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Abstract. The use of sap of plant as electrolyte in Galvanic cell system consisted of zink or iron and copper electrodes is considered as a renewable alternative energy by utilising the spontaneous redox reaction to produce electricity. We study in two ways, in laboratory to learn the effect of sap to Galvanic cell potential and in field with *Spondius pinnata* trees at Rantau Aceh as the pilot place for electricity from trees project. Sap of plants observed were *Aloe vera* as the main object and banana and *Spondius pinnata* stems as comparisons. Then, the saps were used as electrolytes in Galvanic cell to produce electricity. The potential resulted from the cell was measured varied with the pairs electrodes used. The potentials were also measured for the cell using varied electrolytes from saps of plants as well as mineral acids, aquadest and tap water from ground water. Atomic absorption spectrophotometer was used to measure the presence of metal ions in saps. The results showed that the presence of zink or iron and copper ions in sap of the plant observed caused the high potential of the Galvanic cell system as comparison the potentials were lower for electrolytes using mineral acid, tap water as well as aquadest. Meanwhile the distance of electrodes had no potential effect and non linier potential was resulted for the series of the Galvanic cell. To harvest the electricity, iron and copper electrodes inserted in *Spondius pinnata* plants were used as the source of electricity from trees at Rantau, Aceh to illuminate the remote area at the night.

1. Introduction

The use of fossil fuel nowdays still becomes a priority for human being need, such as for industrial activity, electricity generation and fuel for automotive vehicles, but the fuel will soon run out in the near future. Therefore, it needs an alternative renewable energy that are environmentally friendly. The sources of renewable energies can come from wind [1, 2], ocean [3], and photovoltaic cells, as well as the energy comes from plants. Researches of living plant energy by harvesting electricity produced from plants has been carried out. They applied a Galvanic cell reaction on *Aloe vera* leaves using Cu-Zn wire

electrode [4-6], and other plants using Cu-Fe, Al-Zn, Cu-Al electrodes [7], however, they used small wire as the electrodes. In this work plate electrodes as a replacement of small wire were used as a galvanic cell in *Aloe vera* leaf and banana `stem as well as the effect of other electrolytes used in the Galvanic cell to get a higher power than previous work. Then copper pipe and iron rod electrodes of the Galvanic cell with 15 cm length were applied in a bigger living plant (*Spondius pinnata* tree) as an alternative energy to harvest electricity at Rantau, a remote area in Aceh, Indonesia. Since *Spondius pinnata* are easy to be planted and can also be used as anticancer [8], this plant were chosen as a sap source (sticky sap with turpentine smell [9]) of the Galvanic cell.

2. Experiment Methods

Copper and zink electrodes (*pa* grade) were cut with a dimension of 2 cm × 2 cm, then connected with wires by soldering. After that the electrodes were plugged into the objects being studied (*Aloe vera* leaf, banana stem, *Spondius pinnata* stem), the potentials were measured using multitester (Heles). Beside that, mineral acids and tap water of ground water were used as the electrolytes as the replacement of the sap. The potentials were also measured for varied distances of the electrodes when they plugged into the *Aloe vera* leaf. Atomic absorption spectrophotometer (AAS Buck Scientific FTG 210) was used to determine the copper, zink and iron ions in the sap samples using procedure [10]. Since *Spondius pinnata* are easy to be planted, these plant were chosen as a sap source (sticky sap with turpentine smell [9]) for Galvanic cell to harvest electricity from living plants at Rantau, Aceh by inserting iron and copper electrodes. The stem diameter of the living plant was around 20 cm. The electrodes consisted of iron rod (from steel bar 1cm× 1cm×15 cm) and copper pipe (15 cm in length and 1 cm in diameter), then iron (electrode) was inserted into copper pipe after covered with fabric to avoid being contacted with copper pipe. The electrodes were connected with copper wires by soldering as contacts with other electrodes and connected to a load (LED, light emitting diode). To zip the cell in the *Spondius pinnata* stem, a drilling machine was used to drill oblique the stem with depth a little bit more than 15 cm, so that the cell could be inserted well in the plant. In every plant, we inserted 3 cells connected in parallel, and for the experiment we use 10 trees connected in series. To illuminate LEDs 5 W 220V, the potential was converted using inverter from DC to AC 220 V. The potential of the tree's electricity were measured both with and without loads and the potential recovery was observed.

3. Results and discussion

Electricity can be generated by applying Galvanic cell principle by using sap of plants (such as *Aloe vera* and stems of banana and *Spondius pinnata*) as electrolyte sources and iron or zink and copper electrodes. Galvanic cell using copper and zink electrodes has a reduction and oxidation reaction that occurs spontanoeusly. Copper as cathode and zink as anode. Since copper has E^{o}_{sel} = 0.34 V and zink has E^{o}_{sel} = -0.76 V, reduction reaction occurs at a cathode of copper that has a higher E^{o}_{cell}, while oxidation process occurs at zink electrode. Zink electrode releases electrons and becomes Zn^{2+} ion, while Cu^{2+} in the sap receives electrons and the ion become copper solid. The reaction as follows:

Cathode : $Cu^{2+} + 2e^{-} \longrightarrow Cu\ (s)$ (1)

Anode : $Zn\ (s) \longrightarrow Zn^{2+} + 2e^{-}$ (2)

or in cell notation is written as: $Zn(s)|Zn^{2+}||Cu^{2+}|Cu(s)$ (3)

The distances of copper cathode and zink anode electrodes in the Galvanic cell using *Aloe vera* sap were varied, then the potentials produced were measured using voltmeter. The result as is depicted in Fig. 1. The figure shows that the distance of electrode pair has no effect on potential measured, this is due to the similar gel containing in all part of the *Aloe vera* leaf and the potentials were almost similar close to 1.0 volt. The measured potentials were almost similar with Galvanic cell of zink and copper electrodes with their ion solutions of 1 M, namely 1.1 volt. Choo et al [7] measured a lower potential for the similar experiment, due to the lower electrode areas. This shows that in the *Aloe vera* sap contains copper and zink ion that make it possible to be used as an electrolyte in the Galvanic cell system of

copper and zink electrodes (as shown in Table 1). Beside that, the extracted sap of *Aloe vera* also gave a similar potential as living leaf of *Aloe vera*. This means the Galvanic cell still works when the electrolyte (sap) is in the liquid form.

Pair of copper and zink electrodes variation were set in series by inserting the pair of electrodes in a *Aloe vera* leaf as Galvanic cell then the potentials resulted were measured. Fig. 2 shows the result effect of series arrangement of the Galvanic cell.

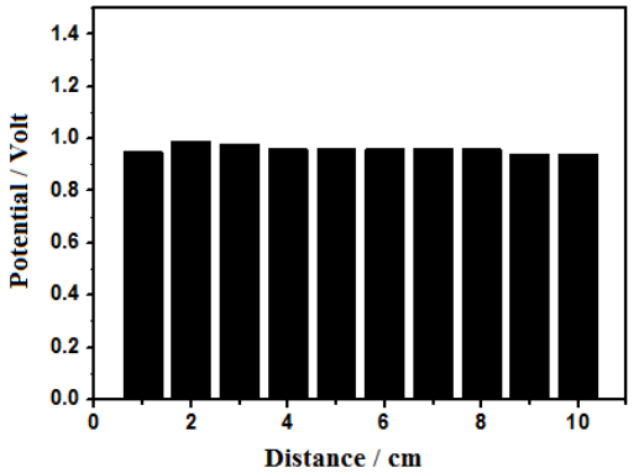

Figure 1. The dependent of potential by the distances of copper cathode and zink anode electrodes in the Galvanic cell using *Aloe vera* sap.

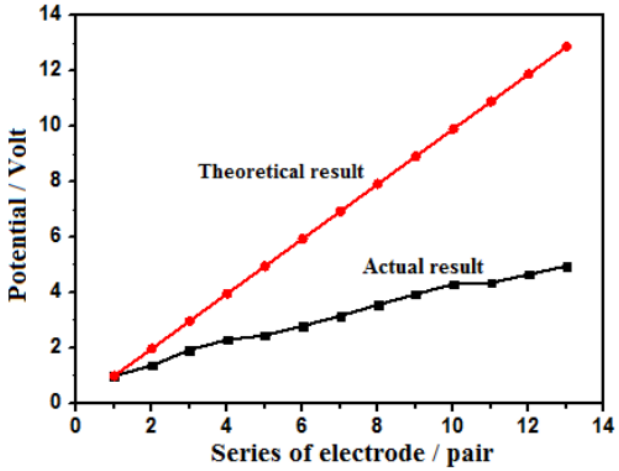

Figure 2. The dependent of potential (actual and theoretical values) by variation of series of electrodes of Galvanic cell using *Aloe vera* sap.

Fig. 2 shows that the more pair of electrodes used the higher potential measured, but the result has far from theoretical values. This might be due to the internal resistant of the Galvanic cell. This phenomenon also occurs by using sap of *Spondius pinnata* stem in the next discussion.

Variation of electrolytes used in the Galvanic cell of copper and zink electrode system with the potentials is depicted in Fig. 3. In the figure shown that the presence of copper and zink ions in the plant saps made the potential of Galvanic cell of copper and zink system higher as seen in banana and *Spondius pinnata* stem as well as *Aloe vera* leaf in the former discussion than in mineral acid (HNO_3, H_2SO_4 and HCl (1:1)) electrolytes. The mineral acids only improve the conductancy of the solution but have no copper and zink ions. Therefore, the pair of copper and zink electrodes system as well as their ions in the Galvanic cell were not formed. The lower potential also occurred using aquadest and tap water. The tap water gave the similar result as mineral acid when used as electrolyte in the Galvanic cell using copper and zink system, since tap water contains iron and mangan as well as calcium and magnesium ions [11]. The use of aquadest as electrolyte gave the lowest potential in Galvanic cell of copper and zink system because it has a bad conductivity (<2 μmhos/cm [16]). The measured potential is due to dissolution of remnant impurities in the electrodes to form ions in the solution. Meanwhile, the copper and zink electrodes dissolved when nitrate acid was used as the electrolyte due to the oxidation reaction by the acid.

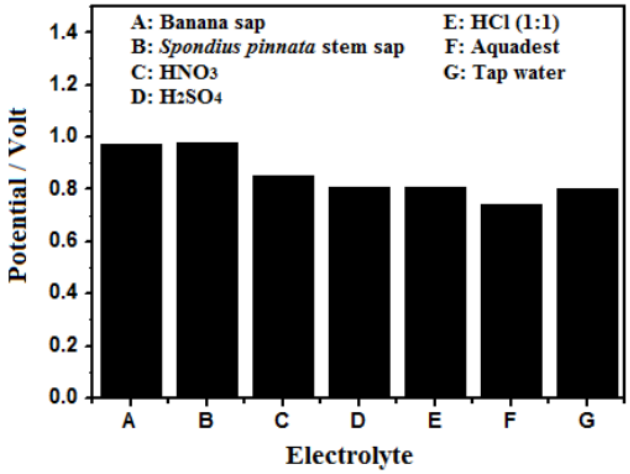

Figure 3. Variation of electrolyte to potensial of Galvanic cell of copper and zink electrode system.

The presences of copper and zink ions in saps of *Aloe vera* leaf, banana stem and *Spondius pinnata* stem were measured using atomic absorption spectrophotometer (AAS) and the results are given in Table 1. The Table shows that the saps of *Aloe vera* leaf, banana stem and *Spondius pinnata* stem contain copper and zink ions, therefore they will form a pair of metal and its ion, namely copper electrode and copper ions, and zink electrode with zink ions in the Galvanic cell that made the measured potential close to ideal (1.1 volt). The endurance of Galvanic cell depends on the ion supplies to the cell.

Table 1. Concentration of copper and zink ion in Sap

Metal	Sap Concentration (mg/kg)		
	Aloe vera leaf	Banana stem	*Spondius pinnata* stem
Cu	0.911	1.217	0.967

Zn	10.807	13.175	12.867

To use the Galvanic cell in remote area, iron rod from steel bar was used as anode electrode and copper pipe electrode as cathode. The iron used is due to the easiness to get in the remote area. Sap of living *Spondius pinnata* stem was used as electrolyte source in Galvanic cell of iron and copper electrode system. The electrodes were inserted in the stem after drilled more than 15 cm depth. Fig. 4 and 5 show the photographs of electrodes used and the potential measurement of a living plant of the Galvanic cell, respectively.

Figure 4. The photograph of electrodes used before inserted in the *Spondius pinnata* stem.

Figure 5. Photograph of potential measurement without load of the Galvanic cell using plant's sap.

To increase the potential of the Galvanic cell of living plant's sap, in one plant was inserted three Galvanic cell and connected in parallel, then from each plant connected in series with other plant (10 plants connected in series). The potential of each plant, and plants connected in series as shown in Fig. 6.

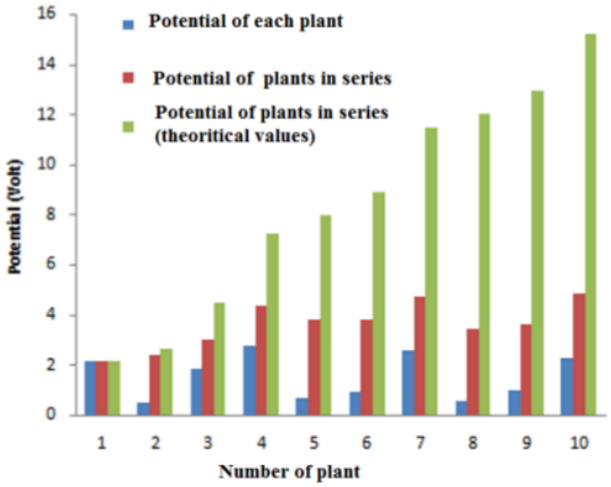

Figure 6. Potential value of plant as Galvanic cell in each plant and plants in series and their theoretical values when connected in series.

Fig. 6 shows that each plant as Galvanic cell has different potential value. Plant 1, 3, 4, 7 and 10 had a higher potential than plant 2, 5, 6, 8 and 9. When the potential of each plant was connected in series for ten plants, the value is lower than theoretical value. The behaviour was similar as the Galvanic cell using *Aloe vera*'s sap in former discussion. This can be the internal resistant of the cells was very high.

The potential of plants in series then, was loaded with small LED and after converted in AC using DC to AC converter, it was load with 2 and 4 lamps of 5 watt LED 220V. The curve is depicted in Fig. 7(a). When using small LED the potential drop was small. But after loaded with 2 pieces of 5 watt LED 220V the potential drop got bigger, even using more LED. The potential drop is due to the power is not high enough to turn on a bigger power of LED shown by increasing current and power consumed (Fig. 7(b-c)). This was also supported by the less brightness of the bigger power of the LED than a small LED. The high power of LED used caused the potential drop was difficult to restore back to the initial potential. But if small power of LED used the potential drop was easy to restore back to the initial potential as shown in Fig. 8.

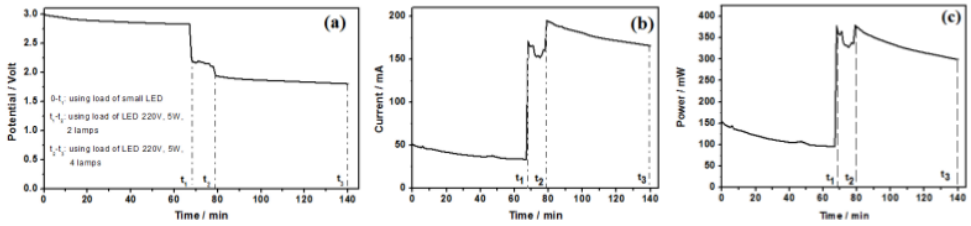

Figure 7. (a) Potential drops after the Galvanic cell of plant's sap was loaded with different lamps (LEDs). (b) and (c) the increasing current and power with the bigger load of the cell.

When the load of LED 5 W, 220 V was used, the output potential of the inverter also was measured at the time of t_2 until t_3. The potential was 18-20 V, while the output load of LED 5 W was 220 V. While $P_{LED\ 5W\ actual} = (20/220)^2 \times 5$ Watt = 0.041 watt or 41 mW. Consequently, the LED intensity was not so bright due to the low power supplied.

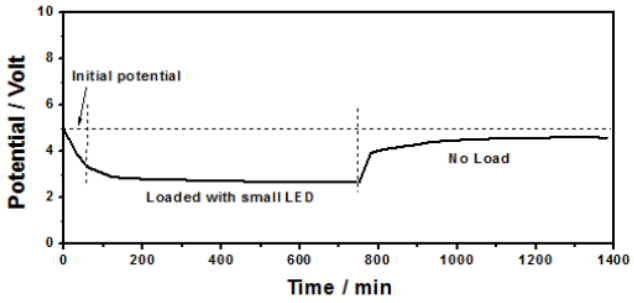

Figure 8. Potential drops after the Galvanic cell of plant's sap was loaded with small LED and the potential drop was restored to initial potential after the load was disconnected from the circuit.

Metal accumulation after the plants were used as Galvanic cell for 7 days can be seen in Table 2. Since there is dissolution of anode electrode (iron), the concentration of iron increased both in stem and leaf after used as Galvanic cell as shown in Table 2. The initial iron concentration in stem was 46.125 mg/kg and increased to 53.709 mg/kg after used as Gavanic cell. The similar behaviour also occured for iron concentration in leaf before and after used as Gavanic cell. However copper concentration was almost constant before and after in the sap of living *Spondius pinnata* stem used as Galvanic cell.

Table 2. Metal contents in *Spondius pinnata* sap before and after used as Galvanic cell measured using atomic absorption spectrophotometer.

Metal (mg/kg)	Sample			
	Stem		Leaf	
	Initial	Final	Initial	Final
Fe	46.125	53.709	83.697	90.185
Cu	0.911	1.217	4.230	4.342

4. Conclusion

Metal ion contents in sap of plants (*Aloe vera* leaf, banana stem, and *Spondius pinnata* stem) can be used as electrolytes in Galvanic cell of zink or iron and copper system with a higher potential compared with electrolytes from mineral acids, tap water of ground water and aquadest. The potential of Galvanic cell of plant's sap was not linear when the cells were set in series, and maximum potential of the series was ca 4 volt for 10 plants. The high power of LED used caused the potential of the cell dropped drastically that made it difficult to restore back to initial potential. Anode metal accumulations in the living plant increased in stem and leaf after used as Galvanic cell, while cathode metal remained constant.

Acknowledgement

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