POPULAR SCIENTIFIC ABSTRACT

The use of non-edible biomass, such as straw, wood pellets, algae oil and switchgrass for biofuels production has the potential to reduce greenhouse gas emissions with minimum interruption of the food supply. Moreover, the use of biomass can develop other production sectors and improve regional energy security. However, manufacturing processes of non-edible biomass are expensive and complex, reducing their competitiveness with respect to fossil fuels. During this PhD work, we focused on finding ways to increase the manufacturing processes' efficiency, thus decreasing their expenses. We proposed a holistic numerical methodology that we named sequential screening-out approach. This approach consisted of three levels where each input was the output of a previous level. Moreover, on each level we screened out alternative cases using different levels of numerical evaluation, letting move forward only the promising cases, while we increased the evaluation numerical precision. The first level consisted in process synthesis, where we generated multiple alternative processing paths to produce biofuels. We combined principles such as heuristics, evolutionary methods and synthesis network superstructures on several software to obtain optimal manufacturing processes. The second level consisted in conceptual technology development of the previous optimal manufacturing processes. We analyzed process integration possibilities through co-generation for energy recycling, wastewater treatment for water recycling, as well as recycling of other valuable substances. We did process intensification in separation sequences, where we modified the separation sequences structures to reduce their number of pieces of equipment and reduce their energy consumption. In the third level, we performed rigorous numerical evaluation to evaluate and compare the performance of the most promising manufacturing processes. We optimized process designs, and performed more precised techno-economic and control comparisons. As main results, we classify the contributions to the state-of-the-art into two categories. The first category represents generic process methodologies, and it includes methodologies for process synthesis (selection between multiple process options), and process intensification (modification of separation sequences to increase their efficiency), as well as the sequential screening-out approach by itself. The second category represents particular contributions to biofuels production processes. For example the synthesis, design, simulation and control of novel lignocellulosic bioethanol separation sequences; the optimal synthesis and integration of co-production of bioethanol and biodiesel, and co-production of biodiesel and hydrotreated vegetable oil; and finally, techno-economic studies of lignocellulosic bioethanol and woody biomass to biofuels processing. In summary, we used chemical and process systems engineering principles to provide conceptual and rigorous numerical proposals to improve biofuels production efficiency.