Techno-Feasibility Analysis and Detailed Process Simulation of Microwave Pyrolysis of Algae Residue and Oily Sludge for Advanced Fuel Production

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The transportation sector has a significant environmental impact, contributing to approximately 25% of global greenhouse gas emissions. In this context, the production of sustainable fuels from microalgae residue or industrial oily sludge through advanced process technologies such as microwave pyrolysis and hydrogen-free hydrodeoxygenation emerges as a promising solution. This work evaluates the technological feasibility of an innovative process variant for producing advanced biofuel from both feedstocks. The feedstock is subjected to microwave pyrolysis generating bio-liquid, pyrolysis-gas and bio-char. These three streams are further processed to produce biofuels and activated carbon, with the process design aiming to maximize energy efficiency and biofuel production. The process layout includes the best available technologies for the post-processing of pyrolysis products. Microwave pyrolysis, pyro-gas reforming and purification and bio-liquid refining are the main sections of the system. Key performance indicators, such as energy efficiency and productivity, are used to assess the process feasibility. Also, the study aims to maximize both hydrogen and bio-liquid production while enhancing overall process efficiency. The novel process was simulated in Aspen HYSYS and Aspen PLUS V.14. The proposed approach achieves a significant reduction in emissions thanks to carbon sequestration capabilities and biochar's application as a soil amendment or as a microwave precursor in microwave pyrolysis. Furthermore, the energy efficiency of the system is comparable to that of current biomass-to-fuel configurations. In conclusion, this process layout can be a viable and realistic alternative for future biofuel production based on microalgae cultivation. Future research will include a detailed economic feasibility analysis and process optimization through experimental data to further enhance the energy efficiency of the system.

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