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PERFORMANCE ENHANCEMENT OF BIOBATTERY FROM TROPICAL ALMOND PASTE USING ACETIC ACID ADDITION

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ABSTRACT

Biobattery is an alternative energy device that uses organic waste without hazardous chemicals. It is further reported that tropical almond (*Terminalia catappa* L.) is rich in glucose content, making it a potential electrolyte for a biobattery device, although the power performance is not optimal. Therefore, this research aims to improve the performance of biobattery from tropical almond paste with the addition of acetic acid. Biobattery cells were constructed using the galvanic cell method, while the tropical almond paste as an electrolyte was stored in a box container with a volume of 600 cm^3, then attached with copper and zinc metal plate as cathode and anode. Five typical devices of biobattery were made with various acid concentrations of 0%, 10%, 20%, 40%, and 80% which were added to the electrolyte. The results showed a significant enhancement of power performance, from 0.25 mW without any acid up to 1.62 mW with acid addition. The biobattery from tropical almond paste added with acetic acid of 20% had the best performance. Based on the results, the characterization of this device had an open cell voltage of 0.93 V, and the power curve showed a peak value of 1.62 mW at a current of 3.29 mA, with a stable current lasting up to 200 hr.

Keywords: biobattery performance, tropical almond, electrolyte paste, glucose, acetic acid.

INTRODUCTION

A battery is an electronic device that works directly to convert chemical energy into electrical through electrochemical reduction and oxidation, also called redox reactions [1]. In general, it consists of an anode or cathode which indicates negative or positive electrode, respectively, and also an electrolyte. Electrochemical charge transfer reactions occur at the interface between the electrodes and the electrolyte, and these reactions convert chemical into electrical energy which is used as an energy source for various electronic devices [2,3]. The chemical energy sources battery widely used currently usually contain heavy metals such as mercury, lead, cadmium, and nickel [4]. The massive use can lead to an increase in heavy metal waste, which might pose a serious environmental threat when there is no proper treatment [5]. Consequently, an alternative environmentally friendly battery source material is needed, such as organic materials [6].

In simple terms, a biobattery is defined as a storage device which energy source comes from organic compounds, and does not contain harmful chemicals[7]. It was popularized by Professor Kenji Kanodari from Kyoto University, who explained that the electrolyte of the battery was replaced as carbohydrates, glucose, amino acids, or protein enzymes [6]. Microbes, fruits, and vegetables are organic compounds that also have high potential as electrolytes because they contain glucose, nitric acid, and enzymes [8,9,10].

Several research have been conducted in Indonesia in relation to the development of biobatteries made from fruits and vegetables. Orange peels which are rich in citric acid content produced an open cell voltage of 1.4 V, while the combination of tamarind and orange peels increased the voltage up to 1.7 V [11]. Furthermore, cassava peels are also commonly used as biobattery materials due to the acidic compounds such as acetic acid (CH_3COOH) and cyanide acid (HCN), as well as pineapple peels which contain citric acid ($C_6H_8O_7$)[12]. The new proposed local Papuan betel nuts were used as a potential electrolyte and produced a voltage of 0.98 V, with current density and power density performance of about 6.67 $\mu W.cm^{-2}$ and 48 $\mu A.cm^{-2}$, respectively[13]. Potatoes, lemons, limes, and apples that can produce bright LEDs also have a high open cell voltage, in the range of 1.35 to 3.4 V [14]. However, the development of biobatteries based on fruits and vegetables requires a very large amount of resources, hence, this can cause new problems, such as a food crisis. As a solution, biobattery development needs to more be focused on non-food crops [15].

The tropical almond plant (*Terminalia catappa* L.) was selected because it has dense leaves, fruit, a high level of productivity, and is widespread in Indonesia [16]. Therefore, tropical almond paste-based biobattery is a good alternative, because it is available in large quantities and is not a source of food [15]. The biobattery energy source comes from the glucose content, where fresh tropical almond pasta can have a glucose concentration of 23.9 mg/ml, which can produce a current of 1 mA, with a 100 resistor [17]. Although the glucose content of the tropical almond has been proven to play a dominant role, the addition of acetic acid is known to be very effective in increasing the performance of biobatteries[18]. Moreover, Kannan et al,[19] revealed that biobattery with natural plant ingredients must have a high acid content, or are strongly acidic.

Researchers continue for the increase of the power and current output, and also the lifetime of the biobattery. In this study, we focused on enhancing the performance of biobattery from a tropical almond paste base with the addition of acetic acid. The aim was to determine the effect of acetic acid addition on the performance of tropical almond paste-based biobatteries. The CH_3COOH acetic acid was chosen as an additional solvent in the electrolytic paste since it is safe, non-toxic, and also inexpensive[20]. The biobattery device performance, before and after CH_3COOH acetic acid addition, were examined, with the following parameters: the open cell voltage through the polarization curve, power and current production, and battery lifetime[15, 21].

METHODS

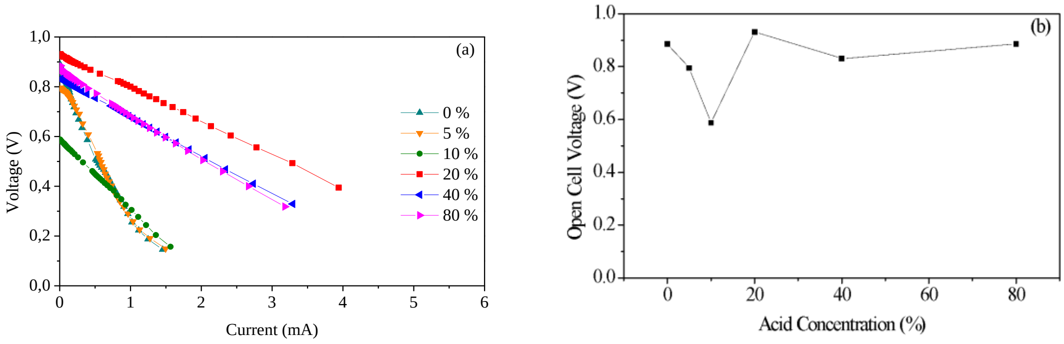
Biobattery cells based on tropical almond paste were made using the galvanic cell method [8]. Cells were stored in a box container with a volume of 600 cm^3, where copper and zinc electrodes were attached on both sides of the container, measuring about 3 cm × 2 cm each. The two electrodes were connected by wires and an alligator clamp. Furthermore, the tropical almond paste was obtained from tropical almond fruit with homogeneous ripeness. It was initially cut into pieces, the seeds were separated, ground until smooth, and then mixed in a ratio of 100 gr and 100 ml for tropical almond and aquadest solution, respectively, thereby making it an electrolyte paste.

The solution for making electrolyte paste was made from aquadest with the addition of CH_3COOH acetic acid with various concentrations of 0%, 5%, 10%, 20%, 40%, and 80%. The degree of acidity was measured using a pH meter sensor (PASCO PS-2102). Each electrolyte paste with various concentrations of prepared CH_3COOH solution was poured evenly into 6 biobattery cells, ensuring that the entire paste had covered the surface.

The performance of the tested device characterized include the open cell voltage, polarization curve, power and current production, as well as battery life-time through current versus time. The voltage was measured using a digital multimeter (ANENG A830L), and the resistor used was a decade resistance box (Extech 380400). After recording the voltage of the open circuit, the biobattery was coupled with a resistor by connecting the positive terminal on the zinc electrode, and the negative on copper. Current characterization was measured when the resistance was 100 every 4 hours, for 200 hours. Polarization characterization and power curves were generated by measuring the current when the resistance varied from 100 to 1 M Ω. The current and power values in each of these conditions were calculated from the measured voltage [13, 15].

RESULTS AND DISCUSSIONS

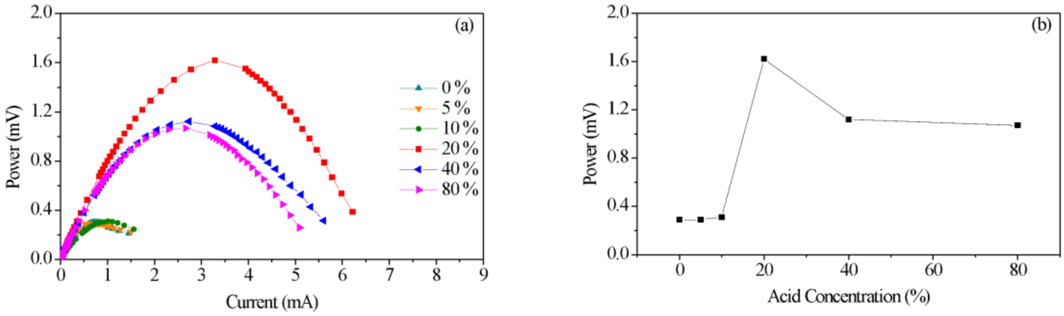
Figure 1 (a) shows the increasing polarization tension of biobatteries when the acid was added, and (b) shows the effects of acid addition to the open cell voltage of the biobattery. The highest open cell voltage received from biobattery tropical almond paste was found in the 20% acid. The open voltage decreased with 5% and 10% acid, but significantly increased with 20%. At the end, saturation was achieved at 40% of the acid concentration. This means the addition of 20% acetic acid on the electrolyte paste was found to be the optimum concentration to increase the performance of open voltage biobattery, since it showed the highest value compared to others.



(a) (b)

Figure 1. (a) The polarization curve, and (b) the effect of acid addition on the open cell voltage of the biobatteries

Figure 2 (a) shows the polarization curve from biobattery with the variation of acid concentrations. The addition of 20% acid to the tropical almond electrolyte paste increased the power production significantly, from 0.25 to 1.62 mW, where this is the highest value compared to others. The effect of acid addition shown in Figure 2 (b) confirmed that the highest performance was achieved from electrolyte paste added with 20% of acid. The subsequent addition of excess acid was found to reduce power production. This implies that the 20% acid addition was the optimum condition for enhancing the performance of biobattery from tropical almond electrolyte paste. Subsequently, the performance of the biobattery without and with 20% acid addition was compared.



(a) (b)

Figure 2. (a) The power curve of the biobatteries device; (b) The effect of acetic acid addition on the power maximum of the biobatteries

The durability of the biobattery was observed from the relation between current production and the period of connection to a 100 Ω resistor. Figure 3 shows the comparison of the durability without acid addition (0%) and with 20% acid addition. The biobattery without acid addition showed a drop in current production at the first 25 hours, then reached saturation of 0.5 mA after 200 hours. Meanwhile, the biobattery with 20% acid addition initially showed 20 hours current drop, but it produced current and was able to reach 2 mA after 200 hours. The decreased current production shown from biobattery without acid addition may come from the lack of glucose present, as has been shown in our previous study [15]. However, the acid content may trigger a hydrolysis of carbohydrates, so that electrons are produced and again increase the current production [22]. In conclusion, the biobattery with 20% acid addition enhanced the performance of the biobattery from tropical almond paste.

To examine the mechanism of current production for the biobattery, the measurement of the pH was conducted while connected to a 100 Ω resistor [13]. Figure 4 shows the changes of the pasta for 200 hours, at the first 50 hours, both curves have constant pH, but the electrolyte paste without acid addition slowly moved towards the neutral state. Therefore, biobattery with 0% acid starts losing its acidity, but 20% acid addition had relatively constant pH which affects its durability from tropical almond paste.

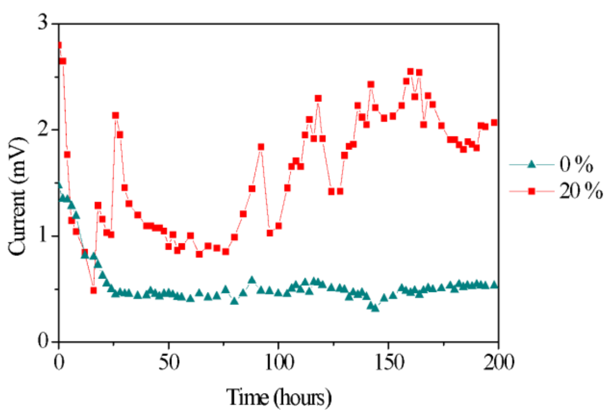


Figure 3. Lifetime of biobattery with a resistance of 100 Ω from that of without acid and with 20% of acetic acid addition

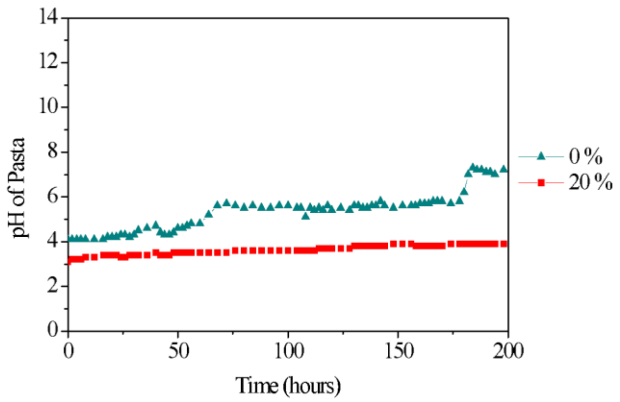


Figure 4. Relation of pH curve during the lifetime of biobattery, up to 200 hours from that of without acid and with 20% of acetic acid addition

Based on the results, the addition of 20% acid enhanced the performance of biobattery from tropical almond paste. Although the open voltage value shows no increase, the power performance was increased up to 1.62 mW or equivalent to a power density of 0.26 mW/cm². It has better performance compared to biobatteries from betel nut paste with a power of 6.67 μW/cm² [13]; or else rotten tomatoes and coconut pulp with a power of 1.56 mW [23]. This was caused by the combined role of glucose in the tropical almond and the acid in the electrolyte paste [17, 18]. As previously known, glucose is one of the promising energy resources used in biofuel cells because it is obtained by degrading cellulose [22, 24]. In this study, the acetic acid plays a role in accelerating the process of hydrolysis of carbohydrates (called the long chains), which are contained in a tropical almond paste into glucose (called the short chains) that can be utilized in biobatteries. When there is more glucose, there are also more electrons, which can improve the performance of the biobattery [22]. However, the excessive addition of acid can actually reduce biobattery performance. This suggests the importance of equal addition of glucose and acid [19].

CONCLUSIONS

Based on the results, the addition of acetic acid to the tropical almond paste-based biobattery significantly enhanced the performance, with the optimum acid concentration of 20%. This biobattery had an open cell voltage of 0.93 V with a power of 1.62 mW at a current of 3.29 mA. The durability also remained at a rated current of about 2 mA for more than 200 hours.

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