



Pilot-Scale cultivation of microalgae in blended effluents: C/N ratio management to boost biomass and biofuel precursors

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ABSTRACT

Algal biotechnology offers a sustainable pathway for wastewater treatment and resource recovery. However, the low carbon-to-nitrogen (C/N) ratio in domestic wastewater often limits microalgal productivity, which may compromise process viability and, consequently, limit its application in bioproduct valorization routes. This study evaluated the effects of blending municipal wastewater (MW) with industrial wastewater from juice processing (IWJ) at different ratios on biomass production, biochemical composition, and pollutant removal. Pilot-scale experiments in outdoor high-rate algal ponds, operated without external carbon dioxide (CO₂) supply (relying on inorganic carbon present in the wastewater and passive diffusion from air). These experiments tested three blends: T1 (60 % MW + 40 % IWJ, C/N 9.25), T2 (40 % MW + 60 % IWJ, C/N 25.31), and T3 (20 % MW + 80 % IWJ, C/N 52.71). T1 achieved the highest biomass productivity and lipid content (14.44 %, $p < 0.05$), while T3 presented the highest levels of saturated fatty acids C16:0 (40.39 %) and C18:0 (10.08 %), supporting its biodiesel potential. Carbohydrate accumulation was enhanced in T2 (18.44 %) and T3 (21.09 %) under nitrogen-limited conditions. Microalgal species composition varied significantly with the C/N ratio, indicating selective adaptation. Additionally, dissolved organic carbon removal followed first-order kinetics across treatments, confirming model applicability. These findings underscore the effectiveness of effluent blending and C/N adjustment to enhance biomass quality, pollutant removal, and suitability for biofuel production in integrated algal-based wastewater treatment systems.

1. Introduction

Microalgae biomass (MB) production is considered a promising alternative for generating biofuels and high-value-added products, owing to its rapid growth and high efficiency in converting sunlight and nutrients [1–3]. In addition, cultivating microalgae provides

environmental benefits by treating wastewater, since microalgal systems can remove nutrients and other contaminants while simultaneously generating biomass [4,5]. However, the large-scale application of this technology faces significant challenges. One of the main obstacles is the variability in the characteristics of the effluents, including factors such as pH, presence of toxic substances, and emerging pollutants such as

Abbreviations: C, Carbon; CO₂, Carbon Dioxide; COD, Chemical Oxygen Demand; DO, Dissolved Oxygen; EC, Electrical Conductivity; FAME, Fatty Acid Methyl Esters; HRAPs, High-rate algal ponds; IC, Inorganic Carbon; IWJ, Industrial Wastewater from Juice Processing; MB, Microalgae Biomass; MUFA, Monounsaturated Fatty Acid; MW, Municipal Wastewater; N, Nitrogen; NH₃, Ammonia; NH₄⁺ - N, Nitrate, AmmoniumNO₃ - N; N_{org}, Organic Nitrogen; PUFA, Polyunsaturated Fatty Acid; SP, Soluble phosphorus; TC, Total Carbon; TKN, Total kjeldahl nitrogen; TOC, Total Organic Carbon; UASB, Upflow Anaerobic Sludge Blanket; VSS, Volatile Suspended Solids.

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