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Hydrothermal liquefaction for algal biorefinery: A critical review

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ABSTRACT

Hydrothermal liquefaction (HTL) has recently received increasing attention due to its advantages in rapid reaction, using wet feedstocks with no lipid-content restriction. These characteristics make HTL especially suitable for conversion of algae into biocrude oil. This paper aims to provide a state-of-the-art review of HTL technologies from a perspective of algal biorefinery. In this review, we first summarize the updated researches and technologies of algae HTL. Specially, an "*Environmental-Enhancing Energy*" (E2E) paradigm based on algal biorefinery has been proposed and discussed. Second, the principles and crucial factors for algae HTL are discussed with focus on (1) algae species and characteristics including lipids, proteins and carbohydrates; (2) the operational parameters including total solids, holding temperature, retention time and catalysts; and (3) the critical principles of HTL reaction and the role of deoxygenation and denitrogenation. In addition, potential applications of HTL are discussed. Prospective and challenges of HTL for algal biorefinery are finally addressed including feedstock preparation, scale-up of algae HTL, and process integration.

Contents

Abbreviations: daf, dry ash-free basis; db, dry basis; E2E, Environment-Enhancing Energy; HHV, higher heating value; HTC, hydrothermal carbonization; HTL, hydrothermal liquefaction; HTG, hydrothermal gasification; TS, total solids

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1. Introduction

Algal biofuel has been proposed as the next generation biofuel [1–3]. The nature of algal biofuel is to convert sunlight into chemical energy through algae growth, which can be used as feedstocks for further biological or thermochemical conversion processes [4,5]. Among these processes, two main routes to produce liquid biofuels from algae are biodiesel via the extraction or transesterification [6], bio-oil via pyrolysis and biocrude oil via hydrothermal liquefaction (HTL) [4,7].

The HTL of algae is defined as the direct liquefaction of algal biomass into biocrude oil in a closed oxygen-free reactor by pressurizing inert gases (e.g., N_2 or He) or reducing gases (e.g., H_2 or CO), at a certain temperature (200–380 °C) and pressure (5–28 MPa) [8–12]. The hot compressed water in the HTL (i.e. sub-/near-critical water) is used for both solvent and reaction medium [13]. A continuous HTL process [14] in detail is presented in Fig. 1. Biocrude oil is the most important product, mainly consisting of hydrocarbons and O/N-containing compounds. Biocrude oil has the potential as feedstocks for co-refining in an existing fossil refinery to produce energy and chemicals [15–17]. Besides

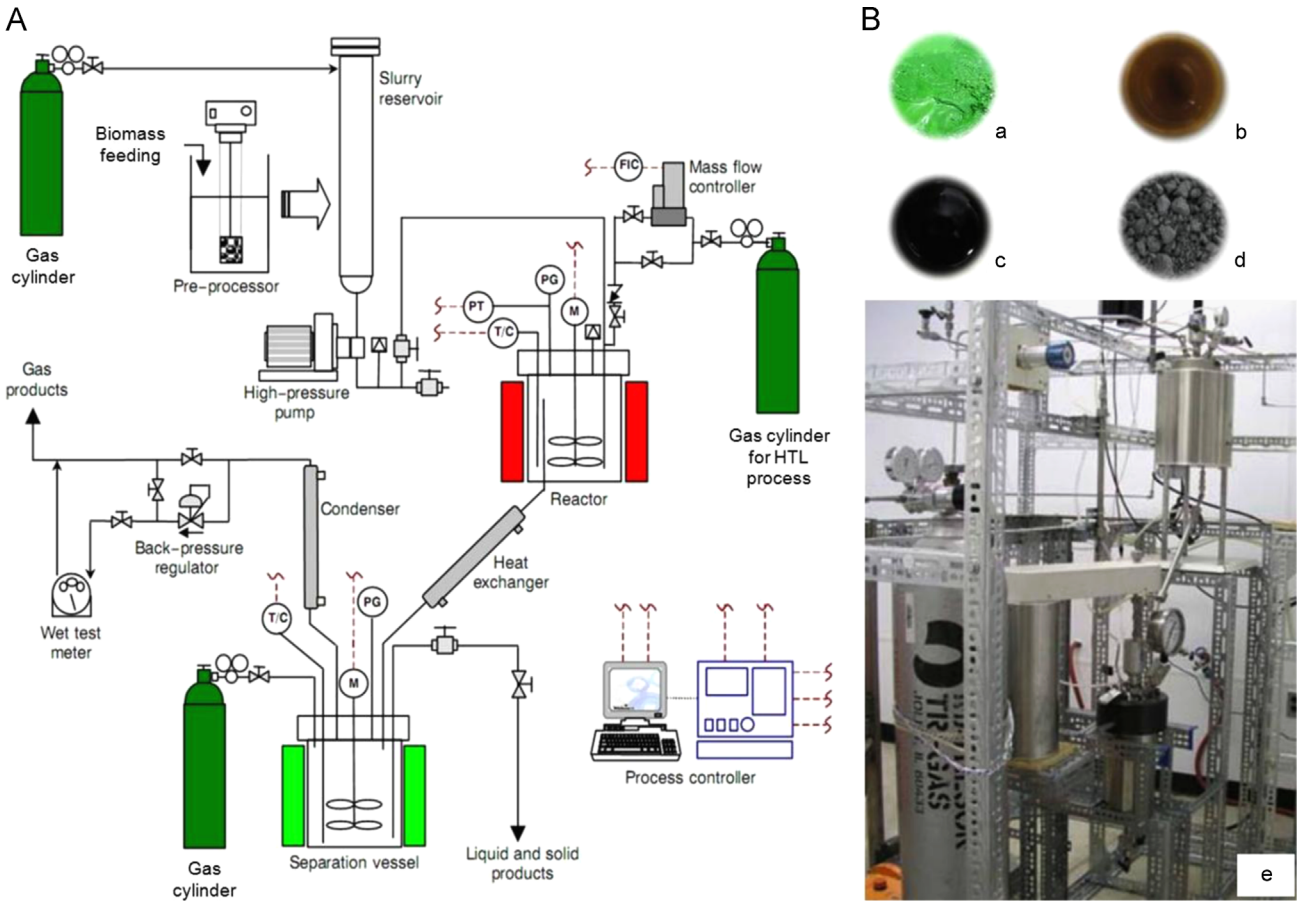

Fig. 1. A continuous hydrothermal liquefaction (HTL) process [14]. (A) A flowchart of HTL; and (B) pictures of algae HTL: (a) algae slurry, (b) aqueous products, (c) biocrude oil, (d) solid residue, and (e) HTL reactor.