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Scenedesmus obliquus as feedstock for biohydrogen production by *Enterobacter aerogenes* and *Clostridium butyricum*

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HIGHLIGHTS

- Biohydrogen is produced from *Scenedesmus obliquus* biomass.
- *Enterobacter aerogenes* and *Clostridium butyricum* are used to ferment dried and wet microalgal biomass.
- *E. aerogenes* produces 57.6 mL H_2/g VS from 2.5 g/L microalgal biomass (wet).
- *C. butyricum* produces 113.1 mL H_2/g VS from 50 g/L microalgal biomass (dried).

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ABSTRACT

Hydrogen (H_2) gas is seen as an ideal future energy carrier because it is easily converted into electricity in fuel cells, liberates a large amount of energy per unit mass, and generates no air pollutants. In this work, biological hydrogen (bioH_2) was produced from the microalgal biomass of *Scenedesmus obliquus* which was used as a substrate for the fermentation by *Enterobacter aerogenes* ATCC 13048 and *Clostridium butyricum* DSM 10702. The bioH_2 produced by each strain was assessed for different *S. obliquus* biomass concentrations, using both dried (5% moisture) and "wet" (69% moisture) biomass. The highest bioH_2 production yields obtained were 57.6 mL H_2/g VS_{alga} from 2.5 g_{alga}/L by *E. aerogenes* and 113.1 mL H_2/g VS_{alga} from 50.0 g_{alga}/L by *C. butyricum*. The bioH_2 production rates, and biogas purity attained by using the wet biomass as a fermentation substrate were similar or higher than those obtained with the dried microalga. This means that the drying step is not needed and therefore saves considerable energy as this is one of the highest energy demanding stages when using this feedstock in fermentations for biofuels production.

1. Introduction

Renewable, sustainable and carbon–neutral energy production is needed to fulfil the growing energy demand and consequential climate changes. Hydrogen (H_2) is an ideal future energy carrier which has technical, socio-economic and environmental benefits. It has the highest energy content per unit weight of any known fuel (142 kJ/g) [1]. It can also be transported for domestic/industrial consumption through conventional means and is easily converted into electricity in fuel cells, generating no air pollutants. H_2 is therefore being explored to be used in combustion engines and fuel-cell electric vehicles and it is expected that its demand increases significantly in the near future [2].

H_2 can be produced through a number of conversion technologies such as thermochemical technologies (e.g. gasification, steam reforming of methane, partial oxidation of oil), water electrolysis and photolysis [3], and using a variety of, either fossil (e.g. coal) or renewable (e.g. biomass) feedstock. H_2 can also be produced through biological conversion by photosynthesis, photo-heterotrophic, and dark fermentation [4]. There is an increased interest in biological hydrogen (bioH_2) production due to the fact that traditional ways of producing H_2 are still costly and display a negative environmental impact. The photosynthetic production of bioH_2 is based on the uptake of carbon dioxide and water by photosynthetic organisms. Its major drawback is the need for a constant light source to supply the reactor [5] and the fact that low yields are obtained [6]. The photo-heterotrophic fermentation is based on a similar process to anaerobic digestion however it is performed by photo-fermentative bacteria which also need light. The process of dark fermentation to produce bioH_2 requires carbohydrate-rich substrates and fermentative bacteria [6,7].

In recent years, bioH_2 production through dark fermentation has received increased attention due to its many advantages, such as the high hydrogen production rates, the potential to convert biomass or bio-wastes into hydrogen, and the feasibility of the effective process design and control [8]. During dark fermentation,

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