HYDROGEN PRODUCTION BY *Spirulina maxima 2342* IN DIFFERENT LIGHT INTENSITIES AND QUANTIFICATION THROUGH A PEMFC

A.U. Juantorena[1], P. J. Sebastian [2], O. Lastres [3], Hernández, G [2] A. Bustos.[4]

[1] Universidad Politécnica del Estado de Morelos. UPEMOR. Boulevard Cuauhnáhuac No. 566. Col. Lomas del Texcal. Jiutepec. Morelos. México. CP. 62550. Tel. 0447772159208. E-mail: alinajt2@yahoo.es

[2] Centro de Investigación en Energía. UNAM. Ave. Xochicalco s/n. Apartado Postal 34. Temixco. Morelos. México.

[3] Instituto de Estudios de la Energía. UNISTMO. Istmo de Tehuantepec. Oaxaca. México.

[4] Instituto de Ciencias Físicas. UNAM. Ave. Universidad 1001. Col. Chamilpa. Cuernavaca. Morelos. México.

ABSTRACT

Research in hydrogen production by biological means has shown the problems and potential of biotechnology hydrogen industrial development as a future energy, allowing considering it as a serious practical possibility. In this work, the hydrogen photosynthetic production for *Spirulina maxima 2342* microorganisms is determined under different experimental conditions, for the same biomass property (concentration) and three different light intensities (150, 112 and 75 $\mu E/m^2.s$) through the Proton Exchange Membrane Fuel Cell (PEMFC) electricity generation. The highest hydrogen flow ratio to the entrance of the PEMFC (kg/h) per biomass (g) was obtained at higher intensity light, 150 $\mu E/m^2$. s, with a value of 1.54×10^{-8}.

Key words: Hydrogen, photosynthetic microorganisms, *Spirulina maxima 2342*, PEMFC.

1. INTRODUCTION

Hydrogen can be the fuel of the future because it is an environmental friendly gas which produces only water when reacted with oxygen. In addition, it is an important chemical feedstock in many chemical industries. Hydrogen can be produced from liquid fuels (gasoline and diesel); gaseous fuels (natural gas); steam reforming, catalytic or thermal partial oxidation and autothermal oxidation.

The first results demonstrated the problems and possibilities of the biotechnology for the development of the hydrogen industry, like a renewable source of energy, allowing considering it like a practical possibility seriously [1].

At the moment the world-wide tendency for the hydrogen production is by biological route. Successful example of some research reported are: continuous production of hydrogen from the anaerobic acidogenesis of a high-strength rice winery wastewater by a mixed bacterial flora employed upflow reactor was demonstrated for [2]**;** the hydrogen production from tofu wastewater by anoxygenic phototrophic bacteria and its potential for wastewater treatment was reported for [3], showing the possibility of co-cultivation with heterotrophic anaerobic bacteria and hydrogen production from the wastewater of tofu factory was examined by using anoxygenic phototrophic bacterium *Rhodobacter sphaeroides* immobilized in agar gels, for [4]**.** The maximum rate of hydrogen production observed from the wastewater was 2.1 l h^{-1} m^2 gel which was even slightly higher than that from glucose medium (as control).

Asada and Kawamura [5], determined that cyanobacteria also produces hydrogen by means of autofermentation, under anaerobic conditions of the darkness and illumination. One demonstrated that the *Spirulina* species, have discharges activities between cyanobacteria studied. Hydrogenases has been purified and partially characterized in some cyanobacteria and seaweed [6]**.**

Spirulina is one of the photosynthetic microorganisms that can produce hydrogen, after being put under conditions of the anaerobiosis-dark, has been of the studied microorganisms less for the hydrogen production, is being reached activity of 1µmol of hydrogen/12 h/mg of dry-weight, under anaerobiosis conditions [7]**.**

The goal of this research is to present the hydrogen photosynthetic production with *Spirulina maxima 2342* microorganisms, determined under different experimental conditions, for the same biomass property (concentration) and three different light intensities.

2. MATERIALS AND METHODS

2.1 *Spirulina maxima 2342 b*iomass characteristics

The experiments were carried out with *Spirulina maxima 2342* (UTEX collection), cultivated in a volume of 15 L autographically, with illumination (4 lamps of 39 W) and bubbling air and employed Complete Standard Mineral Medium described by Ogawa and Terui [8]. The samples were taken from culture, in a certain stage of cellular growth and the concentration adjusted (previously fixed for the experiments), by optical density (750 nm), to guarantee that the biomass characteristics for each experiment, was most similar possible. For each retort to that the measurements are made, 190 mL biomass. To the biomass it was determined to him, dry weight (g/L), pH and chlorophyll a (mg/L) by the spectrophotometric method and the Arnon equations [9] (Table 1).

2.1.1 Anaerobiosis proccess

The culture is subject to anaerobiosis-dark process, (argon low of 20 ± 1 ml/min), to eliminate the oxygen dissolved during 1 h, is connected the bioreactor with 190 mL of culture, to the anode of the PEMFC, so that it passes the flow of gas to the same one and it is added this one, a argon flow of 30±1 mL/min, with the objective to increase the inlet pressure of the gas to the cell and to increase its activity. The hydrogen photoproduction was induced under agitation–illumination conditions. The illumination was supplied by a lamp of 100W, fixing the light intensity to 150, 112 and 75 $\mu E/m^2$. s.

2.2 Experimental installation

The experimental installation is formed by a PEMFC (electrode area of 16 cm^2, power 1, 2 W). The bioreactor is coupled to the PEMFC. Also it is counted on a Voltmeter (mV), an Amperimeter (μA), a Variable resistor (0-5 kΩ), a sensor for the measurement of temperature (°C) and compressed gases of H_2 (g) (Degree 4.5), O_2 (g) (Degree 2.6) and Ar (g), of industrial quality (Figure 1).

Figure 1. Experimental installation

2.3 Faraday Efficiency and hydrogen flows (entrance and used for PEMFC) determination

A regression equation is obtained characteristic of the PEMFC, from experimental data, feeding it with initial flows on O_2 (g) and H_2 (g), measured when coming out of this one (Figure 2).

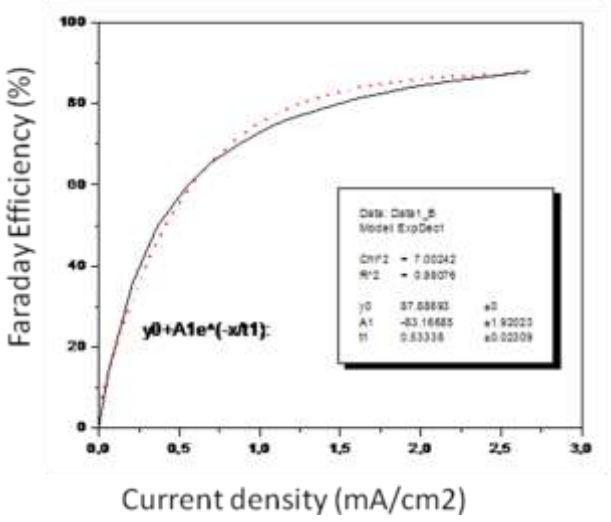

Figure 2. Experimental adjustment

For each experimental case, in which hydrogen by the photosynthetic microorganisms is generated, with the I Maxim average (mA), determines the current density, soon it is replaced in the regression equation and the Faraday Efficiency is obtained. With this one and lows of hydrogen used by cell, determine flows of hydrogen that enters the cell, (Flow H_2 entrance), (mol/h) either (kg/h), which they are the lows generated by the microorganisms for each experimental case, Equation 1.

$$FlowH_2 entrance = \frac{FlowH_2 used}{FaradayEffciency} \quad (1)$$

The hydrogen flow used by PEMFC, Flow H_2 used, (mol/h) or (Kg/h) for experimental data of I (mA), [10], is determined by de following equation (2 and 3):

$$FlowH_2 used(mol/h) = (IA)\left(\frac{1coulomb/s}{1A}\right)\left(\frac{1equiv.dee^-}{96487coulomb}\right)\left(\frac{1molH_2}{2equiv.dee^-}\right)\left(\frac{3600s}{1h}\right) \quad (2)$$

Where I: current generated by PEMFC for experimental data

$$FlowH_2used(kg/h) = FlowH_2used(mol/h)\left(\frac{2.0158g}{1molH_2}\right)\left(\frac{1kg}{1000g}\right) \quad (3)$$

3. RESULTS AND DISCUSSION

3.1 *Spirulina maxima 2342* biomass characteristics

Table1 shows the characteristics of the *Spirulina maxima 2342* biomass

Table 1. *Spirulina maxima 2342* biomass characteristics

Biomass characteristics	*Spirulina maxima* 2342
Dry Biomass (g)	0.210 ± 0.001
pH	10.180 ± 0.001
Chlorophyll a (mg)	1.19 ± 0.06
Chlorophyll a (mg)/biomass (g)	5.7 ± 0.4

The pH values are within the optimal parameters reported for the species used (between 9 and 11) [11], and Chlorophyll a (mg)/biomass (g) are consistent with the quality parameters for photosynthetic organisms biomass (3 to 10) [12].

For each case experimental data collection began after output voltage U (mV) of the PEMFC to stabilize. We measured the voltage with no load and then measured I (mA) and U (mV) varying the load resistance.

Next, is the behavior of the voltage based on the time, for each light intensity, being observed in all the cases, that the values of voltage increase as it increases the intensity light incident.

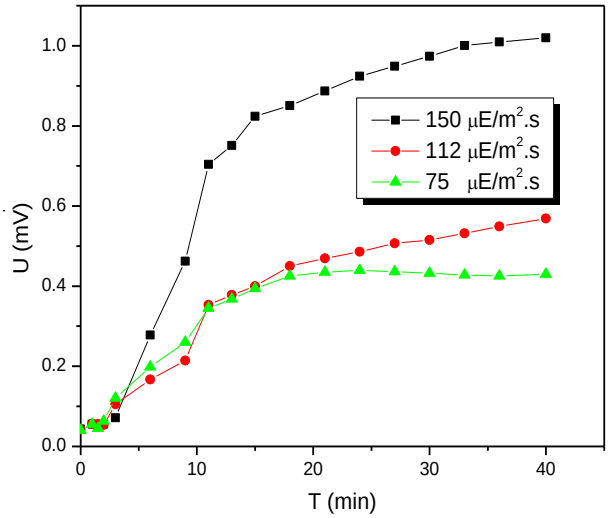

Figure.3. Variation of the voltage generated by the PEMFC in the time

With the data averages of I (mA) and U (mV), for each studied case, the P (mW), generated by the PEMFC calculates for equation (4).

$$P = I \times U \qquad (4)$$

Where:

P: power output (mW)

I: current intensity (mA)

U: voltage (mV)

Next, they appear examples of obtained the characteristic curves average, for the case of the light intensity of 150 $\mu E/m^2$. s.

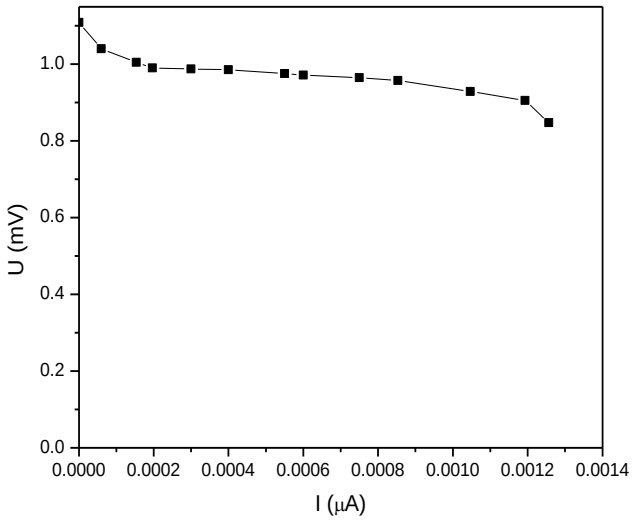

Figure.4. I versus U for the values average of the experiments with 150 μE/m^2. s.

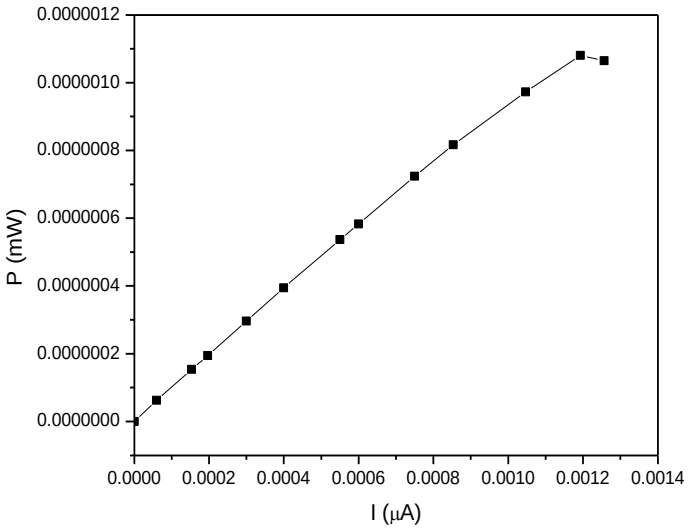

Figure 5. I versus P for the values average of the experiments with 150 μE/m^2. s.

For all the cases, the behavior of curves IU and IP; is the characteristic behavior for a PEMFC. As it increases the voltage, the electrical current diminishes and as it increases the current electrical, it increases the power until a value of maximum power, from as it diminishes.

As it increases the light intensity, they increase power and voltage the values. The PEMFC efficiency calculates and with this one and the power output, determines the entrance power, whereas with the experimental values of I (mA), the hydrogen flows used by the PEMFC are determined. To the maximum power, with the maxim current (I max in mA), for each studied experimental case, the current density calculates (mA/cm^2) and from the obtained regression equation (To see Figure. 2), determines the Faraday Efficiency (Table 2).

Table 2. Faraday Efficiency

Light intensity ($\mu E/m^2.s$)	Imax (mA)	Current Density (x)(mA/cm^2)	Faraday Efficiency(y) (%)
150	$1.19 \times 10^{-3} \pm 5.77 \times 10^{-4}$	7.46×10^{-5}	1.400
112	$6.60 \times 10^{-4} \pm 5.92 \times 10^{-5}$	4.12×10^{-5}	1.389
75	$6.33 \times 10^{-4} \pm 2.60 \times 10^{-5}$	3.96×10^{-5}	1.389

Imax: current intensity maxim (mA)

With this data and the hydrogen flow used by the cell, calculates the hydrogen flow to the entrance, which is the generated one by the photosynthetic microorganisms. In addition the hydrogen flow calculates generated by biomass (g) (Table 3).

Table 3.Relation Flow hydrogen entrance and biomass

Light intensity ($\mu E/m^2.s$)	H_2used (kg/h)	H_2entrance (kg/h)	H_2entrance(kg/h)/ biomass (g)
150	4.49×10^{-11}	3.23×10^{-9}	1.54×10^{-8}
112	2.48×10^{-11}	1.79×10^{-9}	8.53×10^{-9}
75	2.38×10^{-11}	1.72×10^{-9}	8.19×10^{-9}

H_2 used: hydrogen flow used by the PEMFC

H_2 entrance: hydrogen flow of entrance to the PEMFC

The influence of the changes in the intensity of light, during the hydrogen gas production, that produces the operation of the PEMFC, can be followed reading the parameters of exit of the same one directly, being observed the differences for each case. It can to observe, that greater Faraday Efficiency of obtained, corresponds to greater radiation incident, from 150 $\mu E/m^2$. s, and greater flow of hydrogen generated by microorganisms, which it is the flow that enters the anode of the cell, in addition obtains the greater relation of hydrogen flow by biomass (g).

4. CONCLUSIONS

1. Voltage is increasing in the time, as it increases the light intensity incident.

2. The highest values of maximum power (mW) corresponding while it is increasing the light intensity incident.

3. The largest hydrogen flows entering the PEMFC, are obtained at the incident light intensity 150 $\mu E/m^2$. s.

4. Most Faraday Efficiency and highest hydrogen flow per biomass (g) corresponding to the incident light intensity of 150 $\mu E/m^2$. s.

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