Coupling of microbial electrolysis cells and dark fermentation to enhance the production of hydrogen from agro-industrial wastewaters

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COUPLING OF MICROBIAL ELECTROLYSIS CELLS AND DARK FERMENTATION TO ENHANCE THE PRODUCTION OF BIOHYDROGEN FROM AGRO-INDUSTRIAL WASTEWATERS

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***Abstract* - The aim of this work is the development of a feasible, cascade two-step BioH2 production process from Organic Wastewater (WW), combining dark fermentation (DF) and Microbial Electrolysis Cells (MECs). Such coupling of DF and ME constitutes a technological cornerstone within the concept of an environmental biorefinery. Five different WW coming from cheese (CW), fruit juice (FJW), paper (PW), sugar (SW) and fruit processing (FPW) factories were selected among 21 different WW collected from a wide range of industrial sectors (food, manufacturing, biofuel, wastewater treatment, among others) to evaluate the feasibility of two-step process. The results of this work show that dark fermentation linked with ME is a feasible and highly promising option in order to maximize the conversion of WW into bioenergy.**

***Index Terms* – Dark fermentation, hydrogen, microbial electrolysis cells, wastewater treatment.**

I. INTRODUCTION

Among the diverse renewable H_2-producing biotechnologies, dark fermentation (DF) of Organic Wastewater (WW) has received significant attention in recent years since it combines sustainable waste management with pollution control and generation of a highly valuable clean energy product [1]. However, fermentative H_2 production provides only a partial oxidation of the organic substrate. It is likely to be industrially viable only if fermentative bioprocesses are integrated within a stream that can utilize fermentation by-products. Microbial Electrolysis Cells (MECs) are an emerging technology that could utilize the metabolic byproducts generated by DF. Combining DF with MECs in a two-steps cascade process can result in a complete exploitation of biodegradable WW, which maximizes at the same time energy recovery and effluent depollution [2].

The aim of this research is to identify the most suitable WW for the development of a feasible, two-step $BioH_2$ production cascade - process, combining DF and MC within the biorefinery concept. Five different WW coming from cheese (CW), fruit juice (FJW), paper (PW), sugar (SW) and fruit processing (FPW) factories were selected among 21 different WW collected from a wide range of industrial sectors (food, manufacturing, biofuel, wastewater treatment, among others) to evaluate the feasibility of two-step process. The selection was made on the basis of fermentative conversion efficiency (i.e., both H_2 and metabolic by-product accumulation) obtained in DF experiments. The effluents from the fermentation of CW, FJW, PW, SW and FPW were tested in two chambers MECs to further recover H_2 and WW depollution.

II. MATERIALS AND METHODS

A. Experimental set up

CW, FJW, PW, SW and FPW were selected among 21 different WW collected from a wide range of industrial sectors on the basis of fermentative conversion efficiency.
DF experiments carried out in batch reactors (pH 5.5, 37°C) using heat treated anaerobic sludge as inoculum.
MEC experiments were conducted in two chambers (400 mL wV) potentiostatically controlled systems (anode applied potential + 0.2V vs SCE, pH 7, 37°C). An electroactive biofilm enriched from anaerobic sediments using acetate as carbon source is used as biocatalyst.

B. Analytical methods

The volume of biogas production was measured using water column method. The gas compositions of the anode and cathode chambers were determined by a gas chromatograph (Clarus 580 GC). The concentration of soluble metabolic products were analyzed by high-performance liquid chromatography (HPLC).

C. Calculations

The coulombic efficiency (CE, %) was calculated as CE = n_{ce}/n_{th}, where n_{ce} is the moles of hydrogen that could be recovered based on the measured current, and n_{th} was the theoretical maximal production based on COD removal, calculated as described in [3].

The cathodic hydrogen recovery (r_{cat}, %) was calculated as $r_{cat}=n / n_{ce}$, where (n) was the moles of hydrogen produced at the cathode and (n_{ce})the moles of hydrogen that could be recovered based in the measured current.

The energy yield (YE,%) is the term for energy recovery based on the energy content of the hydrogen produced compared to the electrical input. It was calculated as YE = $-W_{H2}/W_e$, where (W_{H2}) was the energy content of the hydrogen produced, calculated based on hydrogen combustion energy and (W_e) was the input electrical energy required to produce the hydrogen in the MEC.

III. Results

The H_2 recovered in DF was linearly correlated with the initial content of soluble sugars and present in WW (R^2= 0.9). The H_2 production obtained from DF of the five WW ranged from 30 to 296 mLH_2/L and CW showed the best H_2 production yield of 120 ± 31 mL H_2/gVS. Acetate, butyrate were the main metabolic by-products in all the experiments (Figure 1).

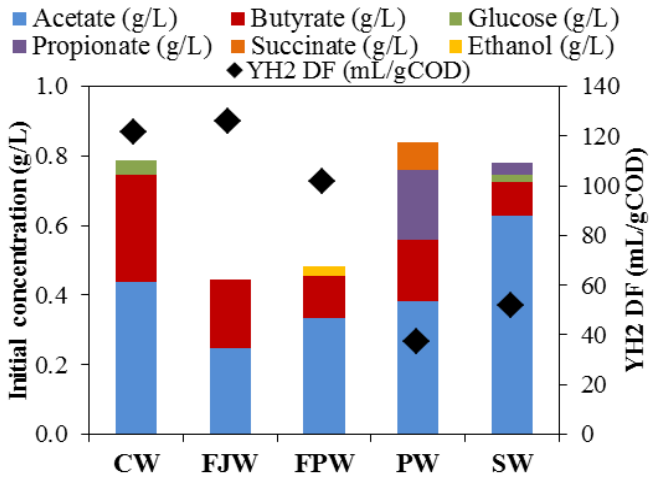

Fig. 1 - Yields of H_2 production in DF and composition of the different effluents obtained from the fermentation of CW, FJW, FPW, PW, and SW, used to feed the MECs.

MECs results show satisfactory performances in terms of Coulombic Efficiency (CE), cathodic hydrogen recovery and H_2 yield. Regarding the energy yields results showed, no only 100% of the electrical input energy could be recovered in all effluents, but at least twice energy amount (217%) could be generated by the combustion of hydrogen produced (Figure 2).

Interestingly, a complete conversion of metabolic by-products into acetate is first observed before acetate consumption started and current began to increase.

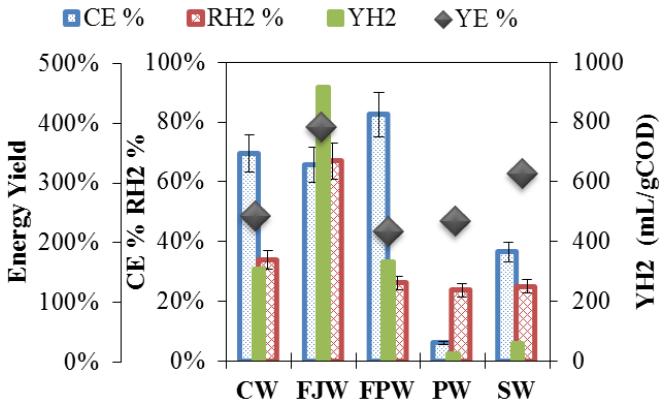

Fig. 2 - Coulombic efficiency (CE%), H_2 yield (YH2), cathodic H_2 recovery (RH2%) and Energy Yield (YE%) in MECs with different effluents.

IV. Conclusion

The results, shown in this paper, are the preliminary experimental data regarding the DF and MECs application for treatment and simultaneous energy recovery from real WWs. These results showed that coupling of DF and MEC for organic WW treatment constitutes a feasible and highly promising route in the environmental biorefinery framework.

Acknowledgment

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Message from the Track Manager

This is a study on MECs – not MFCs – which require energy to run, instead of generating energy. The Authors are therefore asked to include energy consumption figures by the MEC, and clarify whether this external energy input has been included in their coulombic efficiency calculations.