

# WASTEWATER TERTIARY TREATMENT AND CARBON DIOXIDE REMOVAL USING THE MICROALGA *Botryococcus braunii*

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## Abstract

Urban wastewaters, from conventional secondary treatment, are rich in nitrogen, phosphorous and other nutrients. The elimination of these chemical elements, if it takes place, is carried out by means of tertiary treatment. This work is intended to develop an alternative tertiary treatment system using microalgae *Botryococcus braunii*, in which water depuration and carbon dioxide removal happen simultaneously, and hydrocarbons and lipids are produced from the grown biomass. The experiments were made in batch photobioreactors (stirred tank type) on a laboratory scale. The operating conditions were: culture pH of 8.0, temperature 298.15 K, and under a light-dark cycle (12 h illumination per day). Light intensity inside the photobioreactors at the end of the cultures, has been higher than  $0.077 \mu\text{E cm}^{-2} \text{ s}^{-1}$  (wet). The air supply volume was 0.5 v/v/min and the composition of gas phase (Air/CO<sub>2</sub>) was modified using 0.0, 0.5, 1.0, 1.5, 2.0 and 5.0% CO<sub>2</sub>/Air. From the experimental results, the following kinetic parameters were determined: maximum specific growth rate,  $\mu_m$ , and biomass productivity,  $P_b$ . The obtained results show the possibility of using the wastewater (proceeding from secondary treatment) as culture medium for algae and simultaneously to remove nitrates, phosphates, ammonia, sulphate and phenols contents in urban wastewater. *B. braunii* was able to grow well in secondarily treated sewage (STS), the higher values of  $\mu_m(\text{STS})=0.16 \text{ d}^{-1}$ , and  $P_b(\text{STS}) = 0.038 \text{ kg m}^{-3} \text{ d}^{-1}$  when the composition of gas phase was 0.5 % CO<sub>2</sub>/Air, were found. The highest total lipids percentages (44.5%) and total hydrocarbons percentages (26.2%) are determined in cultures using CO<sub>2</sub>-enriched air at a percentage of 0.5% and 1.5% CO<sub>2</sub>/Air respectively.

**Keywords:** Wastewater treatment, Microalgae, *Botryococcus braunii*, Carbon dioxide removal, hydrocarbons, lipids.

## Introduction

Wastewater treatment by microalgal culture has several major advantages: it rests on the principles of natural ecosystems and is therefore not environmentally hazardous; it causes no secondary pollution, as long as the biomass produced is reused, and it allows efficient recycling of nutrients (Martínez *et al*, 2000).

Algae, particularly green unicellular microalgae have been proposed for a long time as a potential renewable fuel source. Microalgae have the potential to generate significant quantities of biomass and oil suitable for conversion to biodiesel. Microalgae have been estimated to have higher biomass productivity than plant crops in terms of land area required for cultivation, are predicted to have lower cost per yield, and have the potential to reduce greenhouse gas emissions through the replacement of fossil fuels.

The green alga *Botryococcus braunii* has an unusually high hydrocarbon content, ranging from 15 to 75% of dry weight, as long-chain unsaturated hydrocarbons (Metzger and Largeau, 2005). This microalga is, therefore, a potentially good renewable source of chemical feedstock or fuel (Jin-Young *et al*/2003).

Many species of microalgae are able to effectively grow in wastewater conditions through their ability to use abundant organic carbon and inorganic N and P compounds in the wastewater. A major requirement of wastewater treatment is the need to remove high concentrations of nutrients in particular N and P, which otherwise can lead to risks of eutrophication if these nutrients accumulate in rivers and lakes. Microalgae are efficient in removing N, P and toxic metals from wastewater and therefore have potential to play an important remediation role particularly during the tertiary treatment of wastewater (Pittman *et al*, 2011).

## Methods

The microalga *Botryococcus braunii* (race A) was grown on batch photobioreactors (stirred tank type) on a laboratory scale (mean volume 500 cm<sup>3</sup>). The pH at the beginning of cultures was adjusted at 7.5, temperature of 298.15 K and under a light-dark cycle 12 h light /12 h dark using fluorescent illumination. Light intensity inside the photobioreactors at the end of the cultures, has been higher than 0.077  $\mu\text{E cm}^{-2} \text{s}^{-1}$  (wet). The air supply volume was 0.5 v/v/min and the composition of gas phase (Air/CO<sub>2</sub>) was modified using 0.0, 0.5, 1.0, 1.5, 2.0 and 5.0% CO<sub>2</sub>/Air. Culture medium was sterilized secondarily treated urban wastewater.

The evolution over time of each growth experiment was monitored determining biomass concentration, by measuring optical density of culture suspension at 600 nm. Also, total chlorophylls and carotenoids were determined. At the end of each culture, the microalgal biomass was separated from liquid medium, biomass hydrocarbon and fatty-acid contents were determined and identified using gas chromatography coupled mass spectrometry.

Secondarily treated urban wastewater was characterized before each experiment determining physical parameters like pH, conductivity, turbidity, total solids and chemical parameters using several specific analysis kits, COD, BOD<sub>5</sub>, total carbon, total organic carbon, inorganic carbon, nitrates, nitrites, ammonium, sulphates, phosphates, phenols, copper, manganese and zinc.

## Results

In all experiments performed with urban wastewater periods of adaptation were detected (lag phase). From the growth curves, the duration of the exponential phase was established and the maximum specific growth rate for each of the experiment performed was calculated. The values of  $\mu_m$  were obtained by least squares adjustment of experimental values of  $\ln(x/x_0)$  versus time  $[\ln(x/x_0) = a + \mu_m t]$ . In those cultures in which the biomass increased linearly (after the exponential phase) cell growth was quantified through biomass productivity ( $P_b$ ,  $\text{mg dm}^{-3} \text{d}^{-1}$ ). Representations of the experimental biomass concentration versus time results allowed the determination of parameter  $P_b$  by least square adjustments to the equation  $(x = a + P_b t)$ . These results, together with the values of  $\mu_m$ , are shown in Figure 1.

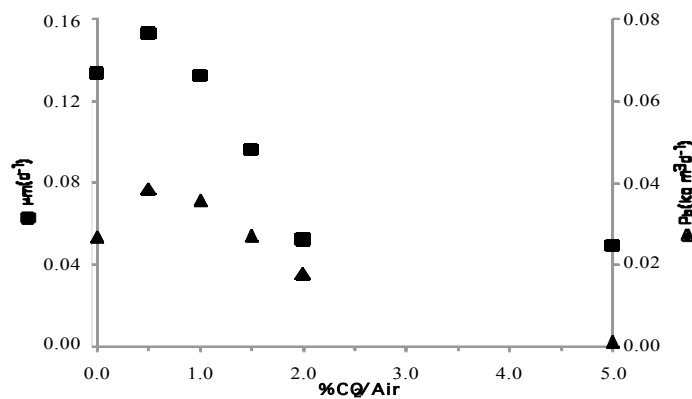


Fig. 1. Effect of gas phase composition on kinetic parameters in cultures using wastewater as culture medium

The results obtained in the characterization of urban wastewater from secondary treatment which include physical and chemical parameters are in Table 1. The biochemical composition of the biomass as a percentage referred to dry weight biomass is shown in Figure 2.

Table 1. Secondarily treated wastewater characterization

Parameter	Value	Parameter	$\text{mg dm}^{-3}$
pH	7.6	Nitrate	15.3
Conductivity	978 $\text{mS cm}^{-1}$	Nitrite	0.30
Turbidity	3.97 FTU	Ammonium	15.0
Total solids	0.06 %	Sulphate	92.0
CDO	49.7 $\text{mg O}_2 \text{dm}^{-3}$	Phosphate	11.5
BOD <sub>5</sub>	16.0 $\text{mg O}_2 \text{dm}^{-3}$	Phenol	0.41
Total Carbon	39.2 $\text{mg C dm}^{-3}$	Copper	< 0.05
Total Organic Carbon	1.2 $\text{mg C dm}^{-3}$	Manganese	< 0.5
Inorganic Carbon	38.0 $\text{mg C dm}^{-3}$	Zinc	< 0.05

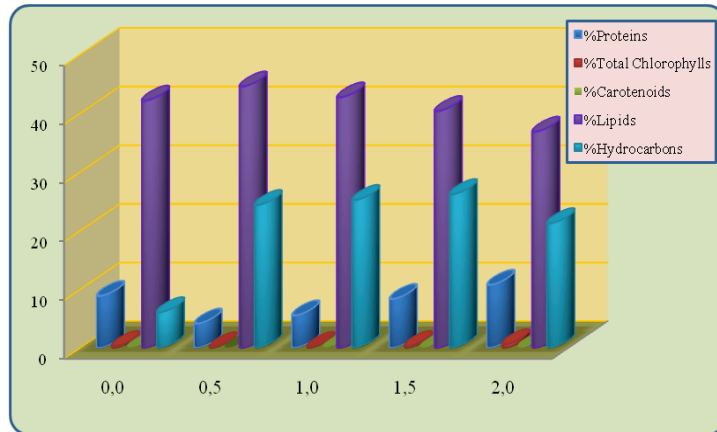


Fig. 2. Biochemical composition of the biomass. Effect of gas phase composition in cultures using wastewater as culture medium

## Conclusions

The urban wastewater from the secondary treatment is an appropriate culture medium for *B. braunii*, being convenient to use enriched air with carbon dioxide by 0.5 % (CO<sub>2</sub>/Air) to maximize the production of lipids (44.48%) and obtain the highest values of maximum specific growth rate ( $\mu_m$ ) and biomass productivity ( $P_b$ ). The use of a mixture richer in carbon dioxide, at 1.5% (CO<sub>2</sub>/Air), seems to lead to a higher percentage of hydrocarbons (26.15 %).

## References

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