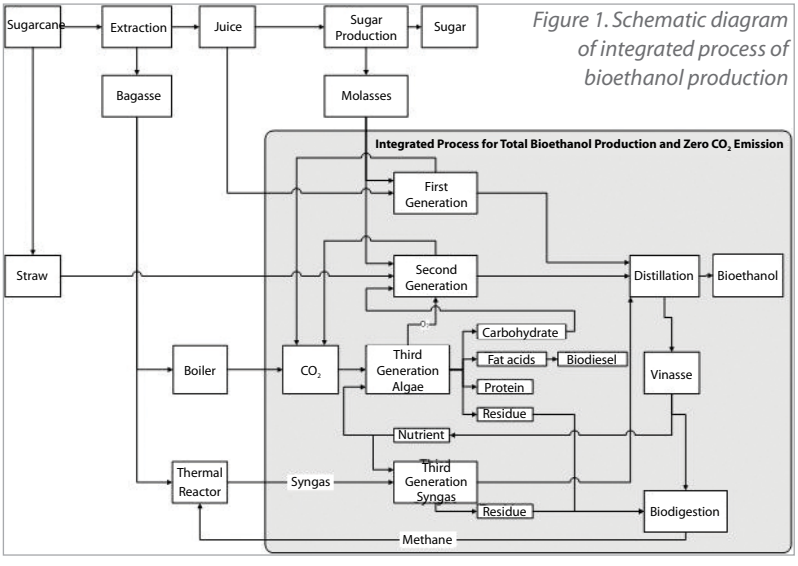

Figure 1. Schematic diagram of integrated process of bioethanol production

Increasing oil prices and global concern about climate change motivate the investigation of more efficient means of bioethanol production. An integrated process is proposed in this Thematic Project, aiming to maximize the productivity of bioethanol from sugarcane molasses, bagasse and straw, which give rise to, respectively, first and second generation bioethanol. The Greenhouse Gas carbon dioxide, produced in this two ethanol generations processes, is proposed to be used in the production of a third generation of ethanol, which comes both from algal/bagass biomass and catalytic transformation or biological fermentation of synthesis gas. This challenging integrated process has the major appeal of not emitting carbon dioxide and makes the best of the carbon-containing material for producing ethanol, turning it, when technically and economically feasible, a milestone for improving Brazilian bioethanol competitiveness.

The specific objectives of this project look for ways of turning this integrated process into a technically and economically feasible one, investigating new technologies for each part of processes, covering first, second and third generation aiming anhydrous low bioethanol production. In this way, it will be studied alternative fermentation processes (extractive units), eco-efficient pretreatments as a part of an integrated bioethanol from sugarcane bagasse and straw, development of high-performing enzyme formulations and process techniques of both enzymatic hydrolysis and fermentation, coupled with the development of suitable yeast to ferment sugarcane biomass carbohydrates. In addition, the possibility of microalgae consuming CO_2 from alcoholic fermentation, constituting energy generation cycle with environment protection and production of bioethanol through the synthesis gas, which is obtained from biomass will be investigated. Besides that, multiple effect operation of the distillation columns of the process will be studied in order to reduce steam consumption on reboilers and compared to alternative strategies, including the hybrid ones. The study of alternative entrainers (ionic liquids and hyperbranched polymers) for the extractive distillation process for anhydrous bioethanol production will be carried out. Process modeling and simulation, either of single units or for the large scale plant will be used as a tool for process evaluation and decision taking. Process optimization will be considered to extract the best yield of each routes so that quantitative discrimination will be possible. In any case, methodologies that may be necessary whenever a re-estimation of parameters is required and among other tools software sensors based on Artificial Neural Network will be developed to infer concentrations of biomass, bioethanol and substrate from secondary measurements, such as pH, turbidity and CO_2 flow rate. The global processes evaluation will make use of the experimental data collected in the experiments, industrial data and information and together with process simulation trough commercial simulators and tailor made softwares. All the routes will be evaluated in the optimal conditions achieved by a set of suitable optimization algorithms including the deterministic and stochastic based ones.

The project proposed concept

This research project aims a totally integrated bioethanol production process, in order to improve the productivity of existing ethanol generation (sugar cane molasse fermentation), the so-called First Generation Bioethanol, to develop suitable processes for improving the Second Generation Bioethanol (from biomasses) and to investigate the viability of the Third Generation Bioethanol, which is produced from algal/bagasse biomass or from catalytical or biological fermentation of synthesis gas. The Third Generation Bioethanol has a major appeal of consuming carbon dioxide produced in the First and Second Generation processes, causing the great impact of almost zero CO_2 emission within the whole integrated process. The improvement of the energy intensive processes that constitute the distillation units are also objective of study in the present project and the proposal of alternatives procedures will be evaluated, including the hybrid configurations. *Figure 1* depicts a schematic diagram of the integrated process for bioethanol production.

MAIN PUBLICATIONS

Cavalett O, Junqueira TL, Dias MOS, Jesus CD, Mantelatto PE, Cunha MP, Franco HCJ, Cardoso TF, Maciel Filho R, Rossell CEV, Bonomi A. 2012. Environmental and economic assessment of sugarcane first generation biorefineries in Brazil. *Clean Technologies and Environmental Policy* (Internet). **14**: 399-410.

Dias MOS, Cunha MP, Maciel Filho R, Bonomi A, Jesus CDF, Rossell CEV. 2011. Simulation of integrated first and second generation bioethanol production from sugarcane: comparison between different biomass pretreatment methods. *Journal of Industrial Microbiology & Biotechnology*. **38**: 955-966.

Dias MOS, Cunha MP, Jesus CDF, Rocha GJM, Pradella JGC, Rossell CEV, Maciel Filho R, Bonomi A. 2011. Second generation ethanol in Brazil: can it compete with electricity production? *Bioresource Technology*. 8964-8971.

Dias MOS, Junqueira TL, Jesus CDF, Rossell CEV, Maciel Filho R, Bonomi A. 2012. Improving second generation ethanol production through optimization of first generation production process from sugarcane. *Energy* (Oxford). **43**: 246-252.

Mariano AP, Qureshi N, Maciel Filho R, Ezeji TC. 2012. Assessment of in situ butanol recovery by vacuum during acetone butanol ethanol (ABE) fermentation. *Journal of Chemical Technology and Biotechnology* (1986). **87**: 334-340.

Dias MOS, Junqueira TL, Cavalett O, Pavanello LG, Cunha MP, Jesus CDF, Maciel Filho R, Bonomi A. 2013. Biorefineries for the production of first and second generation ethanol and electricity from sugarcane. *Applied Energy*. **109**: 72-78.

Dias MOS, Junqueira TL, Jesus CDF, Rossell CEV, Maciel Filho R, Bonomi A. 2012. Improving bioethanol production – comparison between extractive and low temperature fermentation. *Applied Energy*. **98**: 548-555.

Rubens Maciel Filho

Faculdade de Engenharia Química
Universidade Estadual de Campinas (UNICAMP)
Departamento de Desenvolvimento de Processos e Produtos
Av. Albert Einstein, 500 - Cidade Universitária Zeferino Vaz
CEP 13083-852 - Campinas, SP - Brasil

+55-19-3521-3958
maciel@feq.unicamp.br