



Modulating microalgal metabolism and its integration into dark fermentation: Challenges and opportunities with wastewater-grown biomass

Jéssica Ferreira^{a,*}, Thiago Abrantes Silva^a, Alexia Saleme Aona de Paula Pereira^a, Alberto Jose Delgado dos Reis^b, Marcelo Zaiat^c, Maria Lúcia Calijuri^a

^a Civil Engineering Department, Federal University of Viçosa, W/N PH Rolfs Ave, University Campus, Viçosa, MG 36570-900, Brazil

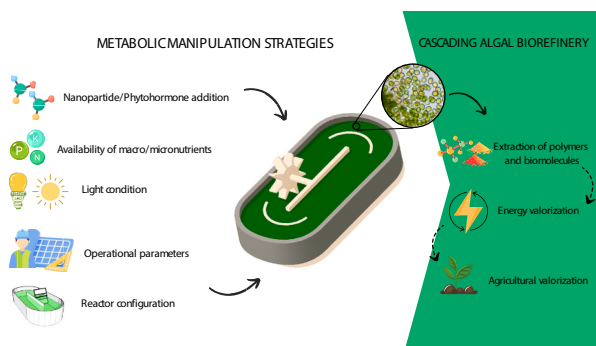
^b Bioenergy and Biorefineries Unit, National Laboratory of Energy and Geology (UBB/LNEG), Lisbon, Portugal

^c Biological Processes Laboratory, São Carlos School of Engineering, University of São Paulo, 1100 João Dagnone Ave, Santa Angelina, São Carlos, SP 13563-120, Brazil

HIGHLIGHTS

- Nutrient availability is the primary factor influencing metabolite accumulation.
- Abiotic stress is easier to apply during microalgae growth in wastewater.
- Two-stage cultivation improves bioremediation and microalgae metabolite production.
- Biomass pretreatment combined with co-fermentation optimizes H₂ production.
- Nanoparticle use in DF of microalgae is promising and needs further investigations.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:

Microalgae valorization
Biomass composition
Cultivation strategies
Biohydrogen
Wastewater treatment
Two-stage cultivation

ABSTRACT

Microalgae represent a promising feedstock for the sustainable production of bioproducts and bioenergy, due to their versatile biochemical composition and environmental adaptability. Given the wide range of bioproducts that can be derived from their biomass, its biochemical composition suggests more favorable conversion routes and can be enhanced through cultivation conditions focused on the synthesis of one (or more) metabolites of interest to the biotechnology market. Accordingly, this review focuses on approaches for modulating microalgal metabolism, such as nutrient depletion and reactor configuration characteristics, among others, as well as on key outcomes obtained through two-stage cultivation, which combine phases of high biomass and metabolite productivity. From a resource recovery perspective, emphasis was placed on approaches that are more readily applicable to wastewater treatment plants. Furthermore, as energy-oriented routes are more suitable for valorizing of biomass grown in wastewater and considering that biohydrogen has been shown to be an emerging product of scientific relevance, this review also analyzes the limitations and strategies for integrating its production via dark fermentation. Pretreatment techniques and co-fermentation approaches were discussed as

* Corresponding author.

E-mail addresses: jessica.f.ferreira@ufv.br (J. Ferreira), thiago.abrantes@ufv.br (T.A. Silva), alexia.pereira@ufv.br (A.S.A.P. Pereira), alberto.reis@lneg.pt (A.J.D. Reis), zaiat@sc.usp.br (M. Zaiat), calijuri@ufv.br (M.L. Calijuri).

<https://doi.org/10.1016/j.scitotenv.2025.180546>

Received 9 May 2025; Received in revised form 16 September 2025; Accepted 17 September 2025

Available online 24 September 2025

0048-9697/© 2025 Elsevier B.V. All rights are reserved, including those for text and data mining, AI training, and similar technologies.