

Production of hydrogen gas from biomass oil palm empty fruit bunch using electrolysis method

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Abstract. Biomass oil palm empty fruit bunch (OPEFB) is a sustainable source for hydrogen production. OPEFB and $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ oxidizers (0.1, 0.2, 0.3 and 0.4 mol) were refluxed at 90-98 °C for 5 hours. The acquired aliquot was used to produce H_2 with variation of storage time (fresh aliquot and old aliquot). The production of H_2 was carried out by electrolysis method where the aliquot was diluted by ratio of 1:10. The electrolysis was carried out using two electrodes as anode (titanium) and cathode (stainless steel) with DC current voltage 15 V. The principle of gas mass transfer in the vessel following Bernoulli's principle was used to calculate the volume of H_2 formed. The change of current by formation of H_2 were used to calculate the volume of H_2 following Faraday's law. The results showed that the storage time of the solution affects the production time of H_2 . The oxidizer concentration has no effect on the H_2 production in the fresh solution but has effect on the old solution. The best solution to produce H_2 is a 0.1 mol oxidizer solution with a production time of 8 minutes. The produced H_2 can be used in power generation by a fuel cell process.

1 Introduction

Environmental pollution and energy crisis are one of many problems faced in this era. Waste and air pollution around us can causes the environment dirty and pose a threat to life like an epidemic that can threaten human life. Therefore, handling is needed to overcome these problems, one of which is utilizing waste as an alternative energy source. Palm empty fruit bunch (OPEFB) is an alternative energy source that can overcome problems in the environment by providing advantages such as the availability of many in the area of oil palm farming and it can be used in the production of hydrogen gas [1].

Hydrogen is the most common element found in nature, but hydrogen in nature is not in gaseous form and combines with other elements such as combined H_2O water and hydrograph. Hydrogen is also found in many organic compounds. To get a pure hydrogen can be done with electrolysis method. Hydrogen has high energy and the engine that burns pure hydrogen hardly produces pollution. Electrolysis method can be used to overcome environmental pollution and energy crisis by utilizing electrochemical reaction to convert organic waste into biomass fuel. In this method we can use both homogeneous and heterogeneous catalysts in which heterogeneous catalysts have the advantage of being environmentally friendly, inexpensive, and reusable [2].

This research uses electrolysis method with gas mass transfer principle to calculate the volume of hydrogen that is formed. The electrolyte used was prepared based on research conducted by Gong *et al.* [3] The change in hydrogen formation is used to calculate the hydrogen volume calculation follows Faraday's law. This research was previously conducted by Wahyono *et al.* [4] electrolysis of seawater by the addition of acetic acid catalyst to analyze the production of hydrogen gas. In this study, modification of electrolysis was done by using solution of OPEFB refluxed at 80-90 °C with mixture of different oxidizer concentration and acid catalysts for the production of H_2 and this study examines the effect of storage of the solution to the production of H_2 produced.

2 Materials and methods

2.1 Materials and equipment

This experiment used Oil Palm Empty Fruit Bunch (OPEFB) obtained from PT. Perkebunan Kelapa Sawit Sungai Parit, Penajaman North Paser, East Kalimantan, Indoneisa and $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ (CAS-No : 10025-77-1, Merck, Germany). Reflux process used a reflux set device with a 250 mL round bottom flask. The electrode used are stainless steel with dimensions of 7 cm (long) x 1.5 cm (wide) and titanium rode with dimension of 7 cm (long)

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1.0 cm (wide) x 3 mm (thick). All the solution preparation use deionized water.

2.2 Reflux process

Before use, the OPEFB biomass sample must be dried under the sunlight and then cut into small pieces with a length of approximately ± 1 cm. Put in the oven for 24 hours at 62 °C to reduce the water rate. 4 grams of OPEFB and FeCl₃.6H₂O (0,1 ; 0,2 ; 0,4 mol), were mixed, HCl solution (10 mL) and deionized water (90 mL) was added. The suspension was heated to reflux at 90-98 °C for 5 hours under stirring. After a certain reaction time, the solution was cooled to room temperature and filtered. Then filtrate was used as an electrolyte in hydrogen gas production.

2.3 H₂ production

The H₂ volume of the solution experimentally was measured using 2 electrodes (stainless steel and Ti) in reactor as shown in Fig. 1. The filtrate was diluted by the ratio 1:10 into 100 mL to keep the pH solution from being too acid and it used as an electrolyte in the electrolysis cell to produce hydrogen.

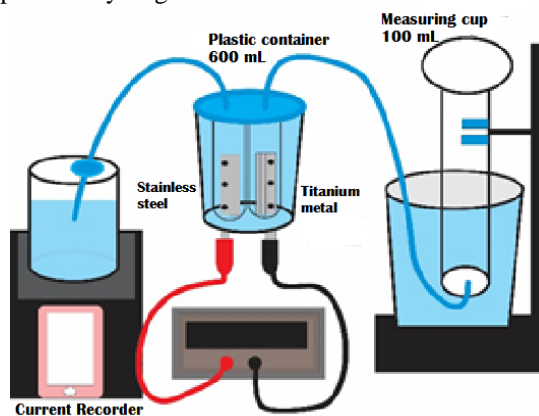


Fig. 1. Illustration of hydrogen gas production tools using electrolysis method

In this experiment, the H₂ volume of the solution was calculated by the principle of water mass displacement is equivalent to the gas volume following the principle of Bernoulli that is “the higher the fluid speed the lower the pressure it becomes and the lower the fluid speed the higher the pressure it becomes”, as shown in the following Eq. 1:

$$P_1 + \frac{1}{2}PV_1^2 + \rho gh_1 = P_2 + \frac{1}{2}PV_2^2 + \rho gh_2 \quad (1)$$

The current during the hydrogen production process was measured using a multimeter (KW06-796, Krisbow, China). The resulted current from multimeter then used as data to confirm the hydrogen production experimentally. The gas hydrogen volume experimentally calculated based on the time required to produce a hydrogen bubble using the ideal gas equation shown in Eq. 2 and Eq. 3:

$$PV = nRT \quad (2)$$

$$V = \frac{nRT}{P} \quad (3)$$

$$n = \frac{M}{Mr} \quad (4)$$

The mass value of the hydrogen gas can be calculated using Faraday’s Law as shown in equation 4 where the electrical charge is calculated by the integral from the current measurement exponential equation.

$$M = \frac{Q \times Ar}{n \times F} \quad (5)$$

$$I(A) = y \times e^{(x) \times t} \quad (6)$$

$$\int_0^{300} I dt = \left(\frac{y}{x} \right) (\exp(x \times 300) - \exp(x \times 0)) \quad (7)$$

3 Results and discussion

In this research, the degraded biomass solution was made by using FeCl₃.6H₂O oxidizer with different concentrations and storage times. Variations FeCl₃.6H₂O concentration and storage time were used to determine the optimal concentration in the production of hydrogen gas.

3.1 H₂ production by fresh solution

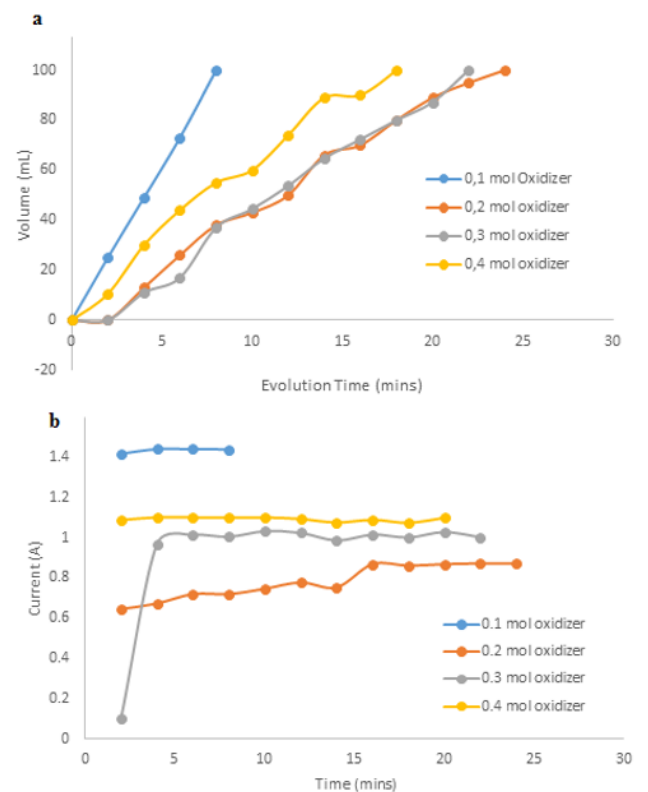


Fig. 2. (a) volume of hydrogen gas experimentally by fresh solution, (b) current applied during hydrogen gas production

Fig. 2(a) shows that a fresh solution with a 0.1 mol oxidizing concentration is the solution that produces the most stable and fastest hydrogen gas. This solution produces 100 mL of hydrogen gas within 8 minutes. The time required to produce 100 mL of hydrogen gas in solution with 0.2, 0.3 and 0.4 mol oxidizing concentrations respectively is 24, 22 and 18 min. **Fig. 2(b)** shows the current used during the process of producing hydrogen gas. The DC current supplied to the reactor is a stable current. This current data is then used to calculate the volume of hydrogen gas produced under Faraday's law shown in **Table 1**.

3.2 H₂ production by old solution

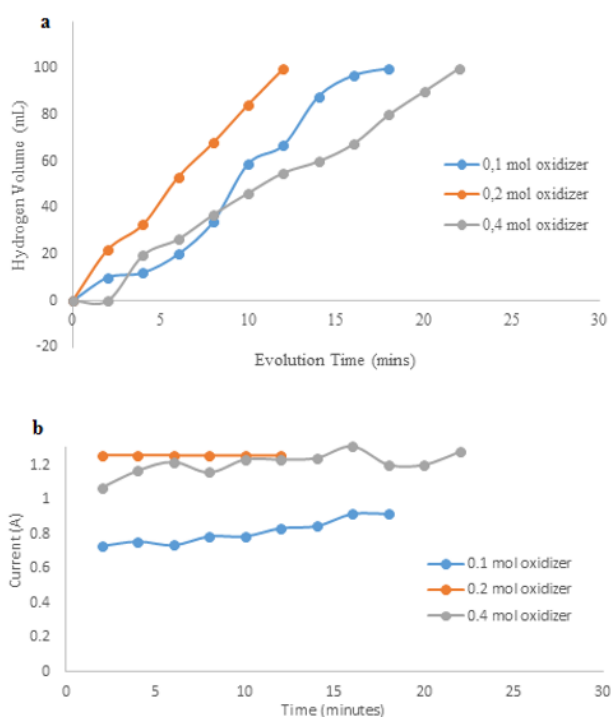


Fig. 3. (a) volume of hydrogen gas experimentally by old solution, and (b) current applied during hydrogen gas production

Fig. 3(a) shows that the old solution with a 0.2 mol oxidizing concentration is the solution that produces the most stable and fastest hydrogen gas. This solution produces 100 mL of hydrogen gas within 12 minutes. The time required to produce 100 mL of hydrogen gas in 0.1 and 0.4 mol oxidizing solutions is 18 and 24 minutes. **Fig. 3(b)** shows the current used during the process of producing hydrogen gas. The DC current supplied to the reactor is a stable current. This current data is then used to calculate the volume of hydrogen gas produced under Faraday's law shown in **Table 1**.

3.3 Calculation of H₂ volume production based on Faraday's law

Table 1 shows that in the fresh aliquot solution, the highest volume during the process of producing hydrogen gas is in 0.3 oxidizer solution that is 88,347 mL. However,

when the calculation of H₂ volume compared to the volume of hydrogen gas experimentally, it is known that the volume of hydrogen gas in 0.2 oxidizer solution is experimentally more than the hydrogen gas volume in theoretical 0.2 oxidizing solution, the experiment is 135.352%. In the old aliquot solution, the highest volume during the process of producing hydrogen gas is in 0.4 oxidizing solution of 136.929 mL. However, if the hydrogen gas volume is theoretically compared to the hydrogen gas volume experimentally, it is known that the volume of hydrogen gas in 0.1 oxidizer solution is experimentally higher than the hydrogen gas volume in the theoretical 0.1 oxidizer solution, experiment that is 102,443%.

Table 1. Volume production of gas hydrogen by fresh and old aliquot solution theoretically

FeCl ₃ .6H ₂ O (mol)	Fresh Aliquot		Old Aliquot	
	^a Volume (mL)	^b % H ₂	^a Volume (mL)	^b % H ₂
0.1	88.347	117.180	97.615	102.443
0.2	79.053	135.352	125.702	81.940
0.3	67.425	102.643	-	-
0.4	85.426	117.060	136.929	77.412

^acalculation of volume H₂ gas, ^bcomparison of hydrogen gas production experimentally and calculation

The difference in the volume of hydrogen gas in experiments and calculations is due to factors affecting the production of hydrogen gas. The calculated hydrogen gas production data is calculated on the basis of ideal conditions and the electrodes used are carbon electrodes [3], while the experimental data are obtained under experimental conditions which may be affected by factors such as the use of different electrode types and the pH of the solution. The use of titanium and stainless steel electrodes causes more hydrogen gas production with shorter production times.

4 Conclusion

This research concluded that the variation of oxidation concentration has no effect on fresh aliquot solution but has an effect on old aliquot solution, this is because the storage time of the solution influences the production of H₂ gas related to the variation of the oxidation concentration. The greater the oxidizing concentration, the time it takes to produce hydrogen gas is longer. In fresh aliquot solution, H₂ gas volume is experimentally higher than the theoretical volume. The highest volume of gas that is in 0.2 mol oxidizer solution is 135.3515%. In the old aliquot solution, the H₂ gas volume is theoretically larger than the volume experimentally. The ratio of the highest gas volume is in the solution of 0.1 mole oxidizer of 102.4434%.

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