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Optimizing a composite bioactive membrane (CBMem) for enhanced $BioH_2$ production and capture from industrial wastewater

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Introduction

Wastewater has been used for decades as a renewable and reliable source of bioenergy. Biohydrogen ($bioH_2$) is a zero-emission biofuel derived from waste fermentation processes. Acidogenic bacteria in particular, play an important role in the fermentative $bioH_2$ production. However, stringent pH control, high H_2 partial pressure, nutrient availability, and microbial competition, are often limiting factors that affect the deployment of acidogenic reactors (Hawkes et al., 2002). To overcome these problems, a novel approach to on-site $bioH_2$ production and capture from wastewater is reported in this study. Hollow fiber (HF) membranes were functionalized using encapsulated acidogenic bacteria to produce a composite bioactive membrane module. While the encapsulation matrix provided a robust platform for acidogenic growth, the produced $bioH_2$ was continuously removed and collected in the hollow fibers for further uses. To our knowledge, there are not reported technologies in literature that allow both efficient production and on-site capture of $bioH_2$ from wastewater.

Methods and Results

The seed culture was obtained by heat-treating a sample of municipal anaerobic sludge at 95 ºC for 40 minutes. Synthetic wastewater was prepared as described in Klatt and LaPara (2003) and modified to a COD content of 6377.3±652.7. The reactor was fed with a peristaltic pump and the HRT was 18 hours. Average liquid temperature was 22ºC. Gas composition was analyzed for hydrogen (H_2) using a gas chromatography (GC-TCD) unit.

The membrane consists on a support/gas transfer layer and a bioactive layer. The support layer is a microporous polyethylene hollow fiber (HF) membrane fabric with a mean pore size of 0.03 µm (pore length 0.2 um), 40% porosity, and active length of 10 cm. HF had an OD of 300 um and 30 um thickness. Five construction methods and combinations of materials were used before defining a successful recipe for the CBMem (Firgure 1). The membrane module produced a maximum of 48.4±9.4 mL H2 g−1 hexose (0.36 ± 0.07 mol H2 mol−1 hexose) and 86±9% of the total H2 produced in the bioreactor was captured by

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the membrane. Additionally, the module was tested with sugar beet wastewater and dairy production wastewater, resulting in yields and capture efficiencies of 19.2 ± 3.0 mL H2 g−1 hexose (0.14 ± 0.02 mol H2 mol−1 hexose) and 99.1 ± 0.2%, and 46.0 ± 15.5 mL H2 g−1 hexose (0.34 ± 0.12 mol H2 mol−1 hexose) and 79 ± 19%; respectively. These results place the CBMem technology in a competitive place compared to other studies that use industrial wastes for H2 production (e.g., noddle and sugar beet production wastewater) and show yields ranging from 45–92 mL H2 g−1 (Table 1) (Prieto et al., 2016).

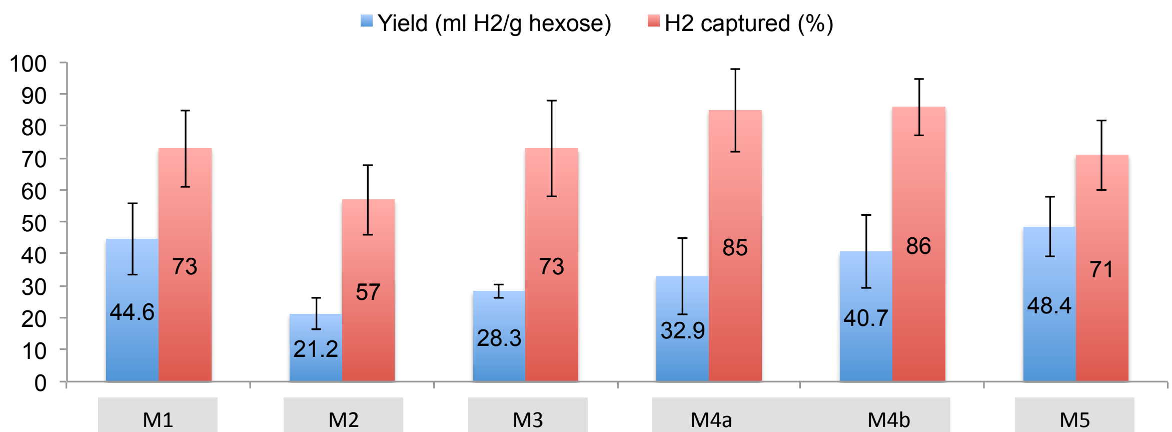

Figure 1: H_2 yields and H_2 captured efficiencies obtained from different membrane modules tested by Prieto et al., 2016. Construction methods and composition of the membrane modules are indicated in the x-axis. M1= PVA + HF, M2= e-spun + HF, M3= e-spun + HF + silica coat, M4a= HF + 1x(PDA + cell coat) + silica gel seal, M4b= HF + 2x(PDA + cell coat) + silica gel seal, and M5= HF + 2x(PDA + cell coat) + PVA seal (Prieto et al., 2016).

Table 1: Comparison of H2 yields at 22 °C. SS indicates sewage sludge, ADS indicates anaerobic digestion sludge, and gs indicates reactors using gas stripping. M5 corresponds to the CBMem materials selected for this study (Prieto et al., 2016).

Carbohydrate substrate	Seed type	Reactor type	Temp (°C)	Yield (mL H_2 g^{-1} hexose)	Estimated yield at 22 °C	Ref.
Glucose	SS	CSTR	36	260	72	32
Sucrose	ADS	CSTR	35	148	45	33
Wheat starch	ADS	CSTR-gs	35	254	77	34
Noodle mfg waste	ADS	CSTR	35	200	61	35
Sugar beet wastewater	ADS	CSTR-gs	32	231	92	36
High strength sewage surrogate	ADS	CSTR	22	48.4	—	This study – M5
Dairy production wastewater	Acclimated ADS	CSTR	22	46.0	—	This study – M5
Sugar beet wastewater	Acclimated ADS	CSTR	22	19.1	—	This study – M5

The composite bioactive membrane proved to be efficient in producing and capturing H_2 from wastewater. This novel approach can potentially overcome many of the problems previously encountered in fermentative H_2 producing reactors. Furthermore, the collected off gas (1.0±0.2% H_2 by volume) can be readily available for on-site energy generation (e.g., combined heat and power), use in fuel cells, or concentration for industrial use and storage.

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