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Optimizing Microalgae Cultivation for Wastewater Phytoremediation and Biodiesel Production

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In recent years, with the growth of the population and the increase in the rate of agricultural and industrial activities, the amount of water consumption has increased. This has caused problems due to the lack of freshwater sources and the large volume of produced wastewater[1]. Therefore, to solve this problem, extensive studies have been conducted on using different wastewater treatment systems to recycle the resulting effluent for non-sanitary and industrial applications[1]. Unfortunately, many conventional wastewater treatment technologies relying on physical and chemical processes are not cost-effective, primarily due to their high expenses[2].

Recently, scientists globally have turned their attention to the innovative use of living microorganisms to improve various processes, particularly wastewater treatment[2]. Among these microorganisms, microalgae have shown significant promise due to their exceptional capacity to eliminate a variety of contaminants, including nitrogen, phosphorus, and toxic metals, from different wastewater sources[3].

Microalgae encompass a diverse group of microorganisms derived from plant species that can thrive in environments rich in organic matter, nitrogen, and phosphorus[4,5]. Consequently, due to the high availability and accessibility of these nutrients in wastewater, this medium can serve as a cost-effective source of nutrients for cultivating microalgae[6,7]. Reports have shown that microalgae synthesis effectively removes dissolved heavy metals such as chromium and cadmium by producing metal-chelating exopolysaccharides in conditions of high metal concentration[5]. In conventional wastewater treatment plants, large volumes of sludge are produced as byproducts, necessitating costly treatment and disposal. Therefore, cultivating microalgae in wastewater as part of an engineering system provides biomass with high economic value instead of generating sludge[4].

Given that fossil fuel sources are non-renewable, depleting, and contribute to pollution and global warming, developing sustainable and environmentally friendly energy sources is essential to support modern societies[8]. One promising energy source is bioenergy, which includes biomethane, bioethanol, biobutanol, and biodiesel produced from photosynthetic organisms.

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Bioenergy has several advantages compared to petroleum diesel, being primarily renewable, biodegradable, low in toxicity, and free of sulfur and aromatic compounds[9].

Microalgae typically consist of a diverse range of macromolecules, including carbohydrates (approximately 12% to 30% of their composition), lipids (4% to 20%), and proteins (30% to 70%), with variations depending on the specific species of microalgae. These intricate biological structures play a crucial role in the physiology and metabolism of microalgae, influencing their growth, nutritional content, and applications[10]. Many microalgae species achieve higher lipid productivity than traditional crops, making them potential substrates for biodiesel fuel production[5,11]. Additionally, these organisms can stabilize CO2 in the environment by using it as a carbon source for growth and reproduction. Therefore, biofuel production from microalgae is a promising alternative to conventional technologies[12].

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