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BIOENERGY AND BIOFUELS

Bioethanol production from *Scenedesmus obliquus* sugars: the influence of photobioreactors and culture conditions on biomass production

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Abstract A closed-loop vertical tubular photobioreactor (PBR), specially designed to operate under conditions of scarce flat land availability and irregular solar irradiance conditions, was used to study the potential of *Scenedesmus obliquus* biomass/sugar production. The results obtained were compared to those from an open-raceway pond and a closed-bubble column. The influence of the type of light source and the regime (natural vs artificial and continuous vs light/dark cycles) on the growth of the microalga and the extent of the sugar accumulation was studied in both PBRs. The best type of reactor studied was a closed-loop PBR illuminated with natural light/dark cycles. In all the cases, the relationship between the nitrate depletion and the sugar accumulation was observed. The microalga *Scenedesmus* was cultivated for 53 days in a raceway pond (4,500 L) and accumulated a maximum sugar content of 29 % g/g. It was pre-treated for carrying out ethanol fermentation assays, and the highest ethanol concentration obtained in the hydrolysate fermented by *Kluyveromyces marxianus* was 11.7 g/L.

Keywords *Scenedesmus obliquus* · Photobioreactors · Light · Sugars · Bioethanol

Introduction

The promotion of ethanol use as a fuel in the last decades has been mostly driven by environmental concerns, oil prices and depletion of oil reserves as well as to reduce the dependency on oil. Microalgal biomass as a feedstock for bioethanol production seems to be a good alternative to sugar crops as it does not compete with food supplies, water or arable lands and has a very short harvesting cycle.

Bioethanol, an already well-established fuel mainly in Brazil and the USA (Goldemberg 2007), is usually obtained by alcoholic fermentation from starch (cereal grains, such as corn or wheat), sugar (sweet sorghum, sugar cane and sugar beet) and lignocellulosic feedstocks (Antolin et al. 2002).

Starch processing is a mature industry and commercial enzymes required for starch hydrolysis are widely used and available at low cost. The glucose released is readily metabolized by different strains of yeasts or bacteria, among which are *Saccharomyces cerevisiae*, the most common organism used for ethanol production, and *Zymomonas mobilis*, respectively (Drapcho et al. 2008). The ethanol is then extracted from the mixture and purified by distillation and dehydration.

Bioethanol from microalgal biomass can be produced through two distinct pathways: direct dark fermentation or yeast fermentation of saccharified biomass. The dark fermentation of microalgae consists of the anaerobic production of bioethanol by the microalgae itself through the consumption of intracellular starch. In spite of being a low-energy intensive process, the yields reported were 1 % g/g for *Chlamydomonas reinhardii* (Hirano et al. 1997) strain and 2.07 % g/g for *Chlorococcum littorale* (Ueno et al. 1998), values that do not make this process appealing to the industry.

The yeast fermentation process is very well-established industrially and a low-energy intensive process. Using algae raw material is strongly advantageous as algae sugars are not only obtained from intracellular starch but also from cell wall. Nevertheless, to achieve higher yields, it is still necessary to screen for high starch producing algae strains and to identify mechanisms and culture conditions for inducing the accumulation of intracellular starch.

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