



Research article

Biofuel from wastewater-grown microalgae: A biorefinery approach using hydrothermal liquefaction and catalyst upgrading

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ABSTRACT

Third-generation biofuels from microalgae are becoming necessary for sustainable energy. In this context, this study explores the hydrothermal liquefaction (HTL) of microalgae biomass grown in wastewater, consisting of 30% *Chlorella vulgaris*, 69% *Tetradismus obliquus*, and 1% cyanobacteria *Limnothrix planctonica*, and the subsequent upgrading of the produced bio-oil. The novelty of the work lies in integrating microalgae cultivation in wastewater with HTL in a biorefinery approach, enhanced using a catalyst to upgrade the bio-oil. Different temperatures (300, 325, and 350 °C) and reaction times (15, 30, and 45 min) were tested. The bio-oil upgrading occurred with a Cobalt-Molybdenum (CoMo) catalyst for 1 h at 375 °C. Post-HTL, although the hydrogen-to-carbon (H/C) ratio decreased from 1.70 to 1.38–1.60, the oxygen-to-carbon (O/C) ratio also decreased from 0.39 to 0.079–0.104, and the higher heating value increased from 20.6 to 36.4–38.3 MJ kg⁻¹. Palmitic acid was the main component in all bio-oil samples. The highest bio-oil yield was at 300 °C for 30 min (23.4%). Upgrading increased long-chain hydrocarbons like heptadecane (5%), indicating biofuel potential, though nitrogenous compounds such as hexadecanenitrile suggest a need for further hydrodenitrogenation. Aqueous phase, solid residues, and gas from HTL can be used for applications such as biomass cultivation, bio-hydrogen, valuable chemicals, and materials like carbon composites and cement additives, promoting a circular economy. The study underscores the potential of microalgae-derived bio-oil as sustainable biofuel, although further refinement is needed to meet current fuel standards.

1. Introduction

Recent developments in sustainable energy alternatives have led to the growing importance of biofuels derived from microalgae cultivated in wastewater (Choudhary et al., 2020). Microalgae biomass is well-known for its potential as a promising feedstock. They offer advantages like continuous cultivation, adaptability to diverse climates, water and soil quality, minimal land-use conflicts, and mitigation of greenhouse gas emissions (GHG) as they consume carbon dioxide (CO₂) from the atmosphere (Singh and Ahluwalia, 2013).

Among the biofuel production strategies, hydrothermal liquefaction

(HTL) presents an effective pathway for converting microalgae biomass into bio-oil (Couto et al., 2018). A previous life cycle assessment (LCA) study for the cultivation of microalgae using food waste revealed that the drying process produced the highest amount of GHGs, contributing to 10.65 kg carbon dioxide equivalent (CO₂-eq) per kg of biomass powder, more than half of the whole emissions attributed to the total production process (19.68 kg CO₂-eq), highlighting how drying can impact negatively microalgal-based processes (Thielemann et al., 2021). The process at high pressure and temperature conditions can effectively transform wet biomass into bio-oil, avoiding energy-intensive drying processes (Mathimani and Mallick, 2019). However, the HTL process

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