Distillation of Biocrude Oil Converted from Biowaste via Hydrothermal Liquefaction

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Introduction

The continuous use of petroleum-based fuels is a crucial problem facing modern society. The solution to this growing issue of petroleum depletion lies in the research and development of biofuel-based means of energy derived from renewable resources. Since biofuels have no carbon footprint, they would have environmental as well as economical benefits. Increased demand for biomass products from which to derive biofuels would increase agronomical practices, thereby effectively leading to an agricultural boom and economic expansion globally.

Figure I depicts a plug-flow reactor used for hydrothermal liquefaction. (Source: Dr. Yuanhui Zhang)

Hydrothermal Liquefaction:

- A plug-flow reactor was used to convert wet biowaste at a temperature of 240-300°C for 15-120 minutes via hydrothermal liquefaction
- Then, distillation separated the biocrude oil into fractions of biofuels with different boiling points and other characteristics

Objective

- Separate HTL biocrude through distillation into fractions usable as transportation biofuels
- Compare biofuel samples of diesel and jet fuel to petroleum-based commercial samples

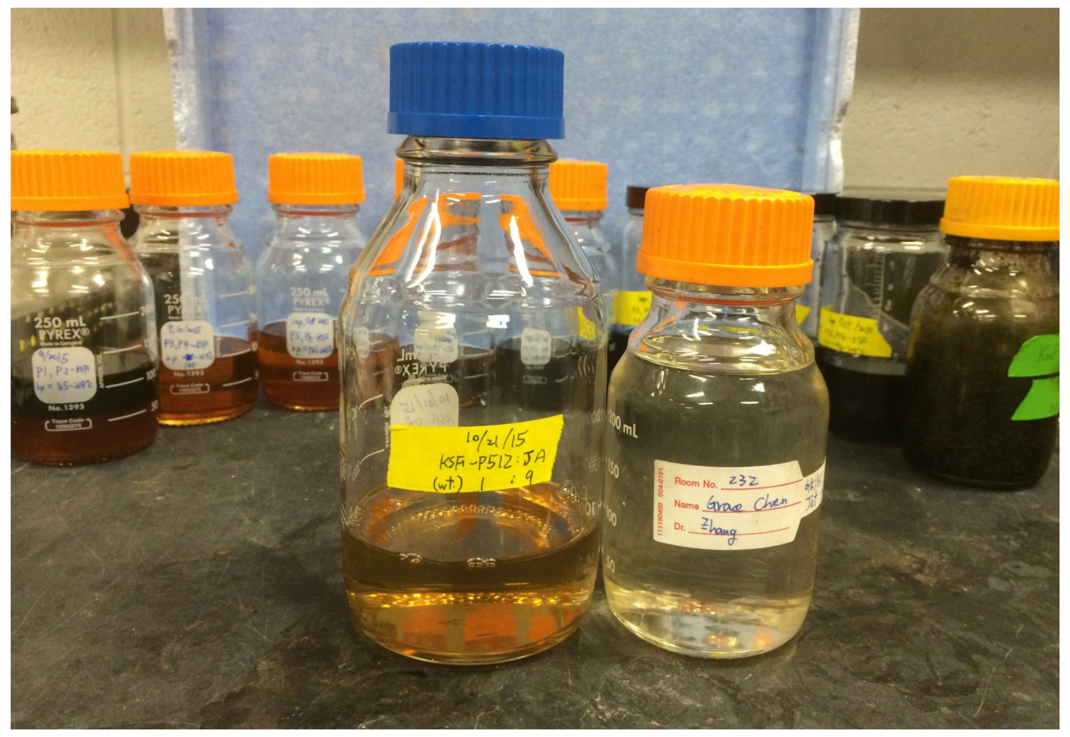

Figure II depicts fractional distillations of biofuel compared to commercial jet fuel.

Method

Materials:

- Distillation column
- Boiler
- Insulation and insulation taped
- Glassware
- Measurement devices (e.g., thermocouple)

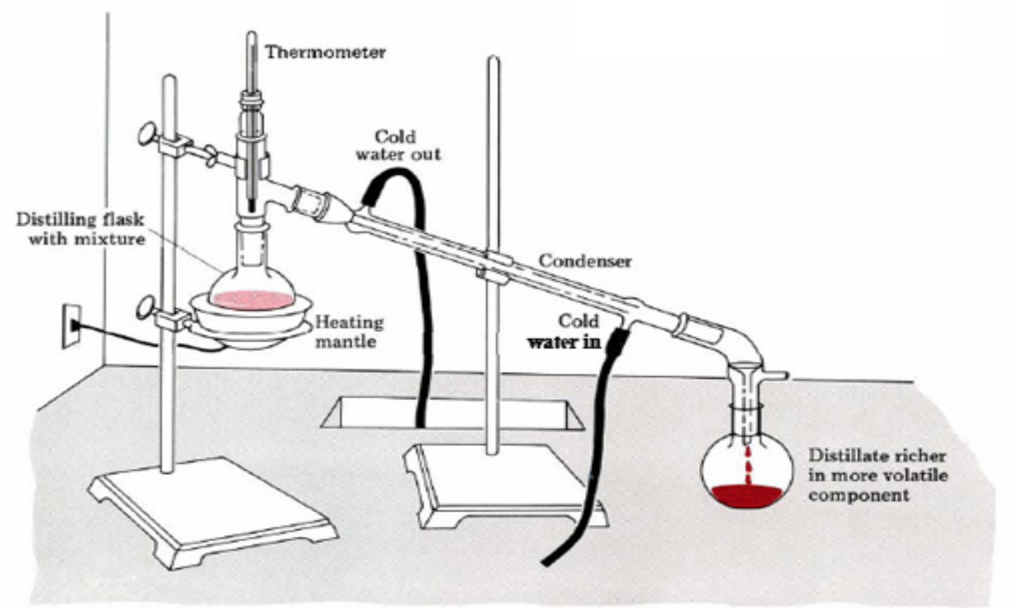

Figure III depicts the construction of a fractional distillation apparatus. (Source: http://chemwiki.ucdavis.edu/Textbook_Maps/General_Chemistry_Textbook_Maps/Map%3A_Lower's_Chem1/07b._Solution_Chemistry/Raoult's_Law_and_Distillation)

Procedure:

- Set up the distillation apparatus
  - Heat source → gas chamber adapter → distillation column → collecting flask
  - Angle boiler and distillation column upward (see Figure III)
- Connect hoses to water source and distillation column
  - Use insulation and insulation tape to ensure airtightness
  - Keep system closed with airtight clamps
- Place the oil sample into boiler
- Set the temperature of the boiler within range between 9-21°C above sample's pour point
  - Allow system to run about 7-8 hours
- Switch collecting flask once filled with about 5% weight distillates
  - Less time at beginning, more time towards end
- Record the the temperature at five minute intervals
- Test chemical properties and traits
  - Density and viscosity.

Things to Note:

- Efficiency of distillation relies largely on setup
  - Insulating the distillation column properly can help prevent leakage
  - Colder water in condenser will improve the recovery of the distillates and prevent the loss of distillates in gaseous form

Results

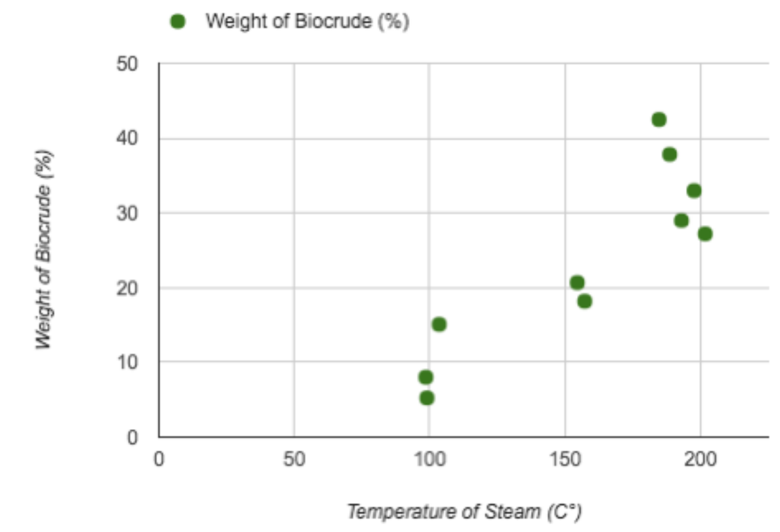

Figure IV depicts the distillation curve (temperature vs. percentage mass) associated with the distilled fractions of biofuel.

Compositions (d.w.%)	Swine Manure	Food processing Waste
Crude protein	24.3	2.76
Crude fat	19.9	40.8
Cellulose	5.1±3.2	Not detected
Non-fiber carbohydrates[a]	6.4±4.5	50.3
Ash content	14.3±2.0	6.17
C	41.1±0.3	54.0±1.7
H	5.42±0.1	7.93±0.3
N	3.36±0.1	0.57±0.01
O[a]	50.1	37.5
Heating Value (MJ/kg)	18.2	22.9
S	0.4	0.04
P	2.47	0.12

[a] calculated by difference [b] not detected

Figure V compares the composition of animal and food waste. (Source: Grace Chen)

- Animal manure efficiency 50-60%
- Food processing waste efficiency 80-90%

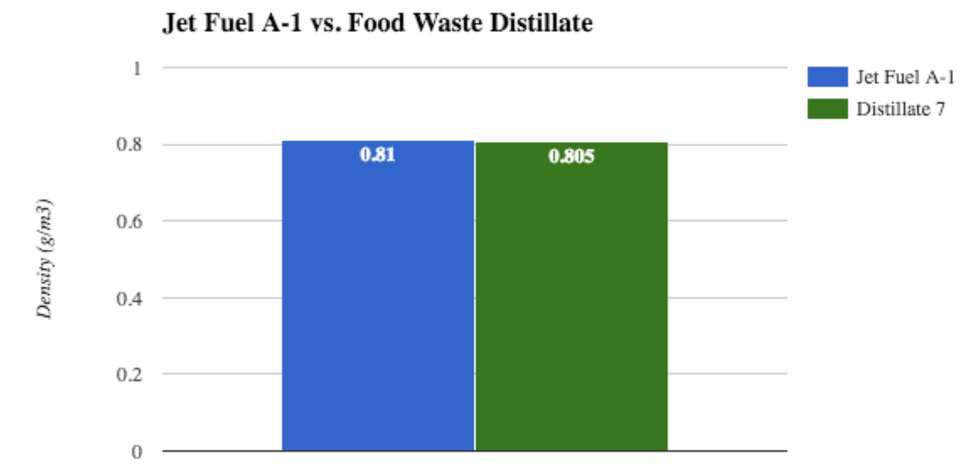

Figure VI compares the density (g/m³)of commercial jet fuel with that of food waste distillate 7.

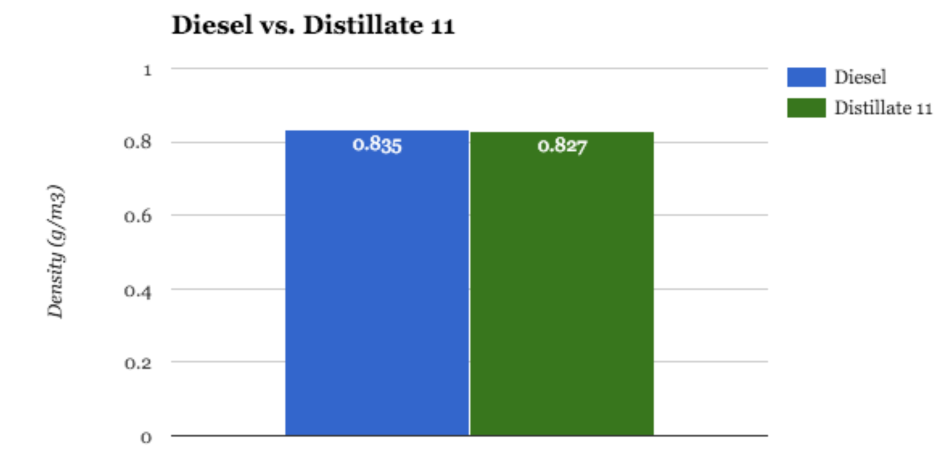

Figure VII compares the density (in g/m³) of commercial diesel with that of food waste distillate 11.

- Food waste biofuel compared more favorably to commercial fuel than animal waste biofuel.
  - Jet Fuel A → Distillate 7
  - Diesel → Distillate 11

Case Study on Cost Efficiency

- Annual operating costs = $cost_{land} + cost_{tax} + cost_{maintenance} + cost_{loan} + cost_{labor}$
  - Largest contributions to costs: loan payments (50-60%), energy and materials (15-20%), labor costs (15-20%)[1]
- Current projects do not break even within first 40 years
  - Biofuel must compete with $2/L crude oil

Conclusions

Based on these findings, carbon neutral bio-oil is an applicable substitution for petroleum-based fuel types without modifying any existing internal combustion engine systems. With more research, better distillation systems can be built, more pure fuel substances can be distilled, and biofuel can be created and distributed on a much larger scale for domestic and international commercial use.

Acknowledgments

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References

[1] Beal, Colin M., Léda N. Gerber, Deborah L. Sills, Mark E. Huntley, Stephen C. Machesky, Michael J. Walsh, Jefferson W. Tester, Ian Archibald, Joe Granados, and Charles H. Greene. "Algal Biofuel Production for Fuels and Feed in a 100-ha Facility: A Comprehensive Techno-economic Analysis and Life Cycle Assessment [Algal Res. 10 (July 2015) 266–279]." *Algal Research* 11 (2015): 375-78. Web.

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