



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Process Development for Microalgal Cultivation System Towards Enhancement of CO₂ Fixation and Biochemical Production Efficiency
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SHORT ABSTRACT

Short Abstract of the Thesis is checked for correctness. Recommended for submission.

Microalgae present a promising avenue for CO₂ sequestration and biofuel production due to their rapid growth and high lipid content. However, their commercial viability faces challenges, such as low CO₂ capture efficiency, sensitivity to environmental stresses, and high water and nutrient demands. This thesis aims to overcome these challenges by focusing on strain selection, optimizing cultivation conditions, ensuring CO₂ utilization stability, achieving high biomass productivity, cost-effective harvesting, and water reuse strategies.

Twelve microalgal strains were initially screened for tolerance to industrial flue gas. Growth rates and photosynthetic efficiency were measured to determine their suitability, and promising strains were further cultivated under bicarbonate and high CO₂ conditions. The study identified NCIM5584 and KMC8 as the most resilient, with KMC8 showing superior biomass production (52.5 mg L⁻¹ day⁻¹), CO₂ fixation (346.43 mg L⁻¹ day⁻¹), and lipid accumulation (up to 20%). This strain's ability to thrive under continuous industrial flue gas conditions highlights its potential for large-scale industrial applications. Further experiments with *Micractinium pusillum* KMC8 investigated its adaptability to varying temperature and light intensities, simulating outdoor environments. The strain maintained photosynthetic efficiency and bioenergy content under extreme summer and winter conditions. CO₂ utilization efficiency reached up to 2.03%, with lipid content ranging from 23% to 34%, primarily C-16 and C-18 fatty acids suitable for biodiesel. Adaptation to high light and temperature conditions enhanced biomass quality by regulating carbon-rich metabolites without compromising growth or photosynthesis.

The impact of nitrogen levels, phosphate availability, and light intensity on growth dynamics, CO₂ utilization, and lipid production was also examined. Doubling and quadrupling nitrogen concentrations in the medium increased biomass by 12.5% and 28.78%, respectively. Nitrogen deprivation enhanced lipid content to 26%, though at the cost of reduced CO₂ assimilation. Phosphate availability, combined with incremental light intensities, significantly improved

biomass productivity ($255 \text{ mg L}^{-1} \text{ day}^{-1}$) and lipid yield ($84.76 \text{ mg L}^{-1} \text{ day}^{-1}$), with CO_2 utilization efficiency peaking at 3.3%. A semi-continuous cultivation system with media recycling was tested for long-term productivity. Gradual light feeding and water recycling enhanced CO_2 fixation to $1.1 \text{ g L}^{-1} \text{ day}^{-1}$ and lipid productivity to $150 \text{ mg L}^{-1} \text{ day}^{-1}$. This approach supports sustainable bioenergy development by minimizing resource use and maintaining carbon fixation. The study also tackled CO_2 acidification and saturation challenges that limit microalgal growth. A transition strategy from 15% to 5% CO_2 exposure over 23 days mitigated media acidification, stabilizing photosynthesis and enhancing carbonic anhydrase activity. This resulted in a 20% increase in CO_2 fixation and a 15% boost in biomass productivity. The incorporation of calcium-induced phosphorus feeding promoted auto-flocculation, improving harvesting efficiency. However, performance declined under continuous 15% CO_2 exposure, highlighting the need for further optimization.

This research provides critical insights into engineering scalable microalgal systems for CO_2 sequestration and biofuel production. It demonstrates the potential of optimized bioprocesses to enhance carbon capture, bioenergy yields, and biomass harvesting, advancing sustainable practices in a circular bio-economy framework.

