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Characteristic of Ceremai Fruit Electrical Properties as Electrolyte Solution in Galvanic Cells

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Abstract: It has been conducted a research to analyze ceremai fruit (Phyllanthus acidus) as an electrolyte solution for galvanic cells. The materials used consisted of copper (Cu), zinc (Zn) electrodes and an electrolyte solution from ceremai fruit. Electrolyte solution with a concentration variation of 60 to 100% was obtained from pure ceremai fruit electrolyte solution mixed with aquades. In addition, the electrolyte solution is fermented in a period of 1 to 5 days. The variables measured were pH, voltage, electric current and electric power. Based on the data analysis, it was found that the value of the acidity level was proportional to the concentration where at 100% solution concentration the pH value was 4.8 and at 60% the pH value was 5.4. The greatest voltage is 1 volt that obtained when the solution is in the most acidic state or highest concentration. It is found that the greater the concentration of the solution, the smaller the pH value (the acidity level increases) the value of the voltage, current and power will increase. However, when the electrolyte solution is fermented, it appears that the pH value is inversely proportional to the voltage generated. The longer of fermentation time, the pH value will increase but the voltage value will decrease. When the electrolyte solution is fresh, the pH value is 4.8 with a voltage of 1 volt, but on the 5th day of fermentation the acidity level increases with pH value of 2.15 but the voltage decreases to 0.65 volts. This is caused by oxygen exposure at the time of measurement so that the oxygen in the solution will increase. An increase of oxygen will reduce the density of electrically charged ions so that the current will decreases and the voltage will also decrease.

Keywords: Ceremai fruit; Electrical properties; Electrolyte solution; Galvanic cell

Introduction

Indonesia is country that still relies on oil and coal as its main source of electrical energy. Currently, the supply of oil and coal is decreasing because the characteristics of these energy sources are non-renewable. But, energy needs are increasing so that the new energy as an alternative energy to be needs (Suciyati et al., 2019).

Alternative energy is an energy source that is produced from materials that have never been used before. Currently, research on alternative energy is increasingly being carried out, especially alternative energy sourced from nature and can be renewed (Sulaiman et al., 2020). Various types of alternative electrical energy have developed including electrical energy from solar cells. Solar cells energy has been used in various fields. However, other problems arise for the lower middleclass economy. Not all levels of society can enjoy this solar energy because the costs to obtain it is very expensive (Atina, 2015).

Basically, electrical energy can be obtained from various sources including fruits and vegetables, especially fruits and vegetables that contain a lot of citric acid (Sulaiman et al., 2020). Acidity in some types of fruit is able to produce electrical energy because it is an electrolyte. Fruits that contain mineral acids in the form of hydrochloric acid and citric acid are strong electrolytes that completely decompose into ions in aqueous solution(Atina, 2015; Sintiya & Nurmasyitah, 2019).

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There are two methods used fruit acid properties become the alternative energy such as bio-batteries (Khairiah, 2017; Pulungan et al., 2017; Sumanzaya et al., 2019) volta cells or galvanic cells (Mertin et al., 2021; Suciyati et al., 2019; Suryaningsih, 2016; Vassel et al., 2021; Vassel & Vassel, 2017, 2020). Bio-Battery is a battery with paste derived from natural that are environmentally friendly and do not contain harmful chemicals. The principle of bio-battery is involves the transport of electrons between two electrodes separated by a conductive medium (electrolyte) and provides electromotive force in the form of electric potential and current (Pulungan et al., 2017; Sumanzaya et al., 2019). Galvanic cell is an electrochemical cell that can cause electrical energy from spontaneous redox reaction. Spontaneous redox reactions can result in the electrical energy. A galvanic cell consists of two different metals used as anode and cathode and an acidic electrolyte solution as a source of ions that produce an electric current (Lacina et al., 2018; Mertin et al., 2021; Shevtsof et al., 2021; Sulaiman et al., 2020).

Previous studies have confirmed that the acidic properties of fruit can be used as an electrolyte solution in galvanic cells. Sulaiman et al., used a mixture using a mixture of star fruit and lemon as an electrolyte solution in several galvanic cells which produced a maximum voltage of 5.73 volts (Sulaiman et al., 2020). Suciyati et al., used oranges and orange peels as electrolyte solutions and produced a maximum voltage of 0.986 volts (Suciyati et al., 2019). Sintiya and Nurmasyitah used oranges and tomatoes as electrolyte solutions and produced a maximum voltage of 0.98 volts on orange electrolytes with Cu and Fe electrodes and 0.77 volts on tomato electrolytes (Sintiya & Nurmasyitah, 2019).

However, previous studies have used more fruits that contain high nutritional value for consumption. Therefore, we need other alternative fruits that are less consumed but have electrolyte properties with a high acidity level so that they can produce high electrical potential.

One of the fruits that can be used as an electrolyte solution is ceremai fruit. Ceremai fruit contains high acid properties (Zulfalina et al., 2018). Ceremai fruit is also quite rarely consumed but contains acid. The acid content in ceremai fruit comes from citric acid ($C_6H_8O_7$) (Suciyati et al., 2019). Therefore, in this study, we tried to analyze the electrical properties of ceremai fruit as an electrolyte in galvanic cells as alternative energi on electrical energy.

Method

This research is an experimental research conducted at the Advanced Physics Laboratory, Mataram State Islamic University. This research was conducted to determine the electrical characteristics of ceremai fruit (Phyllantus acidus) as an electrolyte solution for galvanic cells. The ceremai fruit used is the ceremai fruit which is yellowish green in color and is found in Central Lombok Regency.

The ceremai fruit firstly washed with clean water and then drained. The ceremai fruit then separated from the seeds so that the pulp remains. The pulp of the ceremai fruit is then mashed using a blender and filtered to produce an electrolyte solution. The electrolyte solution from the ceremai fruit was then diluted with several variations in concentration (100%, 90%, 80%, 70% and 60%) by mixing the solution with distilled water (Didik, 2020; Didik et al., 2021). The equation used to dilute the electrolyte solution of ceremai fruit used equation 1 (Didik et al., 2019; Islami et al., 2021).

$$c_1 . V_1 = c_2 V_2 \quad (1)$$

Where, c_1 is the concentration of the pure ceremai fruit electrolit (100%), V_1 is the volume of the pure ceremai fruit electrolit taken (mL), c_2 is the concentration of the desired solution (mL/L), V_2 is the volume of the total solution (100 mL). After solution with several variations in concentration was obtained, the solution was then measured the pH value using a digital pH meter. After that, the solution was then put into a galvanic cell as shown in figure 1.

Based on figure 1, galvanic cells are made using acrylic material shaped like an uncovered beam measuring 7 x 7 x 8 cm (Suciyati et al., 2019). The electrodes used are copper (Cu) as the positive electrode and zinc (Zn) as the negative electrode. The circuit is equipped with a Casey 2 Logger Pro type Laybold-524 002 with a voltage sensor with an accuracy up to 1 nV to measure the voltage value and an electric current sensor with an accuracy up to 1 nA to determine the value of the electric current generated by the galvanic cell. The value of electric power is obtained using the equation 2 (Didik & Wahyudi, 2020; Ningsih; et al., 2019; Sulaiman et al., 2020).

$$P = V \; x \; I \quad (2)$$

Where P is the electric power (watts), V is the voltage (volts) and I is the current generated by the galvanic cell(amperes).

In addition to concentration variations, measurements of voltage and electric current values were also carried out due to the fermentation of the electrolyte solution of the ceremai fruit. This is because fermentation can change the pH value of the solution so that it will affect the value of the voltage and current generated by the galvanic cell (Suciyati et al., 2019). In the study, the electrolyte solution of cermai fruit was fermented for 5 days with the measurement of the electrical characteristics of the cells measured in the span of 1 day.

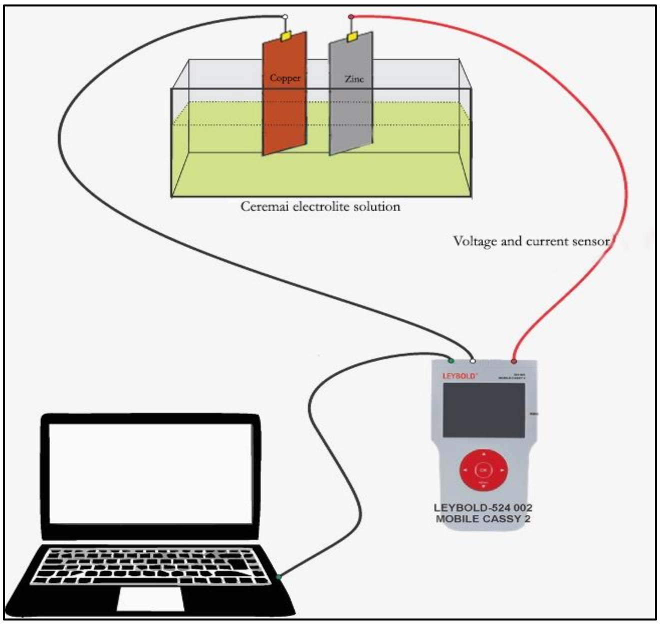

Figure 1. Schematic of voltage and current measurement in Galvanic cell

Result and Discussion

In the first experiment, measurements of pH, maximum output voltage and maximum current output were carried out in a galvanic cell with Cu-Zn electrodes filled with an electrolyte solution of ceremai fruit with several variations in concentration. The measurement of the electrolyte solution pH used digital pH meter while the measurement of the maximum current and voltage used the Casey 2 Logger Pro type Laybold-524 002 which equipped by voltage sensor and electric current sensor. An example of voltage measurement on galvanic cell shown in Figure 2

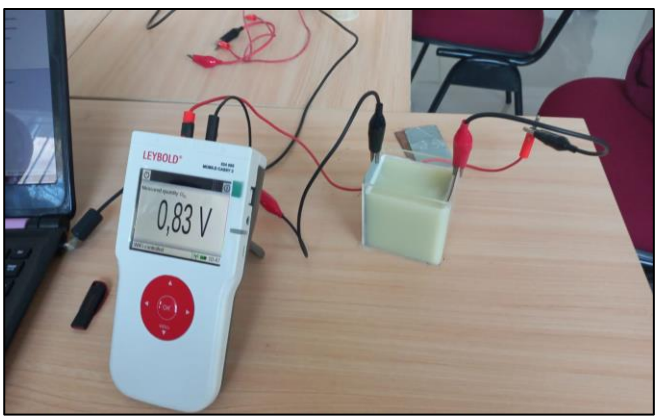

Figure 2. voltage and current measurement in Galvanic cell with concentration of 60%

Figure 2 shows the measurement of galvanized cell voltage at a ceremai solution concentration of 60%. The measurement results of all concentation variation of ceremai electrolite solution are shown in Table 1.

Based on table 1, it can be seen that the higher the concentration of the ceremi fruit solution, the higher the acidity level of the solution. Remember that the lower the pH value, the more acidic the solution (Atina, 2015; Suciyati et al., 2019). According to Ahennius theory, a solution is acidic depending on the concentration of H+ ions in the solution. With the addition of neutral aquadest, there will be a release of H+ ions in the electrolyte solution, as a result the pH of the solution will be greater so that the acidity of the solution will decrease (Suciyati et al., 2019).

Table 1. The results of measuring the electrical characteristics of galvanic cells with several variations in the concentration of electrolyte solutions

Electrolite Solution Concentration (%)	pH	Voltage (volt)	Current (mA)	Electric Power (mW)
100	4.8	1.00	5.13	5.13
90	4.9	0.99	5.08	5.03
80	5.1	0.90	4.73	4.26
70	5.3	0.85	4.48	3.81
60	5.4	0.83	3.28	2.72

Voltage and electric current in a galvanic cell due to the positive electrode of copper and the negative electrode of zinc. Copper and zinc spontaneous oxidation and reduction reactions due to the presence of an acidic electrolyte based on the reaction shown in equation 3 (Austin & Seminario, 2018; Gunawan et al., 2019; Lacina et al., 2018).

$$Cu^{2+} + 2e \rightarrow Cu\ (s)$$
$$Zn\ (s) \rightarrow Zn^{2+} + 2e \quad (3)$$

The reduction reaction occurs in copper which has a higher potential while the oxidation reaction occurs in zinc which has a lower potential. Copper has a cell potential of E^0_{cell} = 0.34 volts and zinc has a cell potential of E^0_{cell} = -0.76 volts (Lacina et al., 2019; Mondal et al., 2019). As a result, the potential difference in the galvanic cell generated by the zinc and copper electrodes theoretically is 1.10 volt (Cek, 2018; Gunawan et al., 2019).

The value of the maximum voltage and current produced by the galvanic cell with Cu-Zn electrodes decreases as the concentration decreases, which is also followed by a decrease in the acidity level of the solution. In a pure electrolyte solution based on ceremai fruit resulting voltage is 1.00 volts, the maximum current is 5.13 mA and the power is 5.13 mW. Electrical parameters of galvanic cell decrease with the decrease in the concentration of the solution that at a concentration of 60% of the electrolyte solution from the ceremai fruit, a voltage of 0.83 volts, a current of 3.28 mA and a power of 2.72 mW as shown in Figure 3.

If an electrolyte-conducting solution has a low acidity level (large pH) then fewer ions are produced so that the electric current produced is also smaller and consequently the conductivity is also getting smaller (Biesheuvel P. M et al., 2009). In simple terms, electric current can be defined as the flow of electrons in a conductor in a certain time. In electrolytic conductors, the flow of electrons is carried by conducting ions. Where the more acidic a solution, the more ions it produces, in other words the solution will be more electrolyte. On the other hand, the weaker the acidity of the solution, the fewer ions will be produced so that the ability to conduct electrons will decrease. The acidity of the solution is inversely proportional to the pH, meaning that if the acidity level of a solution is high, the pH of the solution will be smaller (Atina, 2015; Suciyati et al., 2019).

The smaller the pH of the solution made greater the current generated because more ions can be produced so that the ability to conduct electrons will be better. And the greater the pH of the solution, the smaller electric current produced because fewer ions are produced.

The maximum voltage and maximum current are produced at a concentration of 100% electrolyte solution. The maximum voltage generated is 1 volt. This value is close to the theoretical value of 1.1 volts. This is similar with several previous studies that analyzed galvanic cells with an acidic fruit-based electrolyte solution as shown in Table 2.

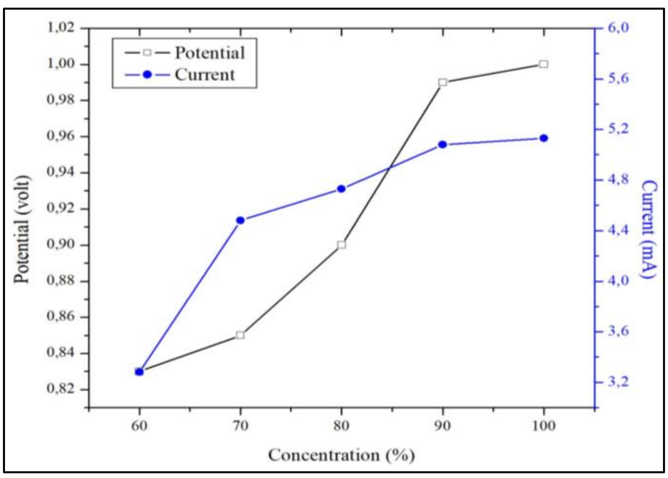

Figure 3. relationship between concentration and the maximum voltage and electric current produced by galvanic cell

Based on table 2, it can be seen that the highest acidity level was obtained from electrolyte sourced from lemons with a pH of 2.9 while the lowest acidity level was obtained from electrolyte sourced from tomatoes with a pH of 5.0. However, the maximum voltage of the highest galvanic cell is produced by ceremai which produces a voltage of 1.00 volts. This shows that the maximum voltage value in the galvanic cell is not only influenced by the level of acidity but is also influenced by other factors.

Table 2. Comparison of pH values and maximum voltage of galvanic cells with ceremai fruit electrolyte compared to other studies

The Fruit of Electrolite Solution Source	pH	Voltage (volt)	Reference
Ceremai	4.8	1.000	This study
Star Fruit	Not measured	0.800	(Suryaningsih, 2016)
Tomato	5.0	0.876	(Atina, 2015)
Pineapple	4.0	0.920	(Atina, 2015)
Apple	3.7	0.974	(Atina, 2015)
Lemon Orange	2.9	0.980	(Suciyati et al., 2019)

There are several factors that affect electrolysis including the distance between the electrodes, the immersed surface area and the metallic properties of the electrode material. The greater the electrode distance, the smaller the current and voltage generated (Lacina et al., 2018). The resistance between the electrodes will be smaller if the distance is getting smaller, so that it affected to the value of the electric current and voltage generated.

In this study, the surface area of the immersed electrode was kept the same for the measurement of each fruit extract. The electrode plate will be coated by a layer of oxidation results. the layer that coated the electrode is getting thicker. It's just that it seems clear that this layer differs from one fruit to another because of the different oxidation speeds between fruits. This of course affects the accuracy of the results of voltage measurements and the electric current produced by the fruit (Atina, 2015).

Table 3. Electrical voltage of a galvanic cell with an electrolyte solution fermented for several days

Fermentation Time (Days)	pH	1/pH	Voltage (volt)
0	4.86	0.20	1.00
1	4.72	0.21	0.93
2	4.61	0.22	0.91
3	4.47	0.23	0.88
4	3.45	0.29	0.72
5	2.15	0.46	0.65

To determine the effect of oxidation and reduction reactions on the electrode, the electric potential value of a galvanic cell was measured with an electrolyte solution that was fermented for several days. The results of measuring the electric potential value of a galvanic cell with a fermented electrolyte solution are shown in table 3.

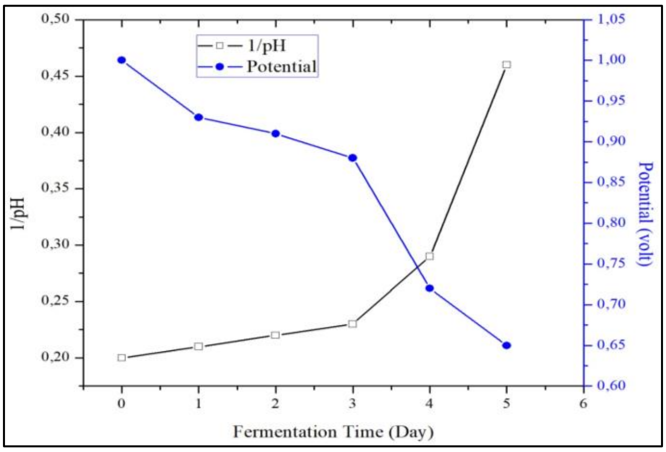

Figure 4. The relationship between the electrolyte solution of ceremai fruit fermentation time and the resulting galvanic cell voltage

When the electrolyte solution is fermented, it will the pH value is decrease which is a result of the electrolyte solution being more acidic when fermented. The highest level of acidity was obtained after the last day with pH value is 2.15. However, an anomaly occurs when the solution is fermented where the acidity level is inversely proportional to the electric potential generated by the galvanic cell. The lowest potential value of 0.65 volts is obtained when the acidity level is greatest, namely on the 5th day as shown in Figure 4.

Figure 4 shows the relationship between the duration of fermentation of the electrolyte solution and the resulting electric potential. It appears that the longer the fermentation time, the smaller the electric potential generated. The highest decreasing value occurred after the electrolyte solution was fermented for more than 3 days. Ceramai fruit electrolytes contain a lot of citric acid (C6H8O7) which is one of the minerals contained in acidic fruit. At the time of fermentation, the citric acid contained in the electrolyte of the ceremai fruit undergoes a process of binding electrically charged ions so that the acid level increases and the process of conducting electric current also increases. However, during the measurement process, there was exposure to oxygen in the electrolyte solution of the ceremai fruit so that it underwent an oxidation process in which hydrogen ions (H+) were released (Suciyati et al., 2019).

The oxidation process also causes the density level of electrically charged ions to decrease due to the increasing amount of oxygen so that the process of conducting electric current in the electrode material becomes increasingly difficult. In addition, this oxidation process causes corrosion to occur on the Zn electrode metal used which also results in smaller currents and voltages with each addition of fermentation time (Cek, 2018; Li et al., 2021).

Conclusion

Based on the results of research and data analysis, it can be concluded that the concentration of the electrolyte solution of ceremai fruit will affect the value of pH, voltage, current and power generated by a galvanic cell with Cu-Zn electrodes. The greater of the solution concentration, the smaller the pH (strong acid) value but increased the value of the voltage, current and power generated. However, when the electrolyte solution is fermented, it appears that the pH value is inversely proportional to the voltage generated by the galvanic cell. The longer the fermentation time, the pH value will increase but the voltage value will decrease. This is due to exposure to oxygen at the time of measurement so that the oxygen in the solution will increase. An increase of oxygen will reduce the density of electrically charged ions so that current decreases and the potential of the galvanic cell will also decrease.

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