Chapter 11
Plasma-Enhanced Microalgal Cultivation:
A Sustainable Approach for Biofuel and Biomass Production

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ABSTRACT

Plasma-supported biochemical reactions have emerged as a promising and environmentally friendly approach for synthesizing microalgae-based biofuels. Microalgae, as single-celled organisms, possess the unique capability of efficiently converting sunlight into organic matter through photosynthesis, positioning them as potential green energy sources for biofuel and biomass production. However, traditional microalgae cultivation methods encounter challenges concerning environmental and economic sustainability, primarily due to their high water and fertilizer consumption. In this context, plasma technology has emerged as a powerful tool supporting biochemical reactions and optimizing microalgae cultivation processes, offering a greener and more sustainable alternative for biomass and biofuel production. This chapter explores the transformative potential of plasma-supported biochemical reactions in microalgal biofuel synthesis. It aims to provide insights into the intricate mechanisms underlying this innovative technology and its implications for the renewable energy landscape.

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INTROCUTION

The contemporary energy paradigm is at a crucial inflection point, necessitating a decisive shift away from conventional fossil-based energy sources. Evidence presented by the Intergovernmental Panel on Climate Change accentuates this imperative, highlighting an alarming elevation of global temperatures by approximately 1.2 °C beyond pre-industrial benchmarks. Such climatic perturbations are not merely environmental challenges but also bear significant socio-economic ramifications. Simultaneously, forecasts by organizations such as the World Energy Council underscore the looming exhaustion of fossil fuel reserves, emphasizing the need for sustainable alternatives to ensure long-term energy security (Intergovernmental Panel on Climate Change, 2023). Within this context, biofuels have crystallized as a beacon of hope. Their inherent renewability and potential for carbon neutrality make them an attractive alternative. Among the myriad biofuel sources, microalgae have ascended as an area of significant research and industrial focus. They also algae an important role in biotechnology like the removal of harmful dyes. Distinct advantages set microalgae apart from their terrestrial counterparts: they eschew competition with food crops for cultivable land, demonstrate adaptability to various water conditions, and, crucially, possess an innate ability for enhanced lipid biosynthesis. Empirical evidence suggests that select microalgae strains can dedicate up to 60% of their dry weight to lipid accumulation, a feat unparalleled by conventional biofuel crops such as soybean or palm (Adeniyi et al., 2018; Zariç et al., 2022). However, the path to microalgae's prominence in biofuel production is fraught with challenges. The traditional methodologies employed in microalgal cultivation and extraction are often resource-intensive, limiting scalability and raising concerns about ecological impact. To navigate these complexities and unlock the latent potential of microalgae, innovative technological solutions are imperative. Enter plasma technology—a domain traditionally revered in fields ranging from electronics to medical sterilization. Its foray into the realm of biotechnology, particularly in enhancing microalgal productivity, is a testament to the versatility and promise of plasma applications. The convergence of plasma physics with biotechnological objectives introduces a novel approach to microalgal cultivation, potentially revolutionizing biomass and biofuel yields (Suparmaniam et al., 2019). This discourse is committed to providing an exhaustive analysis of plasma-assisted microalgal cultivation. It delves into the underlying principles, elucidates the multifaceted advantages, and critically examines the challenges inherent to this interdisciplinary domain. Through this exploration, we endeavor to accentuate the role of plasma-enhanced methodologies in charting a sustainable trajectory for biofuel and biomass production in the 21st century.

Microalgae: An Unparalleled Potential in Biofuel Synthesis

Microalgae represent a heterogeneous assemblage of unicellular photosynthetic entities, revered not just for their taxonomic diversity but also for their myriad biochemical attributes conducive to biofuel production. These organisms are characterized by rapid growth kinetics, an ability to accrue lipids at significant concentrations, and a resilience to thrive across ecological niches. Empirical research underscores the prodigious lipid productivity of certain microalgal strains. Comparative analyses reveal that these strains can manifest lipid yields that surpass terrestrial oilseed crops such as soy or palm by a factor of up to 30 when assessed on a per unit area basis (Brutyan, 2017). Microalgae's ecological adaptability further accentuates this prodigious lipid yield. Their capacity to flourish in habitats unsuitable for conventional agriculture—non-arable terrains or water bodies with heightened salinity or nutrient content—bestows them a unique advantage. Such adaptability eliminates competition with food crops and facilitates the

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