Impact of Tree Age and Anatomical Fraction on Forest Residue Pyrolysis and Hydrotreating

Daniel Carpenter1, Jordan Klinger2, Huamin Wang3, Kristiina Iisa1, Jim Parks4, Gavin Wiggins4, Brennan Pecha1, Matt Wiatrowski1, Hao Cai5, Longwen Ou5

1National Renewable Energy Laboratory, 2Idaho National Laboratory, 3Pacific Northwest National Laboratory, 4Oak Ridge National Laboratory, 5Argonne National Laboratory

Introduction

Utilization of cost-advantaged biomass and waste resources to produce clean, domestic biofuels will be a key factor in decarbonizing transportation in the United States. This study investigates how the distribution of anatomical fractions (stem, wood, bark, needles, branches) from loblolly pine trees of different ages impacts pyrolysis and hydroprocessing processes, including product composition, conversion efficiency, economics, and sustainability. Commercially sourced 13- and 23-year-old loblolly pine residues were chosen to represent available resources; whole tree thinnings, and tops and branches from merchantable timber, respectively. Fast pyrolysis experiments were carried out on the whole samples, separated anatomical fractions, and whole samples that were air-classified to remove loose bark, needs, and soil contaminants. Select samples were processed to hydrocarbon blendstocks, and technoeconomic and life cycle analyses were conducted for the end-to-end process.

Methods

- **Feedstock**: Commerically sourced Loblolly pine
  - “Residues” = 23 yr, tops and branches
  - “Thinnings” = 13 yr, whole trees
  - Anatomical fractions were hand separated
- **Fast pyrolysis**: 2” ID fluidized bed reactor (2FBR)
  - Temperature: 500 °C
  - Feed rate: 0.3 kg/h
  - Product collection: fractional condensation
- **Hydroprocessing**: 40 mL/h fixed trickle bed reactor
  - Two-step process
  - Stabilization: Ru/TiO2, 140 °C, 1800 psi, LHSV 0.23 h-1 in H2
  - Hydrotreating: sulfided NiMo/Al2O3, 400 °C, 1800 psi, LHSV 0.22 h-1 in H2 + DTBDS (sulfiding agent)

Fast Pyrolysis

- Mass balance: 98 ± 2%
- Oil Yield: 53-72% (db)
- Carbon to Oil: 29-64%

Hydroprocessing

Conclusions

- **Higher bio-oil yield was generally correlated with total volatiles, hydrogen, oxygen, glucan, and mannan**
- Lower bio-oil yield was correlated with fixed carbon, nitrogen, sulfur, and extractives
- Air classification reduced ash, extractives, and sulfur, resulting in an increase in yield and GC-detectable compounds
- Sulfer contained in needles appears to disproportionally partition to the oil phase compared to the other fractions
- Hydroprocessing yields and distribution of hydrocarbon fuel products were comparable for thinnings and residues of different ages
- The minimum fuel selling price is similar for thinnings and residues
- GHG emissions for thinnings and residues can achieve >80% reduction vs. fossil-derived equivalents, a large driver being co-product credits

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