Multi-step hydrothermal liquefaction (HTL) of algae with nutrient recycling

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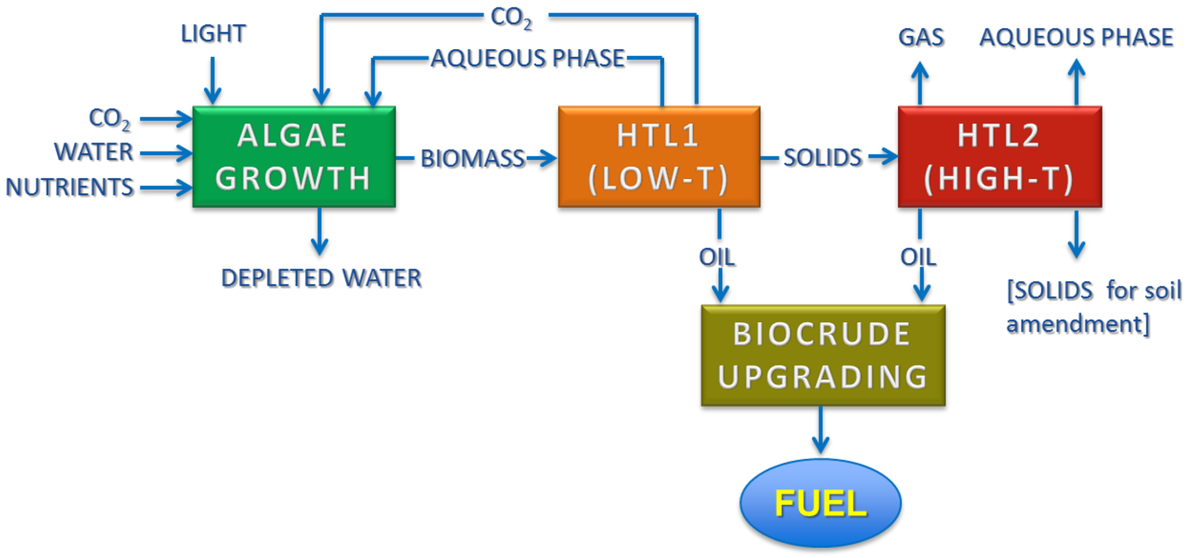
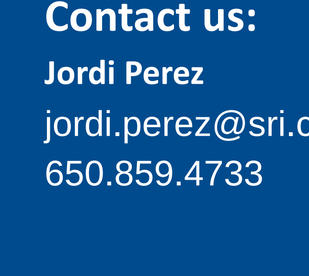
Need: a thermochemical process that allows economic conversion of wet biomass to liquid fuels

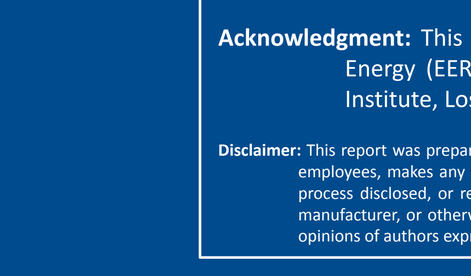
- No energy-intensive drying (HTL can work with wet biomass, unlike pyrolysis or gasification)
- Low heteroatom content (high N content typical of single-step HTL oils limits upgrading to fuels)
- Recycling of valuable nutrients (N, C) to improve biofuel economics

Approach: 2-step HTL with nutrient recycling



- In HTL biomass/water mixtures are heated to 200-400 °C in closed systems to form biocrude oil.
- Algae is suitable for HTL but the resulting biocrude has usually high nitrogen content, often as aromatic heterocycles.
- In multi-step HTL, N-rich compounds are extracted in the water phase during the low-temperature step.
- N, C and other nutrients from the aqueous phase can be recycled for production of biomass.





Benefits

- Wet biomass feedstock → reduces energy requirements
- Nitrogen extraction → reduces N in biocrude oil
- Recycling of nutrients → reduces cost and environmental impact

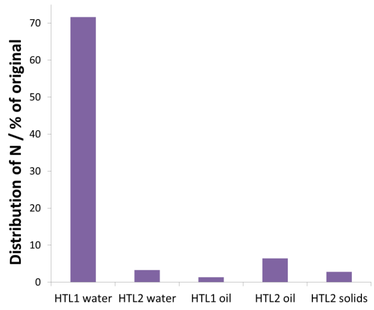
Technology status

- Biocrude with N in the range 1.0 – 2.3 wt% (target is < 1 wt%)
- N extraction in HTL1 water > 70%
- N and C recycling for algae growth demonstrated

Nutrient recycling study

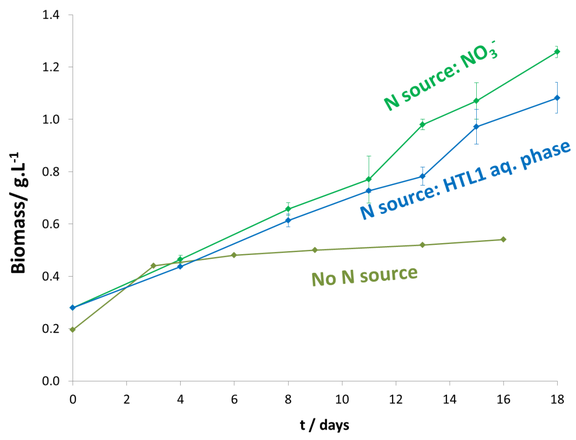
EXTRACTION OF N IN HTL1 AQUEOUS PHASE

- Most of the N from the algae is extracted in the aqueous phase during HTL1, providing opportunities for recycling.
- Low amount of N in HTL1 oil
- Optimization of process is planned to reduce the amount of N that ends up in HTL2 oil.



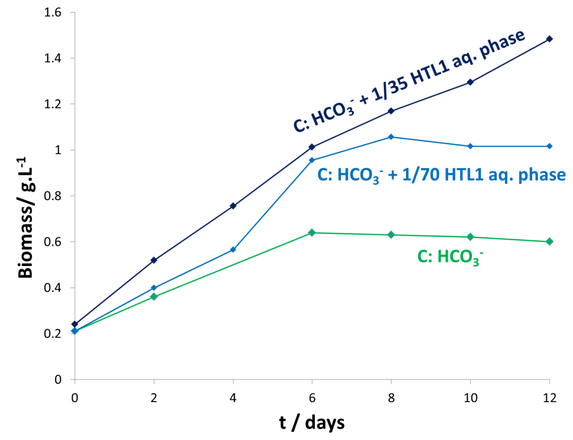
RECYCLING N FROM AQUEOUS PHASE FOR ALGAE GROWTH

- HTL1 aqueous phase was the sole source of N (blue line).
- Biomass concentration was higher than cultures with no N source and close to cultures with excess nitrate.
- 47% of N from HTL1 aqueous phase was consumed during algae growth.
- 35% of N from HTL1 aqueous phase was incorporated into algae cells
- Process optimization underway



MIXOTROPHIC GROWTH USING C FROM AQUEOUS PHASE

- C source (blank): 1 g/L $NaHCO_3$
- C sources (rest): 1 g/L $NaHCO_3$ + HTL1 aqueous phase (dilution factors were x35 and x70)
- Cultures with recycled C grew faster than blank
- Results show that **algae can grow mixotropically using recycled C**.
- Process optimization underway



EXPERIMENTAL: Scendesmus dimorphus *cultures were grown in closed photobioreactors (PBRs). N recycling studies were done using in 4 L conical photobioreactors (PBRs), using a flow of 600 sccm of air with 1 vol% CO_2 to keep algae in suspension and provide C for growth. Mixotropic growth studies were done in 1 L media bottles with mechanical stirring. $NaHCO_3$ was used as C source (1 g/L). The PBRs were illuminated with blue fluorescent lamps at an irradiance level of 125 $\mu mol \cdot m^{-2} \cdot s^{-1}$, with a photoperiod of 14:10 (light:darkness). Blank cultures were grown using M8 nutrient medium. The rest of cultures were grown using a modified nutrient recipe (M8 except that there was no nitrate added as source of N) and the aqueous phase from HTL1 as N and C source (dilution factors were x35 in N recycling tests, and x35 and x70 in mixotrophic growth studies).*

We are a community of innovation.

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In loving memory of Dr. Brian Bedwell, colleague and friend.

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