A microfluidic approach for high-throughput screening of microalgae-to-bioproducts conversions

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Microalgae has attracted great interest in biofuel and bioproducts production due to their high solar energy conversion efficiency resulted in high growth rate and rich lipid content. Downstream processing that converts such biomass into valuable products is critical to the development of algal industry. Current approaches to studying microalgae disruption, extraction and conversion processes in large opaque batch reactors is challenging due to slow heating rate and lack of optical access. In this work, we leverage the precise parameter control and optical access provided by a microfluidic platform to study two promising downstream processes: biomass-to-biocrude conversion using hydrothermal liquefaction and astaxanthin production involving cell-wall disruption and supercritical CO_2 extraction.

In this work, our platform, fabricated from glass and silicon, allows full optical access to the reaction chamber while withstanding temperatures and pressures exceeding 350 °C and 200 bar respectively. Integration with a fluorescence microscope enables direct real-time monitoring of conversion and extraction processes. By monitoring the fluorescence signal of a microalgal slurry, optimal reaction times for hydrothermal liquefaction of biomass–to–biocrude were determined to be between 2 and 10 minutes. During this process, we observe biocrude formation and separation from the aqueous phase into immiscible droplets in real-time. In addition, the role of cell wall disruption during solvent extraction of astaxanthin was explored. Hydrothermal disruption at a temperature of 200 °C was shown to be highly effective, resulting in near-complete astaxanthin extraction from wet biomass whereas conventional acid and base treatments resulted in sub-20% extraction efficiency. Moreover, supercritical CO_2 extraction of astaxanthin were performed on the microfluidic platform to investigate the effects of temperature, pressure and co-solvents.

The results gathered so far using this microfluidic platform have already provided new insights into these important biomass processing techniques. Further development will reveal more detailed information on high temperature and pressure reaction kinetics and extraction dynamics, and ultimately inform large scale reactor design and process optimization.