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J Bioproces Biotechniq 2016, 6:7(Suppl)
http://dx.doi.org/10.4172/2155-9821.C1.010

4th International Conference on

Bioprocess and Bio Therapeutics

October 20-21, 2016 Houston, USA

Reaction parameters and an energy optimization for biodiesel production using a supercritical process

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Biodiesel has been proven to be the best reliable alternative for petroleum diesel. Besides, being renewable, it is biodegradable and non-toxic fuel. This paper aimed to study the production of this green fuel using industrial, competitive techniques; base-catalyzed transesterification and supercritical methanol transesterification. The research involved techniques for reaction parameters optimization and thus embedded optimum values into a simulation-based design procedure for overall energy optimization/integration and emissions reduction. Literature experimental reaction data for the two manufacturing technologies were taken to conduct an optimization for biodiesel production. The state-of-the-art process flow sheets for the two manufacturing processes were used for the study. This optimization was done for the most affecting parameters on the production processes. The experimental results from the literature for the two techniques were optimally analyzed using parameters analyses carried out using Pareto chart, contour plot methodology and surface plot methodology. The research study revealed that the key process variable for the base-catalyzed process was the catalyst loading and the optimum conditions for better yield were found to be at 25˚C, 1.3% NaOH and 6:1 methanol to oil molar ratio. On the other hand, for the supercritical methanol process, the most prominent variable was the methanol to oil ratio and the optimum conditions were found to be at 8 minutes and 42:1 methanol to oil ratio. A simplified linear regression analysis was also performed to correlate the biodiesel yield with the process parameters. The optimal process conditions were used to build an ASPEN HYSYS rigorous simulation model for the previous production techniques. The supercritical based-process was chosen for further studies for its better economic performance. As a result, a process optimization was carried out for the reactor volume and the reflux ratios of the distillation columns. The optimum design parameters achieved for the base process were 12 m3 for the reactor volume, 2 for the methanol recovery column reflux ratio and 3.4 for the biodiesel purification column reflux ratio. Pinch analysis principles through ASPEN Energy Analyzer software were employed to analyze the energy performance of the overall optimum model obtained from ASPEN HYSYS. The energy targets were calculated for biodiesel production using supercritical methanol approach. Composite curves resulted in 3.4 and 3.7 MW for heating and cooling requirements, respectively compared with 4.4 and 4.7 MW for the original process. Finally, a heat exchanger network was developed to accomplish the energy targets proposed by the composite curves. The resulting integrated process has an improvement over the literature process flow sheet for better energy saving opportunities. The energy consumption of the optimum case has been reduced by 25%, and thus substantial cut in the CO_2 emissions. Utility curves were also generated to determine the loads of hot utilities (i.e. superheated steam) to be produced by the proposed energy integration.

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