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Exploring a range of UK seaweed species for the production of fuels and fertiliser

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1. Macroalgae

- Marine biomass has a higher photosynthetic efficiency (*ca.* 6–8 %) than terrestrial crops (*ca.* 1–2 %)[1]
- Macroalgae are an abundant natural resource, and a promising feedstock for third-generation biofuels
- Promising source of novel fuel crops—no competition with agriculture and less areal constraint
- Numerous methods of processing to fuels: chemical, biological, thermochemical

Fig. 1: Common UK macroalga Ascophyllum nodosum

2. Hydrothermal liquefaction

- Hydrothermal liquefaction (HTL) is an inexpensive and energy-efficient thermochemical route to whole biomass conversion
- HTL is carried out using subcritical water (310–360°C, 100–180 bar) as both a solvent and a reactant for the conversion of biomass to a range of products

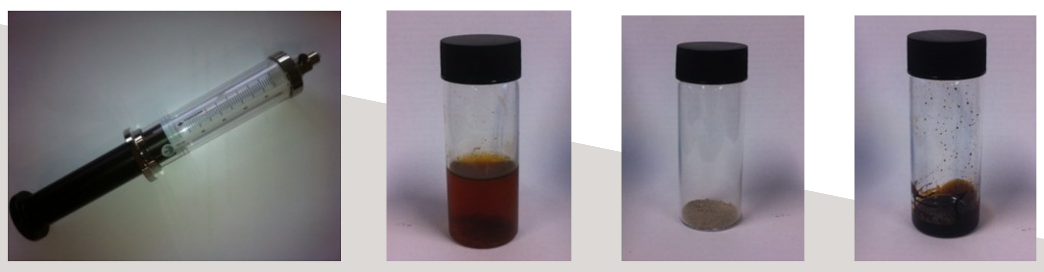

Fig. 2: HTL products. L to R: bio-gas, aqueous phase, bio-char and bio-crude oil

3. Biorefinery concept

All products generated *via* HTL can be used within a biorefinery to create value

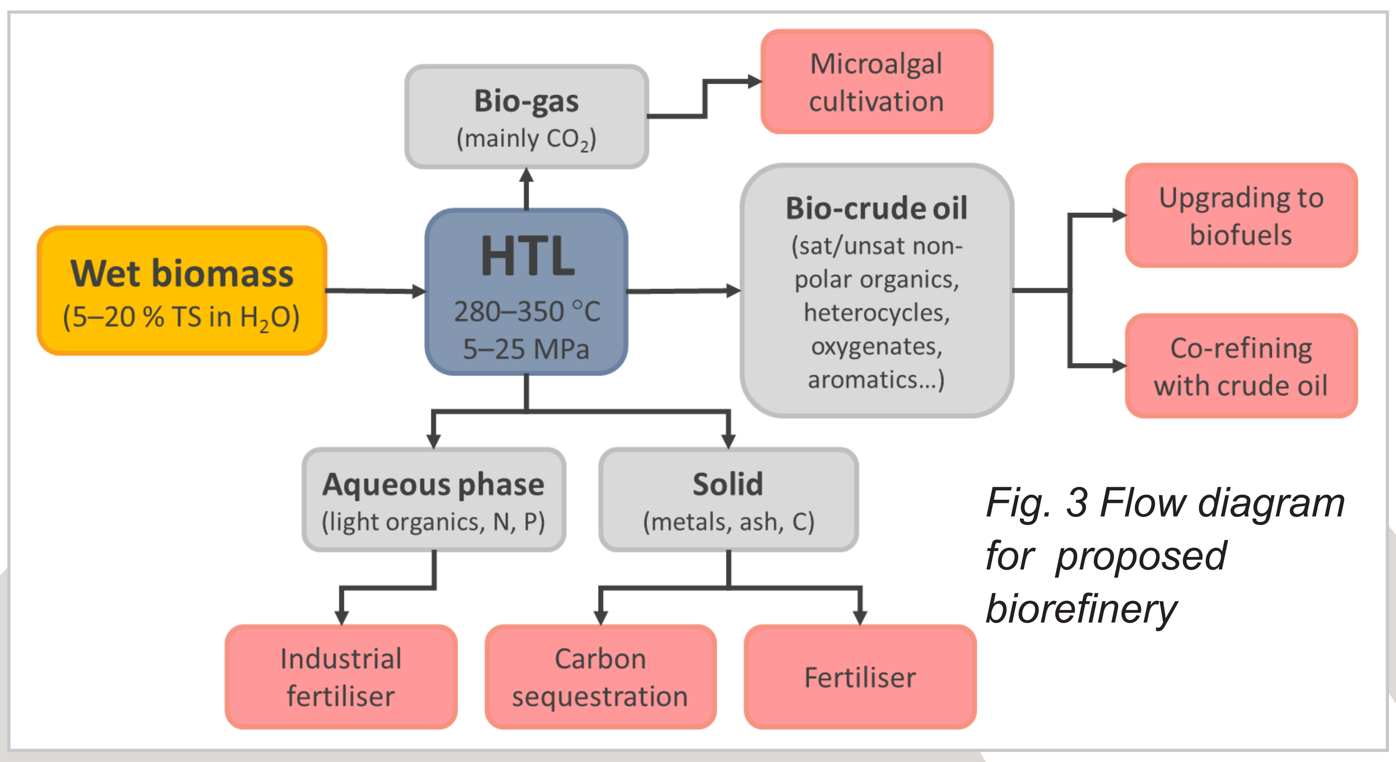

Fig. 3 Flow diagram for proposed biorefinery

Project aims

- Pinpoint HTL conditions for optimal energy and nutrient recovery using brown macroalga *Ascophyllum nodosum*
- Focus on maximising conversion to bio-crude oil and increasing ammonia and phosphate in aqueous products
- Screen a range of South West UK macroalgae for fuel production to build up a UK fuel and fertiliser production biorefinery design

4. System optimisation

- HTL was used to process the macroalga *Ascophyllum nodosum* in a batch system
- A range of temperatures between 300–350 °C was used, as well as a range of heating rates 5–60 °C min^{-1}
- The composition and properties of each product phase were examined

Fig. 4: Batch reactor set-up

5. Optimisation of HTL conditions

- Higher heating rates give higher bio-crude oil yields (literature precedent)[2]
- Higher processing temperatures give higher bio-crude yields
- No notable correlation between temperature and elemental composition or energy recovery in bio-crude oil
- Increasing temperatures improves ammonia recovery in aqueous product, but depletes phosphate

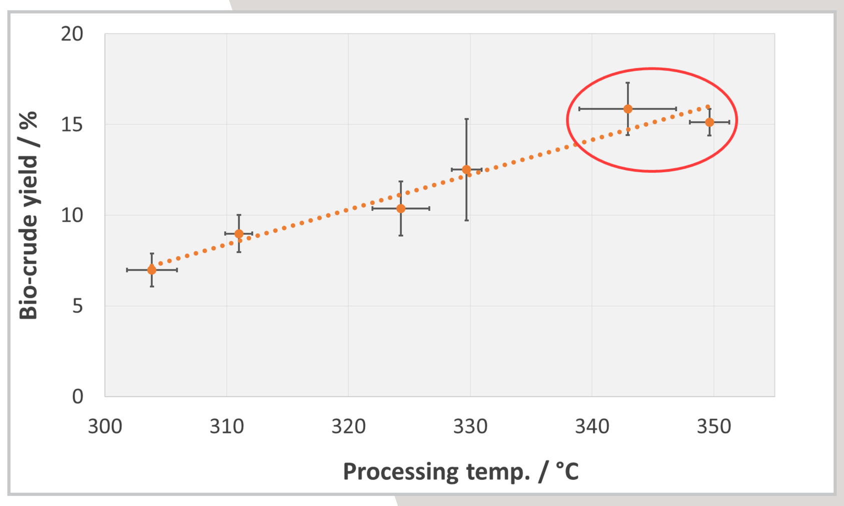

Fig. 5: Effect of temperature on bio-crude oil production

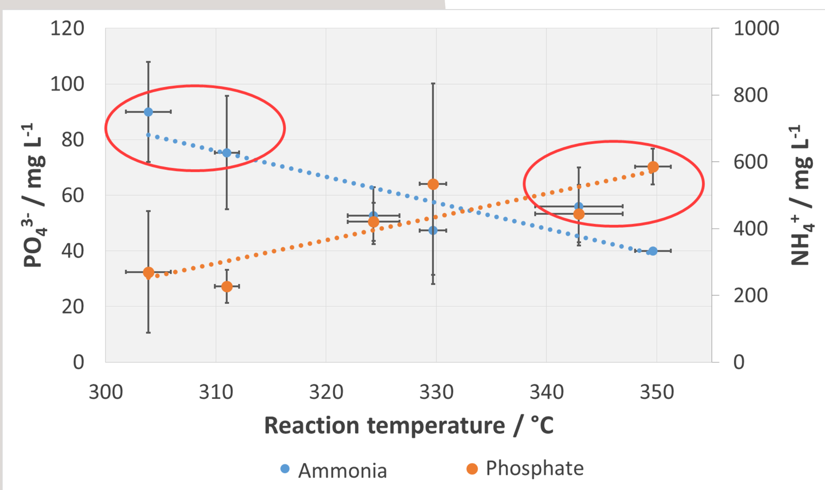

Fig. 6: Effect of temperature on ammonia and phosphate recovery in aqueous products

- From an economic standpoint, maximising bio-crude yields is more favourable – nutrient recovery will be a secondary valorisation route

Temperature	Heating rate
345 °C	*ca.* 30 °C min^{-1}

Table 1: Final optimised HTL conditions

6. Species screening—early findings

- Optimised HTL conditions were used to process a range of South West UK seaweeds

Fig. 7: Several of the macroalgae species used in HTL screening. (L to R: L. hyperborea, C. crispus, U. intestinalis, H. elongata, F. vesiculosis, S. muticum, S. chordalis, U. lactuca)

- Trends relating initial biomass composition to product distribution and properties were analysed

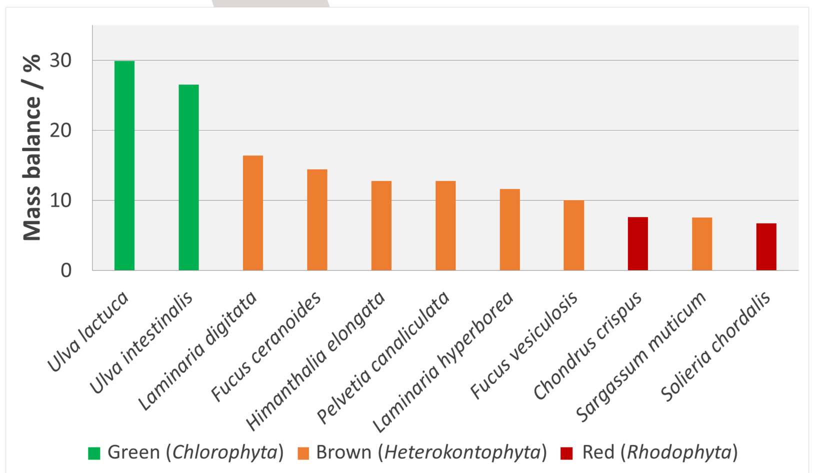

Fig. 8: Species effect on bio-crude recovery

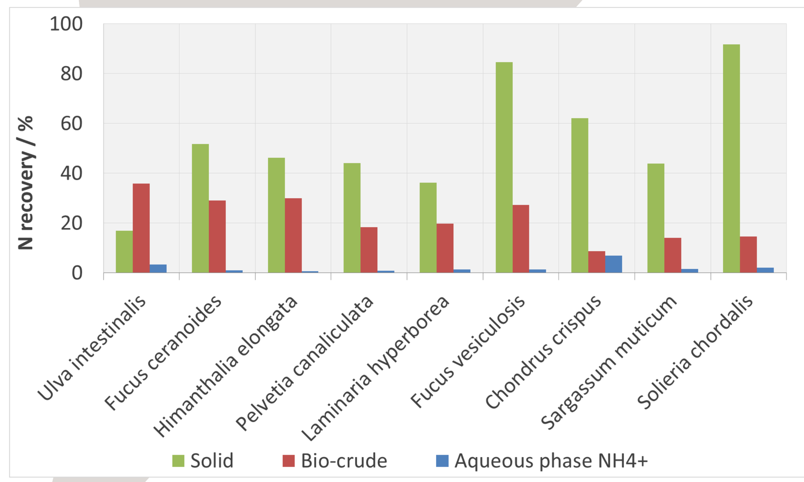

Fig. 9: Nitrogen recovery in product phases

- Green seaweeds (*Chlorophyta*) gave the highest yields of bio-crude oil (*Fig. 8*)
- Nitrogen from biomass proteins was found to accumulate preferentially in the solid residue, but high biomass protein content also resulted in some additional N partitioning to aqueous phase and bio-crude oil (*Fig. 9*)

7. Further work

- Further investigation of the complex relationship between biomass and product composition to rationalise reactivity
- Based on this, a set of specifications for an ideal biomass for the proposed biorefinery model will be laid out
- A theoretical biorefinery model will be built up, and a Life Cycle Assessment (LCA) carried out

References

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