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Microalgae-mediated brewery wastewater treatment: effect of dilution rate on nutrient removal rates, biomass biochemical composition, and cell physiology

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Abstract

Microalgae have been used to remove nitrogen, phosphorus, and chemical oxygen demand (COD) from brewery wastewater (BWW). The microalga *Scenedesmus obliquus* was grown on BWW, using bubble column photobioreactors that operated under batch and continuous regimes. For the first time, the cell physiological status cell membrane integrity and enzymatic activity was monitored during the microalgae based BWW treatment, using flow cytometry. All the cultivations batch and continuous displayed a proportion of cells with intact membrane > 87%, although the continuous cultivations displayed a lower proportion of cells with enzymatic activity (20–40%) than the batch cultivations (97%). The dilution rate of 0.26 day^{-1} was the most favorable condition, since the microalgae cultivation attained the maximum biomass productivity (0.2 g ash-free dry weight day^{-1}) and the total nitrogen and COD removal rates were the highest (97 and 74%, respectively), while the phosphorous removal rate was the third (23%).

Keywords Brewery wastewater treatment · *Scenedesmus obliquus* · Flow cytometry · Continuous cultivations · Dilution rate

Introduction

The high organic load of effluents originated from different industries, namely those from the agro-food industries, is a major global environmental problem. The treatment of wastewater by municipal treatment plants represents a very significant cost to brewery operators. There are several technologies associated with the treatment of effluents derived from the agro-food industries, such as physical, chemical, or biological, to remove the organic and inorganic nutrients, such as nitrogen ammonia or nitrate, and phosphorus, as is the case of high rate ponds (Raposo et al. 2010; Mata et al. 2012).

Effluents derived from the brewery sectors are rich in organic compounds, such as sugars, soluble starch, proteins, phosphates, ammonia, ethanol, and/or nitrate which are easily biodegradable. Bioremediation of such compounds using microalgae has proven to be proficient and economic method of wastewater treatment due to their adaptability of growing in various wastewater streams and also useful in the process of carbon dioxide fixation (Doria et al. 2012; Mata et al. 2014a, b; Jia et al. 2016).

By removing nitrogen, phosphorus, and carbon from water, microalgae can help reducing eutrophication in the aquatic environment (Ruiz et al. 2011; Olguín 2003) and, are unique in sequestering carbon dioxide, one of the main contributors to the greenhouse effect. Moreover, microalgae can grow rapidly and in inhospitable conditions, using water unfit for human consumption and in land not appropriate for food production (Mata et al. 2010). Indeed microalgae have already been applied for effluent treatment to remove nitrogen, phosphorus, and chemical oxygen demand (COD), from different types of effluents, including BWW (Batista et al. 2015; Gouveia et al. 2016; Barata et al. 2017). Moreover, this technology has the competence of producing high added value products such as proteins and lipids, and biofuels as an alternative energy resource in the form of biodiesel, bioethanol, biohydrogen, and biogas (Batista et al. 2015; Umamaheswari and Shanthakumar 2016).

BWW may contain low levels anti-microbial compounds added to kill bacteria known as "biocides," depending on what cleaners and other materials the brewery uses. Therefore, it is crucial to monitor the microalgal cells physiological status during the BWW treatment, as a high number of dormant or

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