



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
PhD-17 SHORT ABSTRACT OF THESIS

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Thesis Title: **Treatment of Dairy Wastewater using *Monoraphidium* sp. KMC4 and Subsequent Thermochemical Conversion of the Biomass to Biofuels**

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SHORT ABSTRACT

The depletion of fossil fuel reserves, rising environmental pollution, and accelerating climate change have driven the global search for clean and renewable energy alternatives. Bio-oil offers a promising substitute, and microalgae represent an encouraging third-generation feedstock capable of generating biofuel year-round. However, the high cost of microalgal biomass production limits commercial sustainability. Cultivating microalgae in nutrient-rich wastewater such as dairy wastewater enriched with nitrogen, phosphorus, and organic carbon can substantially reduce production costs while delivering bioremediation benefits, and mixotrophic growth further enhances biomass productivity compared with heterotrophic cultivation. This thesis proposes an integrated microalgae-based biorefinery for the concurrent treatment of simulated synthetic dairy wastewater and bio-oil production.

In the upstream stage, *Monoraphidium* sp. KMC4 was cultivated mixotrophically at varying COD concentrations of dairy wastewater. The strain performed best at 50% wastewater strength, achieving a biomass concentration of 1.47 g L⁻¹ and biomass productivity of 122 mg L⁻¹ day⁻¹, with carbohydrate (28.73±1.6 wt%), protein (48.50±1.3 wt%), and lipid (20.29±2.3 wt%) accumulation. The biomass exhibited high volatile matter, a significant heating value, and suitable thermal degradation behaviour, confirming its feasibility as a feedstock for thermochemical conversion.

In downstream processing, hydrothermal liquefaction (HTL) and pyrolysis were investigated. Direct HTL yielded 33.50% bio-oil but with high heteroatom content (N/C 0.05, H/C 1.36, O/C 0.11 mol/mol). Furthermore, a two-stage HTL approach employing mild-temperature pretreatment

for partial deamination and hydrolysis, followed by higher-temperature conversion and showed improvement in bio-oil quality without compromising yield. Also, nitrogen-based compounds decreased from 13.36% in direct HTL bio-oil to 1.98% in two-stage HTL bio-oil, resulting in a 38% reduction in nitrogen, as confirmed by elemental analysis.

To address waste valorisation, co-hydrothermal liquefaction (co-HTL) of microalgae with dairy sludge was performed at three ratios (75:25, 50:50, 25:75). While HTL of dairy sludge alone produced only 18.16% bio-oil but the 75:25 algae-to-sludge ratio yielded 32.94 wt% bio-oil with the highest heating value of 38.24 MJ kg⁻¹. Co-HTL bio-oil exhibited increased H/C and reduced O/C and N/C ratios due to deoxygenation and dehydration, with fewer N-heterocyclics and aromatics, more esters, and improved heavy naphtha and kerosene fractions, demonstrating a clear synergistic effect.

Co-pyrolysis of microalgae and dairy sludge in a fixed-bed reactor produced the highest bio-oil yield at 550 °C, 20 °C min⁻¹, and 60 min. Without a catalyst, co-pyrolysis reduced the yields of nitrogenous and aromatic compounds relative to individual feedstocks. Introducing H-ZSM-5 promoted deoxygenation, decarboxylation, and dehydration, increasing hydrocarbons and esters and reduced cyclic nitrogenated compounds, though at the cost of lower bio-oil yield. The catalyst also decreased vacuum residue, indicating fewer heavy fractions.

Overall, HTL and co-HTL produced higher bio-oil yields and energy densities than co-pyrolysis, while two-stage HTL delivered the best bio-oil quality without yield loss. By simultaneously addressing wastewater pollution, waste-to-energy conversion, and sustainable biofuel production, this integrated microalgae-based biorefinery offers a viable pathway toward resource recovery and renewable bioenergy generation.