Adding the activated carbon of rice husk to increase hydrogen production on water electrolysis

Purnami*, ING. Wardana, Sudjito, Denny Widhiyanuriyawan, Nurkholis Hamidi
1 Mechanical Engineering Department, Brawijaya University
MT Haryono 167 Malang Indonesia
*Email: purnami.ftub@ub.ac.id

Abstract. Water electrolysis is decomposing water (H₂O) into Oxygen and Hydrogen with the help of electric current. At present, the conventional electrolysis efficiency is around 50%. The use of catalysts is partly engineered to increase the hydrogen production. In this paper, activated carbons from rice husk (RHAC) of 50 ppm and 100 ppm were added as the catalyst to increase Hydrogen production. FTIR tests showed that RHAC had an aromatic ring functional group with magnetic field. By the help of ImageJ software, it was proven that RHAC surface has an electric charge dominated by a positive charge. The magnetic field weakens the hydrogen bonding, while the electric charge increases the solution acidity, and makes it a good electrical conductor. As a result, greater addition of RHAC increases Hydrogen production. The largest hydrogen production of 8.2 ml for 10 minutes was obtained by the addition of 100 ppm.

Keywords: water electrolysis, activated carbon of rice husk, Hydrogen production, magnetic field

1. Introduction

Energy demand continues to increase until 2050, while fossil reserves will be exhausted within the next 9 years. In addition to the availability problem, fossil fuels also produce pollution from a combustion process [1]. One alternative fossil fuel substitute is Hydrogen. Hydrogen is available in large quantities and not cause combustion pollution, since it is an energy carrier considered as the cleanest energy [2]. Many hydrogen production routes are available including steam reforming [3], photocatalysis[4], and water electrolysis [5]. Water electrolysis is widely used to produce hydrogen as it requires simple equipment and produces hydrogen with a high purity of 99.9%. However, the problem in water electrolysis is the low efficiency [6].

Using magnetic fields is the most effective way to increase Hydrogen production as the magnetic field is confirmed to be able to weaken the Hydrogen bond [7][8]. In addition to magnetic fields, using electric fields is also effective at increasing Hydrogen production, since it is effective in reducing polarity and affecting the acidity of electrolyte solution [9].

Rice shells are waste materials from rice processing and not widely used [10]. Meanwhile, activated carbon is a substance with magnetic and electrical potential [11]. Due to rice shells (RHAC) having magnetic and electrical potential, it is a potential material to increase Hydrogen production rate by water electrolysis. This research studied the increase of hydrogen production rate on water electrolysis with the addition of RHAC.
2. Method
A reactor tube with 500ml volume size was prepared by alkaline water and electrolyte filling. The electrolyte was 0.05 mole of NaCl. 60 by 10 by 2 mm³ electrodes made of 316 L carbon steel were used as cathodes. The anodes were placed 5 cm away from the cathodes. 50 ppm and 100 ppm of RHAC were poured and mixed in the reactor by evenly stirred the mixture mechanically. A Volume tube was placed on top of the cathode to measure the volume. The research installation is as presented in Figure 1.

![Research installation](image1)

The temperature stability was maintained at 25°C during electrolysis. The main voltage stability also maintained at 5V. The PH level of the solution was measured using pH meter, and the electric charge stream represented by electric current measured by an ammeter. The electrolysis duration of the solution was 10 minutes and measurement data were reported every 1 minute. The data collection repetition was five times and the average value was taken as the data representation. SEM-EDX test was used to determine the surface contour and content of RHAC chemical element. The charges on RHAC surface was analyzed using a digital imaging software(ImageJ) based on SEM-EDX data. Then, to find out the functional group in RHAC, FTIR test was used.

3. Result
The chemical elements' content of RHAC SEM-EDX test results were shown in Figure 2. The elements contained in RHAC were Oxygen (44.2%), Carbon (24.2%), Potassium (11.5%), Aluminum (10.36%), and Silica (9.66%). It was known that elements of Oxygen and carbon dominated almost 67% of all elements.

![RHAC chemical elements](image2)
RHAC surface contours is served in Figure 3. The figure was depict the uneven porous surface of RHAC. They were the characteristics of activated carbon surface [12]. The existence of electric charge on RHAC surface could be seen in Figure 4. It was the result of processed image 2 with the help of ImageJ software. It could be seen from Figure 4 that RHAC surface was dominated by bright colors. Bright colors came from more electron concentrations compared to other surfaces. More electron concentration occured since many electrons were bound by RHAC surface. Therefore, it can be concluded that RHAC surface is dominated by positive charge. FTIR test results on RHAC were shown in Figure 5. The image showed the appearance of absorption bands at 1548.73. This frequency indicated the existence of functional groups in aromatic compounds containing magnetic potential.

![Figure 3. RHAC Surface](image)

![Figure 4. RHAC surface electric charge](image)

![Figure 5. RHAC FTIR test results](image)

Hydrogen production could be seen in Figure 6. Based on the picture, the Hydrogen volume was enlarged by the increased time. Conventional water electrolysis produced the least amount of Hydrogen, while adding 100 ppm of RHAC produced more Hydrogen than adding 50 ppm.
4. Discussion

From SEM-EDX and FTIR tests it was conclusively proven that RHAC had the potential for electric and magnetic charges. These two things were very influential in the process of electrolysis of water. RHAC surface dominated by positive charges bound more OH- ions from solution, consequently, more H+ ions were move freely in the solution. More H+ ions in solution has caused the solution to be more acidic. It was confirmed in Figure 7. The picture showed the more addition of RHAC was, the more acidic the solution would be. In other words, pH value was smaller. It caused the solution to be easier to conduct electric current.

On the other hand, RHAC’s magneticity caused the hydrogen bonds to be weakened. The weakening due to the influence of magnetic fields had been described in many papers. The possible mechanism to explain was due to the diamagnetic nature of water. Diamagnetic nature would provide a repulsive force when it was influenced by a magnetic field. The repulsive force which caused hydrogen bonds to become bent was eventually broken [13].

The existence of magnetic field gave rise to the Lorentz force. It would increase the mobility of the electrolyte in the solution which is NaCl ions acting as the charge carriers [14]. This resulted in faster electrical charges moving in solution. The ease of electrical conduction of the solution has increases the ionic motions speed. As a result, the electric current in the solution was increased denoted by the raise of current density value. Another result of the increased of ion transfer speed, the hydrogen production rate is also risen. A visualization of RHAC addition to increase Hydrogen production which could weaken the Hydrogen bond and increased the electric current density as illustrated in Figure 9.
5. **Conclusion**

The results of SEM-EDX and FTIR tests assisted with ImageJ software have shown that RHAC has the potential of magnetism and electricity on its surface. The magnetic potential is effective for weakening hydrogen bonds and increasing NaCl ion mobility, while the potential for electric charge is effective for increasing the solution’s electrical conductivity. The accumulation of both has been proven to be able to increase hydrogen production. Adding 100 ppm RHAC produces 8.2 ml of Hydrogen for 10 minutes.

6. **Acknowledgement**

This work is made possible by the Indonesian Ministry of Research and Higher Education and funded under the grant number: [03/UN10.F07/PN/2019].

7. **References**

[1] Purnami, I. N. G. Wardana, N. Hamidi, M. N. Sasongko, and D. B. Darmadi, “The effect of rhodium (III) sulfate and clove oil catalysts on the droplet combustion characteristics of castor oil,” *Int. J. Integr. Eng.*, 2019.

[2] K. Zeng and D. Zhang, “Recent progress in alkaline water electrolysis for hydrogen production and applications,” *Progress in Energy and Combustion Science*. 2010.

[3] C. M. Kalamaras and A. M. Efstatiou, “Hydrogen Production Technologies: Current State and Future Developments,” *Conf. Pap. Energy*, 2013.

[4] X. Fang *et al.*, “Graphitic carbon nitride-stabilized CdS@CoS nanorods: An efficient visible-light-driven photocatalyst for hydrogen evolution with enhanced photo-corrosion resistance,” *Int. J. Hydrogen Energy*, 2017.
[5] N. Willy Satrio, Winarto, Sugiono, and I. N. G. Wardana, “Hydrogen production from instant noodle wastewater by organic electrocatalyst coated on PVC surface,” *Int. J. Hydrogen Energy*, 2020.

[6] V. M. Nikolic, G. S. Tasic, A. D. Maksic, D. P. Saponjic, S. M. Miulovic, and M. P. Marceta Kaninski, “Raising efficiency of hydrogen generation from alkaline water electrolysis - Energy saving,” *Int. J. Hydrogen Energy*, 2010.

[7] Y. Liu, L. ming Pan, H. Liu, T. Chen, S. Yin, and M. Liu, “Effects of magnetic field on water electrolysis using foam electrodes,” *Int. J. Hydrogen Energy*, 2019.

[8] M. Y. Lin, W. N. Hsu, L. W. Hourng, T. S. Shih, and C. M. Hung, “Effect of Lorentz force on hydrogen production in water electrolysis employing multielectrodes,” *J. Mar. Sci. Technol.*, 2016.

[9] N. Bidin et al., “The effect of sunlight in hydrogen production from water electrolysis,” *Int. J. Hydrogen Energy*, 2017.

[10] N. Yalçin and V. Sevinç, “Studies of the surface area and porosity of activated carbons prepared from rice husks,” *Carbon N. Y.*, 2000.

[11] Purnami, N. Hamidi, M. N. Sasongko, D. Widhiyanuriyawan, and I. N. G. Wardana, “Strengthening external magnetic fields with activated carbon graphene for increasing hydrogen production in water electrolysis,” *Int. J. Hydrogen Energy*, 2020.

[12] M. S. Masoud, W. M. El-Saraf, A. M. Abdel - Halim, A. E. Ali, E. A. Mohamed, and H. M. I. Hasan, “Rice husk and activated carbon for waste water treatment of El-Mex Bay, Alexandria Coast, Egypt,” *Arab. J. Chem.*, 2016.

[13] J. A. Koza et al., “Hydrogen evolution under the influence of a magnetic field,” *Electrochim. Acta*, 2011.

[14] E. Chibowski and A. Szczęs, “Magnetic water treatment–A review of the latest approaches,” *Chemosphere*. 2018.

[15] W. K. Chen, *The electrical engineering handbook*. 2005.