Title:

Analysis of environmental process performance metrics of integrated first- and second-generation bioethanol production plants through biochemical and thermochemical conversion pathways

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Abstract:

Bioethanol is the most common biofuel worldwide and significantly contributes to reduce greenhouse gas emissions compared to fossil fuels. Bioethanol can be produced from different raw materials such as sucrose, starch, lignocellulosic and algal biomass; and it can also be produced by a wide range of technological routes. Driven by a range of sustainability challenges, effective conversion of biomass to energy and biofuels will require the careful pairing of advanced conversion technologies necessary to reduce costs, environmental impacts, and increase the process productivity/efficiency in order to move lignocellulosic biofuel production from pilot scales industrial implementation.

This study analyses integrated first (1G) and second (2G) generation bioethanol production plants via biochemical and thermochemical routes to improve sustainability-related indexes of sugarcane-based biorefineries in Brazil. In this context, the biochemical conversion process evaluated includes steam explosion pre-treatment followed by enzymatic hydrolysis, whereas the selected thermochemical route focuses on the transformation of synthesis gas via catalytic conversion into ethanol.

The integrated 1G + 2G designs (combining biochemical and thermochemical conversion routes) for bioethanol production from sugarcane bagasse are analysed using technical and environmental performance metrics: i) global exergy efficiency, ii) average unitary exergy cost, iii) global CO_2 emissions, iv) CO_2 equivalent index in exergetic base and v) renewability exergy index (λ).

Results regarding the technical conversion of the systems indicated that the global exergy efficiency of the integrated 1G + 2G biochemical process was 33.80 % and the average unitary exergy cost was 2.98. Furthermore, the global CO_2 emissions was 4.04 $kgCO_2$equiv./kg ethanol and the CO_2 equivalent index in exergetic base was 149.48 gCO_2/MJ ethanol. Lastly, the renewability exergy index (λ=0.58) was environmentally unfavourable ($\lambda < 1$), indicating that the exergy of the products could not be used to restore the environment to the prior conditions of the process occurrence.

Keywords

- Biochemical conversion pathways
- Thermochemical conversion pathways
- Exergy analysis
- Environmental performance