Abstract

Traditional processing methods of algae to biofuels require dewatering after harvesting of the algae before the lipids can be extracted. This is typically the most energy intensive and therefore the most expensive step. Old Dominion University has successfully utilized a flash hydrolysis process where proteins are solubilized into the liquid phase of product and the remainder lipid-rich, low nitrogen product is separated into a solid phase. The GREET model was used to quantify the LCA from WTW production of biodiesel, renewable gasoline, and renewable diesel II utilizing the flash hydrolysis process. Results were compared with existing model simulations from their algae Harmonization study and algae HTL study and also with existing conventional petroleum based reformulated gasoline (RFG) and conventional petroleum based low-sulfur diesel (LSD) LCA’s.

Introduction

• Utilized Argonne National Laboratory GREET model.
• Algae Process Description (APD) and GREET1 MS Excel based programs
• Compared results with 2 existing and published models for well-to-wheels algae biofuel production: harmonization study, hydrothermother liquefaction study (HTL)
• Functional Unit based on 1 mmBtu of fuel production.
• Excluded Activities: Human activities, infrastructure and facility construction, and land use change.

ODU Biofuels Research

• Virginia Coastal Energy Research Consortium 1 acre raceway pond in Spring Grove, VA
• NSF CAREER Award #CBET-1351413 (2013-18)
• EPA-P3 Phase I Award #SU835501 (2013-14)
• Scenedesmus sp. Algae used in Flash Hydrolysis experiments.

Methods, Materials, and Results

Flash Hydrolysis Experimental Setup

• Mass and energy balance utilized for Scenedesmus sp. at 280 °C, 12s residence time which produced maximum lipid content.
  - 20% slurry concentration.
  - 48 kg/h continuous flow reactor (28% slurry = 9.6 kg/h).
  - 30% solid product (lipid rich for oil extraction) from flash hydrolysis process = 2.88 kg/h
  - Assumes 74.1% solid product = lipid (2.13 kg/h)
  - Utilized an 85% heat exchanger to recover heat from temperature drop from 280 °C to 99 °C
  - \( Q (\text{recycle water}) = m \Delta \text{enthalpy} = 38.40 kg \times (1231.13 \text{kJ/kg} - 414.88 \text{kJ/kg}) = 31.34 \text{MJ} \)
  - The efficiency of the heat exchanger is assumed to be 85%. 85% of 31.34 MJ yields 26.64 MJ.
  - The total heat requirement for the flash hydrolysis process is therefore 47.65 MJ – 26.64 MJ for a yield of 21.01 MJ at a 20% slurry.

Flash hydrolysis model utilized same parameters as the Harmonization model except for dewatering and extraction phases in the biofuel production life cycle stage.
• Dewatering phase utilized dissolved air flotation in addition to flash hydrolysis.
• Extraction phase utilized a hexane extraction with same material requirements as the NREL wet extraction.

Sensitivity analysis conducted at 15% and 25% concentrations.

Conclusions

• HTL/Flash Hydrolysis conditions similar, same Heat exchanger efficiency (85%), similar temperatures and pressures.
• Primary reason for better Flash Hydrolysis performance is the reactor residence time.
• HTL = 1.5 L/h vs Flash = 48 L/h
• Local growing and environmental conditions must be considered for a more accurate model.
• Harmonization model performed poorly but it is considered a very conservative model.
• It also has an extra pressure homogenization step for disrupting cells.
• No centrifuge assumed for Flash Hydrolysis, only utilized dissolved air floatation process. Model needs to incorporate the polymer flocculent used to collect the algae.
• Sensitivity comparison showed that increasing the slurry concentration to 25% did not considerably reduce the total energy consumption.
• Biodiesel was only reduced by 1.1%.
• Renewable diesel II reduced by 6.2%.
• Renewable gasoline reduced by 6.7%.

Future Work

• Utilize liquid hydrolyzate as a coproduct
• Market based protein product
• Nutrient recycling
• Use actual conditions from Virginia experimental raceway ponds.
• Incorporate hydrothermal mineralization (HTM) process for nutrient collection.
• ODU currently conducting experiments
• Techno-economic analysis needs to be conducted.

References


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• Argonne National Laboratory