Nordic Microalgae-Assisted Valorization of Anaerobic Digestion Liquid and Gas Effluents

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Abstract

Anaerobic digestion (AD) is widely applied for the treatment of organic waste, yet dewatering of the AD digestate produces a liquid effluent rich in ammonium and organic pollutants that can pose environmental risks if discharged untreated or add extra load to wastewater treatment systems. In addition, upgrading biogas produced through AD generates a CO_2 stream, which requires appropriate handling to minimize emissions. This study explores the use of microalgae as a sustainable strategy to address both challenges by converting nutrient-rich effluents into valuable biomass while simultaneously enabling CO_2 biofixation.

The project began with a screening phase in which native Nordic microalgal strains, *Chlorella vulgaris*, *Coelastrella* sp., *Chlorococcum* sp., *Scotiellopsis reticulata*, and *Desmodesmus* sp., were assessed for their growth performance and nutrient removal efficiency in AD effluents from chicken manure, pulp and paper sludge, and food waste. This stage identified strains capable of efficiently assimilating volatile fatty acids and ammonium nitrogen. Based on these results, *Coelastrella* sp., *Chlorella vulgaris*, and *Chlorococcum* sp. were selected for further evaluation of total ammonia nitrogen tolerance in AD effluent of municipal sewage sludge under different dilution conditions. Subsequent experiments investigated the effects of light availability and CO_2 sparging on the growth, nitrogen removal and biomass composition of *Chlorella vulgaris* and *Chlorococcum* sp. While CO_2 supplementation enhanced biomass accumulation and fatty acid production, higher nitrogen removal was achieved under conditions without CO_2 sparging. The final stage, cultivations was scaled up in 4.5 L reactors to assess *Chlorococcum* sp. performance under different CO_2 concentration (0.04, 3, 6, and 9%) and bioreactor configurations. Aeration with 6% CO_2 yielded the highest biomass production and was selected for the comparison of the effect of reactor design (bubble column bioreactors, airlift bioreactors, and bubble column bioreactors containing carriers). Bubble column bioreactors showed superior nutrient removal efficiency, whereas airlift bioreactors supported faster cell growth.

Overall, this thesis demonstrates that native Nordic microalgae offer strong potential for the treatment of AD effluents while simultaneously utilizing CO_2 through biofixation. The findings provide a foundation for integrating microalgal cultivation into waste management systems, mitigating environmental impact while generating valuable biomass with potential for applications such as biofertilizers, biochar, biodiesel and bioplastics production.

Keywords: anaerobic digestion effluent, Nordic microalgae, nitrogen removal, light:dark cycle, CO_2 concentration, reactor configuration