Characterization of Bio-battery from Tropical Almond Paste

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Abstract. Bio-battery is a device that generates electricity from organic compounds. However, organic compounds derived from crops should be avoided in order to prevent food shortages. The tropical almond (Terminalia catappa L.) widely known as “ketapang” in Indonesia is considered as potential bio-fuel cells for bio-batteries since it is rich in sugar, a non-crop and grows abundantly in Indonesia. In this study we developed a bio-battery prototype from tropical almond paste. The characterization of this device yields an average open cell voltage of 0.98 ± 0.09 V, and the power curve shows a peak value of 0.25 mW with a stable current lasting up to 2 days while observed when the device was connected to a load of 100Ω. This device may be suitable to apply in rural communities.

1. Introduction

Energy is the primary requirement of human survival, which may come from non-renewable energy sources such as petroleum, coal, oil, natural gases, and also from renewable sources such as geothermal, solar energy, wind, water and biomass [1]. Currently, the non-renewable sources are still dominantly used worldwide. However, the significant increase of the human population has created energy crisis problems [2]. On the other hand, the damage to the environment caused by emissions of carbon dioxide added other serious issues we must face. These issues lead to the development of renewable energy technology inventions [3].

The renewable energy technologies basically produce energy by converting natural resources into useful energy forms [4]. One example is the bio-battery, a device that generates electricity from organic compounds. Similar to the conventional one, bio-batteries have three major parts, an anode (-), a cathode (+), and an electrolyte [5]. Here, the electrolytes were used for bio-fuel cells instead of chemical fuel cells.

In most studies of bio-batteries, the glucose bio-fuel cell has become one of the most important potential energy sources. Glucose bio-fuel cells have an advantage over conventional fuel cells since they use enzymes as catalysts to directly transform chemical energy to electrical energy, where the enzymes break down glucose and release several electrons and protons [6]. Fruits and plants that contain sugar were recommended due to the fact that they have sufficient chemical energy that can be converted into electrical energy [1]. In addition, cornstalks, citrus fruits, and other agricultural crops were known for their potential as bio-fuel cells [1-2]. Nevertheless, the high demand of food may raise the food vs. bio-energy issue, consequently non-crop fruits or plants are more desirable to be used to produce bio-batteries.

Terminalia catappa L, popularly known in Indonesia as “ketapang”, is a spreading tree that belongs to the Combretaceae family [7]. It is highly distributed in many tropical areas, including Indonesia [8]. The nut within the fruit has a similar taste to that of the almond; therefore, this particular fruit is called the tropical almond. The physiochemical study of the almond nut has revealed that the seed is rich in
sucrose and had trace amounts of glucose and fructose [9]. Although known as a source of nutritional oil [10] it is also reported as a possible source for biodiesel oil production [11]. These facts had driven us to discover the prospect of tropical almonds as a source of bio-fuel in bio-battery devices. Moreover, the abundance of tropical almonds leads to a low risk of food shortages. The purpose of this study is to develop an inexpensive, simple, and practical type of bio-battery from tropical almonds, making it extremely suitable for rural communities.

2. Experimental Methods

2.1. Materials and instruments
The materials used in this research were tropical almond fruits, sterile water (Wida WI Uncap), copper electrodes, zinc electrodes, copper electrical wire, alligator clips, and beakers. The instruments used in this research included an electronic blender (GMC Dry & Wet Mill BL-001), electronic scale balance (Ohaus AV812), a digital multimeter (Extech MN35), and a decade resistance box (Extech 380400).

2.2. Bio-battery construction
A bio-battery device was constructed using an indirect galvanic cell [1]. In this experiment, the tropical almond paste was made by grinding then blending with sterile water with a ratio of 1 to 1 using a household blender. The paste was transferred to a plastic container (4 cm × 4 cm × 5 cm). One electrode of each metal (zinc and copper) of dimension 3 cm × 3 cm was inserted into the paste with a distance 4 cm apart from each other. A copper wire was connected to each electrode on one end and the other end was connected to crocodile clips. Two identical devices were made for both current production and electrochemical characteristics.

2.3. Bio-battery characterization
The open circuit voltage was measured by connecting the positive terminal to the zinc electrode and the negative terminal to the copper electrode. Current production characterization was measured while the device was connected to a 100 Ω resistor for every 4 hours up to 7 days of measurement. The electrochemical characterization was revealed from the polarization and power curve. This was done by measuring the voltage obtained from varying the resistance (10000, 8000, 5000, 3000, 1000, 800, 500, 300, and 100 Ω) between anodes and cathodes of the cells. The current and the power at each resistance were calculated from the measured voltage.

3. Results and Discussions
The bio-battery prototype from tropical almond paste was successfully developed showing an open circuit voltage of 0.865 V (Fig.1). This result was comparable with the similar indirect galvanic cell from juice of citrus fruits, such as the lemon (0.91 V), orange (0.82 V) and grapefruit (0.88 V) [1].

The benefit of using this tropical almond paste was due to abundant stock in Indonesia. Moreover, the procedure used to develop this bio-battery device was found easy and reproducible just by using household appliances. For future application, such as LED or cell phone charging power source, the cell units may be connected in a series combination to achieve higher circuit voltage [1].

Figure 2 shows (a) the polarization curve and (b) the power density curve from the bio-battery device measured on day 0. The polarization curve shows an average open cell voltage (OCV) of 0.98 ± 0.09 V, and the power curve shows a peak value of 0.25 mW (at $V_{\text{cell}} = 0.498$ V). Although this power value was observed to be relatively lower, this power can be increased by applying parallel combinations.

![Figure 2](image_url)

**Figure 2.** (a) the polarization curve and (b) the power density curve of the bio-battery device.

Current production characterization for more than 7 days was shown in figure 3. The currents were found to increase slightly up to 2 days. However, the trend showed a significant decrease over 7 days with a minor spike in current production between day 5 and day 6. Hence, we studied more details of the electrochemical properties of our device.

![Figure 3](image_url)

**Figure 3.** Current production of the bio-battery device ($R = 100 \, \Omega$)

We plotted the power curve every 24 hours and observed interesting trends. Figure 4 (a) shows the power curve of the device measured on day 0 (scatter line), days 1-3 (dash line), and day 4 (solid line). Meanwhile, figure 4 (b) shows the power curve measured on day 5 (scatter line), day 6 (dash line), and day 7 (solid line). There are obvious increases in the current and power from the curve measured on
days 0-3, with decreases in the peak power value. However, no peak was observed from the curve measured on day 5. Figure 4 (a) indicated the presence of enough glucose on day 0, and gradually decreased till day 4.

![Power Curve](image)

Figure 4. The power curve of the bio-battery device measured on (a) day 0, days 1-3, day 4; (b) day 5, day 6, day 7.

Additionally, the power curve again shows peak on day 5 probably due to the presence of other sugar compounds that had already been naturally converted into simple form of glucose. Moreover, some double hump shapes observed on day 6 and day 7 possibly indicated a lack of glucose present [4]. The secondary current production suggested that it may come from decomposition of the electrolyte paste on day 5 and thereafter [12]. Further studies on the presence of glucose may be needed in order to confirm the mechanism of the current production in the device.

4. Conclusion
A prototype of bio-battery device from tropical almond paste was been developed. The device was inexpensive and easy to reproduce, making it suitable to apply in rural areas. The characterization of the device yielded an average open cell voltage of 0.98 ± 0.09 V and power of 0.25 mW. The daily power curve trend indicated that a presence of glucose may be responsible for the current production. Series and parallel combinations should be developed in the future to achieve higher circuit voltage and power values.

References
[1] Khan A M and Obaid M 2015 J. energy South. Afr. 26(3) 90-9.
[2] Pathak S 2014 Int. J. Eng. Res. Appl. 4(3) 845-51.
[3] Dincer I 2000 Renew. Sustainable Energy Rev. 4(2) 157-75.
[4] Hartley DL. 1990 Perspectives on renewable energy and the environment ed J W Tester, D O Wood, N A Ferrari (Massachusetts: MIT) p 14-27
[5] Siddqui U Z and Pathrikar A K 2013 IJRET2(1) 99-111.
[6] Wang J-Y, Nien P-C, Chen C-H, Chen L-C, and Ho K-C 2012 Bioresour. Technol. 116 502-6.
[7] Nwosu FO, Dosumu OO, Okocha JOC. 2008 Afr J Biotechnol. 7(24) 4576-80.
[8] Thomson L A J and Evans B 2006 Species Profiles for Pacific Island Agroforestry Terminalia catappa (tropical almond)ver 2.2, ed C R Elevitch (Hōlualoa, Hawaii: Permanent Agriculture Resources) p 1-20.
[9] Majdeckaa D, Draminskaa S, StolarczykaK, Kizlinga M, Krysinska P, Golimowska J, Biernatb J F and Bilewiczca R 2015J. Electrochem. Soc. 162(6) F555-9.
[10] Agunbiade S O and Olanlokun J O 2006 PJN 5(4) 316-8.
[11] Dos Santos IC, de Carvalho SH, Solleti JI, Ferreira de La Salles W, Teixeira da Silva de La Salles K, Meneghetti SM. 2008 Bioresour Technol. 99 6545-9.
[12] Schröder U 2007 Phys. Chem. Chem. Phys. 9(21) 2619-29.