IEA Bioenergy

Round Robin on Fast Pyrolysis Bio-oil Production

Comparison of bio-oil production technologies from various institutions

Summary Series

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SUMMARY

IEA Bioenergy Task 34, "Direct Thermochemical Liquefaction" represents a collaboration of international researchers advancing the production and use of biomass for energy and chemicals enabled by thermochemical liquefaction technologies. Originally focused on fast pyrolysis, the Task expanded in 2016 to include hydrothermal liquefaction and solvent liquefaction. These technologies convert biomass to produce a liquefied intermediate for use as a fuel or be refined and/or separated into advanced fuels and chemical products.

In 2015, when the focus was exclusively on fast pyrolysis, this international group undertook a round robin study to validate the pyrolysis community understanding of production of fast pyrolysis bio-oil (FPBO) by controlling the following factors:

- All participants were provided the same set of biomass feeds
- All participants submitted FPBO samples to be analysed by a single, central laboratory

A total of 15 institutions in six countries contributed with technologies included bubbling bed (BFB), bubbling bed and entrained flow with hot vapour filtration (BFB/EF+HVF), screw reactors (SR), and ablative reactors (AR).

The round robin included: distribution of three feedstock samples, hybrid poplar, wheat straw, and a blend of lignocellulosic biomasses, from a common source to each participating laboratory; preparation of FPBO in each laboratory with the three feedstocks provided; and return of the three FPBO products (500 mL minimum) with operational description to a central analytical laboratory for FPBO property determination. The analyses of interest were CHN, S, trace element analysis,

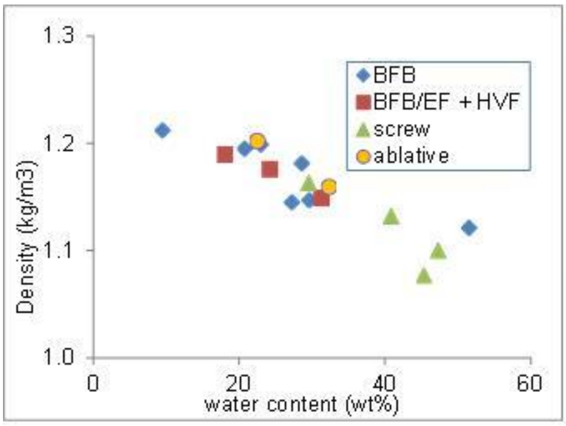

Figure 1. Density/water correlation versus technology.

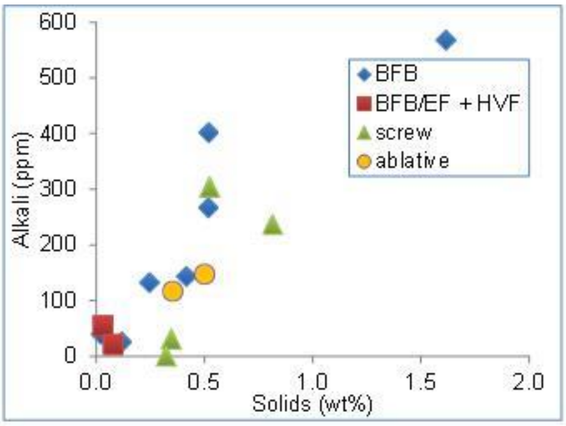

Figure 2 Correlation of solid and alkali contents (on weight basis) versus technology.

water, ash, solids, pyrolytic lignin (PL), density, viscosity, carboxylic acid number, and accelerated aging of FPBO. In addition, an effort was made to compare the FPBO components to the products of analytical pyrolysis through gas chromatography/ mass spectrometry (GC/MS) analysis.

The results showed that clear differences can occur in FPBO properties by applying different process configurations and reactor designs in small scale.

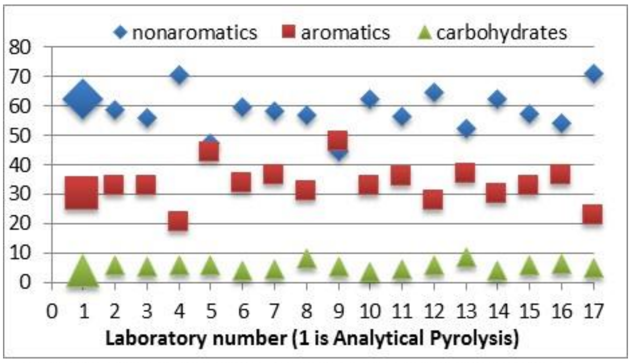

Figure 3. Yields of main chemical groups as obtained from analytical pyrolysis (large marks) and in bio-oils from poplar.

Correlations include: amounts of mono- and non-aromatics in FPBO by GC/MS negatively correlate; the mean molecular weight of the FPBO correlates with that from PL; viscosity correlates with the PL content; the water content negatively correlates with the PL content; and viscosity correlates with the water content. The parameters of water, solids, viscosity, and total acid number were able to discriminate the four technologies applied (BFB, BFB/EF+HVF, SR, AR). Most negative results were obtained from SR, whereas BFB/EF+HVF showed the most positive FPBO characteristics, mainly in terms of solids and ash contents. The difference may be explained by longer residence time in SR reactors. Furthermore, hot vapour filtration generally resulted in more favourable FPBO product, with respect to water, solids, viscosity, and carboxylic acid number.

Comparison to analytical pyrolysis method suggested that pyrolysis (Py)-GC/MS could serve as rapid qualitative screening for FPBO composition produced in small-scale fluid-bed reactors. Gel permeation chromatography was also applied to determine molecular weight information. These results are helpful in understanding the variation in FPBO production methods and their effects on product composition.

The full report is available from: DOI: 10.1021/acs.energyfuels.6b03502

Conclusions

All laboratory reactor systems for FPBO production do not produce equivalent products. However, this round robin provided insights on difference between performance of laboratory and bench-scale pyrolysis systems, and benchmarked participant results compared to other laboratories to aid in interpretation of published research data from other institutions.

The correlations developed were made possible by the extensive pool of data and samples available and that all samples were analysed by a single laboratory. The conclusions are:

- FPBO properties of water, solids, viscosity, and total acid number were found to relate to pyrolysis technology used to produce it.
- Variations in bio-oil characteristics among technologies may be impacted by differences in heat transfer and/or in reported pyrolysis temperature if not measured identically between systems.
- FPBO collection can impact product composition.
- None of the laboratories could produce single-phase oil from wheat straw. This relates to the amount of ash in the feedstock.
- Blended feedstocks resulted in FPBO with less phase separation.
- All laboratories produced single-phase FPBO from hybrid poplar that could be fully analysed.

Overall, the use of round robins is useful for both providing insights on differences between performance of laboratory and bench-scale pyrolysis units and helping the participants by allowing for a comparison of results to other laboratories. It must be pointed out that FPBO are completely different from mineral oils or biodiesels. Special care has to be used in the proper product collection, handling, and sampling of these bio-oils to ensure the homogeneity.