A preliminary study of corn cobs-clam shell (CCCS) biobattery

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Abstract. This study aims to determine the effect of calcium carbonate (CaCO₃) electrolyte on the conductivity value of electrolyte paste and electrical properties of batteries such as voltage, current and power generated. The electrolyte paste in this study was prepared by mixing corn cobs powder as sources of cellulose, PVA as gelling agent, and HCl as catalyst. The best conductivity value obtained from a mixture of CaCO₃ electrolyte of 0.5:1 (w/v) with addition of 0.5 grams of corn cobs powder and 1 gram of polyvinyl alcohol (PVA). The best result of electrical properties obtained from electrolyte paste with ratio approximately 0.5:1 (w/v). Overall electrical properties resulted from this study meet properties of commercial battery.

1. Introduction
Battery is an energy storage device transforming chemical reaction occurs within it to electricity [1, 2]. Currently circulating batteries is lithium-ion batteries. Lithium-ion batteries have several disadvantages such as flammable if exposed to heat and decreasing performance as the batteries gets hotter [3, 4]. As lithium content inside battery is a hazardous substance, battery disposal upon utilization become main environmental issue. Biobattery is one of the alternatives to replace lithium-ion batteries by using biological cells as their component [3]. Most of biobatteries today uses enzyme and microbes from natural materials as their components especially biomass originated from plantation, agriculture and upstream industrial activities [5, 6].

In spite of biobattery is safer and environmentally friendly, the shortcoming of biobatteries as electrolyte solid paste polymer is their low electrical conductivity value [7, 8]. Battery’s electrical properties such as voltage, current, and power are indicators to show performance qualities of batteries [9]. To increase the conductivity value, electrolytes such as salt of calcium carbonate (CaCO₃) can be added to replace lithium [10, 11]. Pulungan reported elsewhere fabrication of electrolyte paste biobattery from combination of banana skin and salt. Prior banana skin was mixed with salt to make electrolyte paste, banana skin was pureed. So far Pulungan’s report did not provide any information regarding conductivity values of his electrolytes paste [12, 13]. Minimum conductivity value requirement of a biobattery according to Linden and Reddy (1981) is 2 x 10⁻² S/cm [1]. With respect to Pulungan’s study, a preliminary study had carried out using corn cobs from agriculture waste as sources of electrolyte paste mixed with calcium carbonate (CaCO₃). The conductivity value of this particular biobattery was more than 2 x 10⁻² S/cm but should be increased so it able to supply energy required by simple electrical devices. For the purpose above, this study aims to investigate and evaluate corn cobs biobattery with clam shell CaCO₃ electrolyte paste especially the effect of CaCO₃ electrolyte to biobattery performance with respect to their conductivity value and level of voltage (V), current (I) and power. Overall, this study is expected to produce high quality and environmentally friendly biobattery.
2. Materials and Methods

2.1 Materials

Material used in this study consists of corn cobs powder as cellulose sources to form electrolyte paste, hydrochloric acid (HCl) as catalyst for gelling and calcium carbonate (CaCO₃) hydrolyzer, distill water (H₂O), polyvinyl alcohol (PVA) as gelling agent for paste making and sodium hydroxide as agent for precipitation. Except for corn cobs that obtained from local seller around Soewondo Air Base area in Medan, all materials for paste making is obtained from UD Rudang Jaya, Medan, North Sumatera while calcium carbonate as electrolyte extracted from clam shells (Anadara gradosa) bought from boiled shellfish sellers on Pandu Street, Medan, North Sumatera.

2.2 Preparation of CaCO₃ Electrolyte

A 1000 grams of clam shells are dried in the oven at 105°C for 2 hours. The shells then crushed with a ball mill and sieved for 150 mesh to obtain clam shell powder. The shells were then hydrolyzed with 1 M HCl and stirred with a magnetic stirrer at a speed of 500 rpm with temperature of 90°C above the hotplate. The mixture was filtered with Whatman filter paper no. 42. The filtrate was then precipitated by adding 1 M NaOH and washed with distill water until the pH was neutral. The precipitate CaCO₃ was calcinated in the furnace at 500°C for 2 hours.

2.3 Corn Cobs Paste Making

20 ml of HCl 0.1 M poured into a beaker glass and placed on the hotplate while heated. PVA of approximately 1 gram was added into HCl solution while dissolving it evenly using a magnetic stirrer at 90°C with a speed of 400 rpm until the solution has thickened and gel was formed. Corn cobs powder of 0.5 was added into gel solution until homogenized paste solution obtained and extracted CaCO₃ as much as 0.1:1; 0.25:1 and 0.5:1 (w/v) of paste solution respectively was added into the solution, stirred it until CaCO₃ has thickened evenly.

2.4 Battery Packing

The battery was fabricated by inserting the solution into the emptied and cleaned battery, with the only remaining material are cathode and anode. Conventional tissue used as the separator for the battery. Once the paste inserted, the battery then sealed using sealer [14, 15].

2.5 Testing Battery Performance

Battery performance is indicated by their conductivity value and electrical properties. Determination of battery’s conductivity and electrical properties in this study carried out at Physical Chemistry Laboratory of Chemical Engineering Department of Universitas Sumatera Utara. The electrolyte paste in this study was tested for its conductivity using Ohmic Heating Cell method while the electrical properties of fabricated battery was measured with Multimeter UNI T61E at response frequency of 45Hz ~ 10kHz and AC power supply of 0-220V/50-60Hz and current of 0-4A. The power was adjusted at 2A and 4V to record the voltage and current value on the paste during heating process while temperature was measured manually by a thermocouple and resistance (R) obtained from calculation by using Ohm’s law formula [16, 17]:

\[ R = \frac{V}{I} \]  

(1)

R value will be then used to calculate conductivity per square area (A) using Eq.(2) [18, 19]:

\[ \text{Conductivity} = \frac{I}{R \cdot A} \]  

(2)

The multiplication between voltage and current will obtained the generated battery power (P) by using equation:
3. Result and Discussion

Paste electrolyte in this study represent total of corn cobs, CaCO$_3$, PVA and HCl content inside the battery. In this study, various gram of clam shell CaCO$_3$ was added into biobattery electrolyte paste at constant corn cobs and PVA mass that represents as ratio of CaCO$_3$ to electrolyte paste in the following discussion. Design composition of electrolyte paste has explained in section 2.3. This CaCO$_3$ addition was expected to increase paste’s conductivity. Following discussion explained level of their presence in electrolyte paste that influences battery performance such as paste electrical properties and conductivity.

3.1 The Effect of Clam Shell CaCO$_3$ on Paste Ion Conductivity of CCCS Biobattery

Figure 1 shows relationship between ratio of CaCO$_3$ content in electrolyte paste with conductivity value results. Addition of CaCO$_3$ in electrolyte paste indicates increment of CaCO$_3$ - electrolyte paste ratio. CaCO$_3$ salt addition increases the number of ions within the electrolyte paste. The greater the number of ions present in the paste, the greater the movement between the ions, which results a higher conductivity value [20, 21]. It also increases the ionic charge and reduces the distance between ions [22, 23]. The best conductivity value result in this study was 2.412 x 10$^{-1}$ S/cm obtained from treatment combination of 0.5:1 (w/v) CaCO$_3$ - electrolyte paste ratio, 0.5 grams of corn cob powder and 1 gram of PVA. Maximum ion conductivity in this study is 12 times higher as compare to minimum conductivity of 2 x 10$^{-2}$ S/cm required by simple electronic devices. The lowest conductivity value is 1.961 x 10$^{-1}$ S/cm obtained from combination CaCO$_3$ to electrolyte paste of approximately 0.1:1 (w/v).

![Figure 1. Effect of CaCO$_3$ on paste ion conductivity of CCCS biobattery](image)

3.2 The Effect of Clam Shell CaCO$_3$ on electrical properties of CCCS Biobattery

In this study battery performance indicated by electrical voltage, current and power. The effect of clam shell CaCO$_3$ content level in electrolyte paste are illustrated in Figure 2 to Figure 4. Relationship between ratio of CaCO$_3$ content in electrolyte paste with voltage value in CCCS biobattery is shown in Figure 2. Figure 2 shows electrical voltage increases significantly at elevated ratio of CaCO$_3$ to electrolyte paste from 0.1 to 0.5 (w/v). Increment of CaCO$_3$ content in electrolyte paste gives rise to density of ion mobility or number of ion carriers within the paste, shorten the distance between ions and increase ions interaction within paste material. Thus, influences electrical properties of CCCS biobattery such as voltage [8].
This study observed maximum electrical voltage of 1.52 V as shown in Figure 2 from battery with CaCO$_3$ to electrolyte paste ratio while the lowest voltage was 1.38 V obtained from measurement of battery with CaCO$_3$ to electrolyte paste ratio of approximately 0.5:1 (w/v). All of electrolyte paste were mixed using similar mass of corn cob powder and PVA. Both maximum and minimum level of electrical voltage value meets nominal voltage of commercial battery in the market. Usually 1 commercial battery has nominal voltage of approximately 1.2 to 1.5 V depending to the brand product. Electrolyte conductivity in Figure 1 has actually derived from calculation of electrical voltage using Eq.(2).

The electric current of this CCCS biobattery is shown in Figure 3. Experimental data in Figure 3 explains relationship between ratio of CaCO$_3$ to electrolyte paste with electric current. Similar with electrical voltage, electric current increase at elevated CaCO$_3$ to paste ratio. The experiment conducted in this study resulted electrical properties that meet Eq.(1) as explained in the methodology section. Eq. (1) expresses electrical voltage is proportional with electric current. The amount of paste electrolyte of biobattery in this study affects the strength of the electric current produced. The more CaCO$_3$ content added into electrolyte paste, the higher the electric current produced by the battery. Electrolytes affects ions movement in the resulting paste. The greater the number of ions contained in the paste, the greater the electrical properties of the electrolyte material [8]. Thus, the strong current generated from the biobattery increases with the addition of CaCO$_3$ electrolyte. The best electric current in this study is approximately 28.430 mA while the lowest ones is approximately 6.110 mA that obtained from battery with CaCO$_3$ to electrolyte paste ratio of 0.5:1 and 0.1:1 (w/v) respectively. All of electrolyte paste that resulting maximum and minimum electric current in this study were mixed using similar amount of mass of corn cob powder and PVA. Biobattery in this study has capacity max of 28.430 mA or 50% below 50 mA. With refer to commercial battery with zinc-carbon, NiCd, Li-ion, NiMH, NiZn alkaline and Li-FeS$_2$ electrolyte respectively, battery capacity below 50 mA should provide current of approximately 400 to 2400 mAh.

Power resulting from biobattery in this study is calculated using Eq. (3) with respect to electrical voltage and current obtained from direct measurement utilizing Multimeter UNI T61E. The power and CaCO$_3$ to electrolyte paste ratio is shown in Figure 4. Power is obtained as the result of the voltage and electric current multiplication. Electrolytes increase the number of ions and affect ion mobility which increase battery voltage. As input voltage of battery is applied, the number of ions from electrolyte affects the amount of ionic charge that can be delivered from the anode to the cathode [5] so that the amount of electrolyte affects the power value because both are directly proportional to each other. The higher power observed in this study was approximately 42.986 mW while the lowest was 8.420 mW, each obtained from battery with CaCO$_3$ to electrolyte paste ratio of 0.5:1 and 0.1:1 (w/v) respectively. Maximum energy at nominal voltage and 50 mA drain with respect to commercial battery was 1.20 to 3.90 Wh for zinc-carbon, NiCd, Li-ion, NiMH, NiZn alkaline and Li-FeS$_2$ electrolyte respectively.
Figure 3. Effect of CaCO$_3$ on electric current of CCCS biobattery

Figure 4. Effect of CaCO$_3$ on power of CCCS biobattery

4. Conclusion
Electrolyte paste in this study resulted conductivity of approximately $2.412 \times 10^{-1}$ S/cm that 12 times greater as compare to minimum conductivity of $2 \times 10^{-2}$ S/cm required by simple electronic devices. It provides electrical voltage, electric current and power that meet commercial battery specification. The best biobattery in this study has electrolyte paste from combination of 0.5 gram corn cobs powder, 1 gram PVA and clam shell CaCO$_3$ content of 50% from total electrolyte paste (w/v).

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