The Virtual Sugarcane Biorefinery (VSB) – second generation ethanol production from sugarcane in Brazil

Antonio Bonomi[1], Marina O.S. Dias[1,2], Tassia L. Junqueira[1,2], Otavio Cavalett[1], Charles D.F. Jesus[1], Rubens Maciel Filho[1,2], Carlos E.V. Rossell[1,2], Marcelo P. Cunha[1]

[1] Laboratório Nacional de Ciência e Tecnologia do Bioetanol (CTBE)
[2] Faculdade de Engenharia Química, Universidade Estadual de Campinas (UNICAMP)

One of the greatest concerns of society and governments nowadays regards the large scale production of alternative forms of energy, such as biofuels, which are able to reduce greenhouse gases emissions and improve energy security when compared to their fossil counterparts. However, issues about biofuels sustainability, including environmental, economical and social aspects, have been raised around the world.

A comprehensive strategy to evaluate the sustainability of different biofuels production routes using sugarcane as raw material is under development at the Brazilian Bioethanol Science and Technology Laboratory (CTBE) integrating different computer platforms such as Aspen Plus®, SimaPro® and electronic spreadsheets. This tool, so called the Virtual Sugarcane Biorefinery (VSB), allows the comparison of technical, economic, social and environmental impacts of different production technologies regarding the production of bioethanol, sugar, bioelectricity and other products, such as the ones derived from termochemical conversion, sugarchemistry and alcoholchemistry. Since the agricultural phase is also being modeled and integrated with the simulation of the industrial phase, the impacts of the agricultural technologies on the industrial phase (and vice-versa) are also evaluated in the VSB.

Differently from other countries, production of second generation ethanol in Brazil will be strongly based in sugarcane lignocellulosic fractions: bagasse, already at conventional bioethanol production site, and trash, available in the field. Therefore, integrated first and second generation production seems a natural choice in the Brazilian context. Nevertheless, independent and integrated second generation bioethanol production from sugarcane should be analyzed in order to demonstrate strategic advantages.

In this work, VSB framework was used to simulate sugarcane plants producing sugar, ethanol and electricity, considering an integrated first and second generation and a separate second generation bioethanol production units. For the first generation, typical industrial plants were considered, where 500 tons of sugarcane are processed per hour, producing ethanol and electricity (in the autonomous distillery) in addition to sugar (in the annexed plant). Process simulation was performed using data from the literature and from Brazilian industrial plants, considering all the steps present in the industrial unit, from extraction of sugars to ethanol dehydration and co-production of heat and power using bagasse and trash. Surplus bagasse and trash are used as raw material for second generation ethanol production.

This paper reports the use of the VSB to evaluate the production of second generation bioethanol from sugarcane bagasse and trash in different backgrounds: (a) integrated to conventional ethanol production from sugarcane (first generation bioethanol), using current hydrolysis technology and also

improved technologies; and (b) stand-alone second generation plant. These results are compared to conventional and optimized first generation units existing today in Brazil. In the scenario integrating first and second generation ethanol production process, part of the infrastructure required (juice concentration, fermentation, distillation and cogeneration) are shared between both processes, reducing the equipment investment required.
In the VSB framework, process simulation developed in Aspen Plus® provides data for evaluation of economic and environmental impacts of different evaluated scenarios. Using the VSB it is possible to demonstrate that integrated first and second generation plants outperforms stand-alone second generation units, presenting higher internal rate of return and lower ethanol production costs. It is also shown that second generation ethanol production from sugarcane does not exclude surplus electricity output: both may be produced, provided that the proper equipment (high pressure boilers) are employed. In addition, the use of the VSB shows that in the short to mid-term, electricity production is more attractive to the investor; however, on the long-term, when pentose fermentation and advanced hydrolysis technologies are expected to be available, production of second generation ethanol is clearly more advantageous.
The environmental impacts of the different alternatives are also evaluated using the Life Cycle Analysis (LCA) in the VSB framework. The environmental impact indicators were calculated using software package SimaPro® (PRé Consultants), and considering the CML 2 Baseline 2000 v2.05 Life Cycle Assessment Method. Results showed that the agricultural phase has a strong influence on both environmental and economical impacts of ethanol production; consequently, improvements on this phase may lead to significant gains for the whole process. Integrated first and second generation plants have better environmental performance than stand-alone second generation process.
Once the VSB is finalized and validated, it will be very helpful as a tool to aid companies and research institutions interested in the subject to drive their research and investments, as well as to support funding agencies, policy makers and governments on their planning efforts on the bioenergy sector.

Author Publications

Dias, M.O.S.; Cunha, M.P.; Jesus, C.D.F.; Scandiffio, M.I.; Rossell, C.E.; Maciel Filho, R.; Bonomi, A. (2010). Simulation of ethanol production from sugarcane in Brazil: economic study of an autonomous distillery. Computer-Aided Chemical Engineering, 28, 733-738.

Dias, M.O.S.; Cunha, M.P.; Maciel Filho, R.; Bonomi, A.; Jesus, C.D.F.; Rossell, C.E.V. (2010). Simulation of integrated first and second generation bioethanol production from sugarcane: comparison between different biomass pretreatment methods. Journal of Industrial Microbiology & Biotechnology, DOI: 10.1007/s10295-010-0867-6.

Bonomi, A. and Felipe, M.G.A. (2010). Parte 4 - Novo modelo industrial e usos finais do etanol. Introdução. In: Luís Augusto Barbosa Cortez (Org.). Bioetanol

de Cana-de-Açúcar: P&D para Produtividade e Sustentabilidade. 1ª ed. São Paulo, SP - Brasil: Editora Blucher, 1, 543-545.

Bonomi, A. (2010). Workshop hidrólise de material lignocelulósico. In: Luís Augusto Barbosa Cortez (Org.). Bioetanol de Cana-de-Açúcar: P&D para Produtividade e Sustentabilidade. 1ª ed. São Paulo, SP - BRASIL: Editora Blucher, 1, 679-695.

Bonomi, A. (2010). Projeto de Políticas Públicas para o Etanol: Qualidade e normalização do etanol. In: Luís Augusto Barbosa Cortez (Org.). Bioetanol de Cana-de-Açúcar: P&D para produtividade e sustentabilidade. 1ª ed. São Paulo, SP - BRASIL: Editora Blucher, 1, 801-811.

Bonomi, A. and Felipe, M.G.A. (2010) Part 4 - A new model for industrial production and final uses of ethanol. Introduction. In: Luis Augusto Barbosa Cortez (Org.). Sugarcane Bioethanol: R&D for productivity and sustainability. 1st ed. São Paulo, SP - Brasil: Editora Blucher, 1, 541-545.

Bonomi, A. (2010) Workshop on the hydrolysis of lignocellulosic material. In: Luis Augusto Barbosa Cortez (Org.). Sugarcane Bioethanol: R&D for productivity and sustainability. 1st ed. São Paulo, SP - Brasil: Editora Blucher, 1, 679-695.

Bonomi, A. (2010) Ethanol quality regulation. In: Luis Augusto Barbosa Cortez (Org.). Sugarcane Bioethanol: R&D for productivity and sustainability. 1st ed. São Paulo, SP - Brasil: Editora Blucher, 1, 801-811.

Authors submitted papers

Dias, M.O.S.; Cunha, M.P.; Jesus, C.D.F.; Rocha, G.J.; Pradella, J.G.C.; Rossell, C.E.V.; Maciel Filho, R. and Bonomi, A. (2011) Second generation ethanol in Brazil: Who are the real competitors? Submitted for publication at Bioresource Technology.

Dias, M.O.S.; Cunha, M.P.; Jesus, C.D.F.; Rossell, C.E.V.; Maciel Filho, R. and Bonomi, A. (2011). Evaluation of ethanol and bioelectricity production from sugarcane in autonomous distilleries. Submitted for publication at Biomass and Bioenergy.