Proceedings of the Technical Sessions, 28 (2012) 92-99
Institute of Physics – Sri Lanka

Biodegradable Plantain Pith for Galvanic Cells

N. Jayashantha, K.D. Jayasuriya and R.P. Wijesundera
Department of Physics, University of Kelaniya

ABSRACT

A number of locally available tubers/yams were studied as an electrolytic material for low cost environment friendly Galvanic cell. The cell was fabricated by sandwiching tissues made out of different types of tubers/yams slices between parallel Zn and Cu plates. A preliminary study revealed that cells made with plantain pith show comparatively better performance among the tested electrolytic materials. The performance of the cell was investigated by varying the separation between the electrodes and also by performing various treatments to the electrolytic material such as boiling and chopping after boiling. Best battery performance was obtained for chopped plantain pith after boiling. Stability of the battery fabricated with chopped plantain pith after boiling was tested by measuring the light intensity of a normal white LED with time. Results revealed that it is possible to light up LEDs for more than 500 hours provided the electrolyte is prevented from drying.

1. INTRODUCTION

An electrical battery is an electrochemical cell that converts stored chemical energy into electrical energy. Commercially available batteries contain heavy metals such as mercury, lead, cadmium, and nickel, which contaminate the environment when batteries are improperly disposed. Also they are very expensive to be used for long term lighting purposes. Studies on lemon cells [1, 2, 3] have shown promising results for possible power applications. Recently Golberg et al [4, 5] reported a significant performance improvement in a Zn/Cu-potato Galvanic cell. The objective of present study is to find a cheap biodegradable electrolytic material to fabricate an environment friendly low cost Galvanic cell.

2. EXPERIMENTAL

The Galvanic cell was fabricated by sandwiching tissues made out of different types of tubers/yams slices between parallel Zn and Cu plates of area 5×9 cm^2. Initially separation between two electrodes was set to 1 cm as shown in the Fig. 1. The entire cell was covered with polythene in order to maintain a well moist electrolyte medium throughout the investigation. Untreated, boiled, and chopped after boiling (CAB) states of plantain pith were further tested in order to determine the best state of the electrolyte for better battery performance.

Electrical properties of the cells were characterized by discharging through different resistors of 1.1, 2.0 and 3.1 Ω. Performance of the cell was studied by changing the separation between two electrodes (different thicknesses of the electrolytic material) in order to achieve optimum electrical output of the cell.

Fig. 1: A typical cell made out of chopped *habarala petiole*

The stability and life time of the Galvanic cell fabricated using CAB plantain pith was measured by testing the capability of the plantain pith battery to light normal white LED bulb. Four cells made out by sandwiching CAB plantain pith with a separation of d = 2.0 cm (which is the optimized separation) between the Cu and Zn electrodes were connected in series to a normal white LED bulb as shown in Fig. 2. Emitted light intensity from the LED bulb was continuously measured till the end of the life time of the Galvanic cell by without and with adding water to the plantain pith. Light intensity was measured by using automated light sensing system.

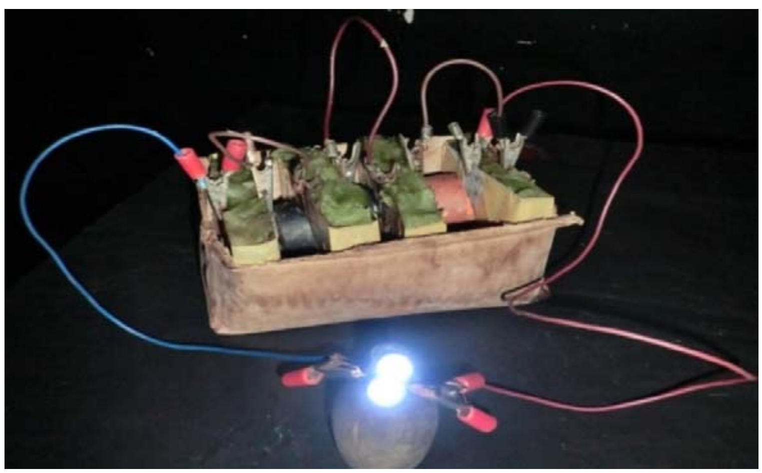

Fig. 2: A typical circuit arrangement for characterization of lighting application

Mineral composition of plantain pith was determined by colorimetric method, flame atomic absorption spectrometry and titration method in order to determine the internal reaction within the plantain pith. Further, different electrodes were tested to find out alternatives for Zn/Cu in order to enhance the OCV of the Galvanic cell.

Proceedings of the Technical Sessions, 28 (2012) 92-99
Institute of Physics – Sri Lanka

3. RESULTS AND DISCUSSION

Almost all locally available tubers/yams were studied as an electrolytic material for low cost environment friendly Galvanic cell. The cell was fabricated by sandwiching tissues made out of different types of tubers/yams slices between parallel Zn and Cu plates. Electrical performance of the cells fabricated using different tubers/yams available in Sri Lanka are shown in Table 1. Best cell performances can be obtained for the Knodala and Jawa ala. However, *Knodala* and *Jawa ala* are not better candidate for the low cost electrolytic materials for the Galvanic cell due to the rareness of the material. Considering the abundance and the costs involved, *habarala petiole* and plantain Pith were selected for further studies.

Table 1: Electrical performance of the cells fabricated using different tubers/yams available in Sri Lanka

Name	Before Boiling				After Boiling			
	Open circuit voltage (V)	Discharging current I(10^{-3}A)			Open circuit voltage (V)	Discharging current I(10^{-3}A)		
		R_1=1.1Ω	R_1=2.0Ω	R_1=3.1Ω		R_1=1.1Ω	R_1=2.0Ω	R_1=3.1Ω
Taro bole	0.906	0.403	0.364	0.347	0.926	6.62	4.83	4.49
Taro corm	0.886	0.689	0.679	0.661	0.916	5.51	4.91	4.62
Hingurala	0.880	0.676	0.620	0.610	0.953	3.73	3.18	3.06
Ratala	0.828	0.881	0.834	0.817	0.927	1.31	1.23	1.21
Manioc	0.863	1.656	1.615	1.585	0.967	4.41	4.26	4.09
Kondala	0.814	1.268	1.240	1.221	0.936	8.31	7.12	6.84
Kahata ala	0.859	1.649	1.535	1.518	0.925	4.81	4.70	4.69
Kiriala	0.873	1.004	0.924	0.718	0.855	4.57	4.08	3.74
Sweet potato	0.760	0.517	0.506	0.502	0.800	1.65	1.64	1.63
Rajala	0.832	1.142	1.074	1.048	0.899	3.96	3.89	3.76
Jawa ala	0.849	1.621	1.583	1.558	0.965	8.30	8.18	8.10
Ketala	0.815	1.230	1.160	1.060	0.851	4.28	3.76	3.50
Asparagus	0.698	0.885	0.859	0.839	0.858	5.02	4.40	4.21
Diyahabarala	0.852	0.489	0.443	0.340	0.909	6.64	4.87	4.28
Plantain corm	0.875	0.952	0.879	0.861	0.914	3.46	3.26	3.17
Plantain Pith	0.878	1.370	1.272	1.228	0.873	5.73	5.12	4.30
Habarala petiole	0.900	2.170	2.060	1.970	0.911	6.95	6.71	6.62
Habarala bole	0.816	1.070	1.010	0.990	0.892	6.59	4.59	4.27

Proceedings of the Technical Sessions, 28 (2012) 92-99
Institute of Physics – Sri Lanka

Zn/Cu-potato Galvanic cell has been well understood and reported in the literature [4]. Therefore the plantain pith and the habarala petiole Galvanic cells performances were compared with that of potato Galvanic cell. Table 2 shows the comparison of electrical performance of Zn/Cu – potato, Zn/Cu – plantain pith and Zn/Cu – habarala petiole Galvanic cells. Although high performance can be obtained for treated materials, highest performance was observed for chopped after boiling (CAB) plantain pith. Discharge currents of the cell have enhanced after boiling the electrolytic material. Treatment of boiling enhances charge transfer through the medium and more free chargers are available in the medium for the Galvanic cell process. Nearly four fold increment of the discharge current can be observed for the plantain pith.

Table 2: Comparison of the electrical performance of the Galvanic cells with potato, plantain pith and *habarala petiole* as electrolytic material under different treatments

Name	Type of treatment	Open circuit voltage (V)	Discharging current $I(10^{-3}A)$
Potato	Untreated	0.780	2.50
	After boiling	0.890	6.01
	Chopped after boiling	0.885	5.78
Plantain pith	Untreated	0.718	1.20
	After boiling	0.862	3.81
	Chopped after boiling	0.852	6.29
Habarala petiole	Untreated	0.900	0.882
	After boiling	0.911	5.45
	Chopped after boiling	0.948	1.868

These results reveal that plantain pith is a better electrolytic material than both *Habarala* petiole and potato and is the best option as it is a thrown away biodegradable material after the plantain yield.

The purpose of the battery is to store and release energy at the desired time in a controlled manner. Hence when a current is drawn out from a battery, the variations of both cell current and voltage with time, which is normally called a discharge curves, are important characteristics of a battery. Therefore discharge curves through a 300 Ω resistor for both potato and plantain pith Galvanic cells were measured and compared.

Fig. 3 shows the variation of current and voltage outputs of the cells with time for untreated, boiled and CAB potato electrolyte. At the beginning current and voltage outputs are high as shown in Table 2 but these values drop down to almost stable values within a short period. Results reveal that the better performance can be obtained for the boiled potato cells.

Proceedings of the Technical Sessions, 28 (2012) 92-99
Institute of Physics – Sri Lanka

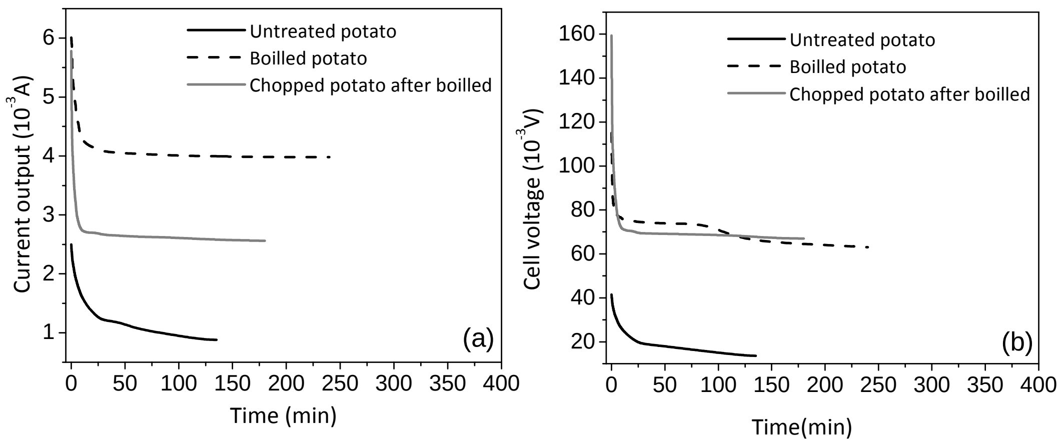

Fig. 3: Variations of (a) discharge current and (b) discharge voltage of the potato battery through a 300 Ω resistor with time

In the case of plantain pith batteries almost similar discharge curves were obtained as shown in Fig. 4. It was seen that the performance of the cells made from treated plantain pith were higher than that of the untreated state. Although the cell made from CAB plantain pith gave a high output current initially (~6.3 mA), both cells made from boiled and CAB plantain pith gave almost unchanged output currents (around 3 mA) after several hours. However, abnormal behavior in the discharge curves can be seen for the CAB plantain pith batteries before current and voltage outputs settled down to stable values. This may be due to rapid change in ion concentrations within the CAB plantain pith, but however further investigations are needed to explain this behavior.

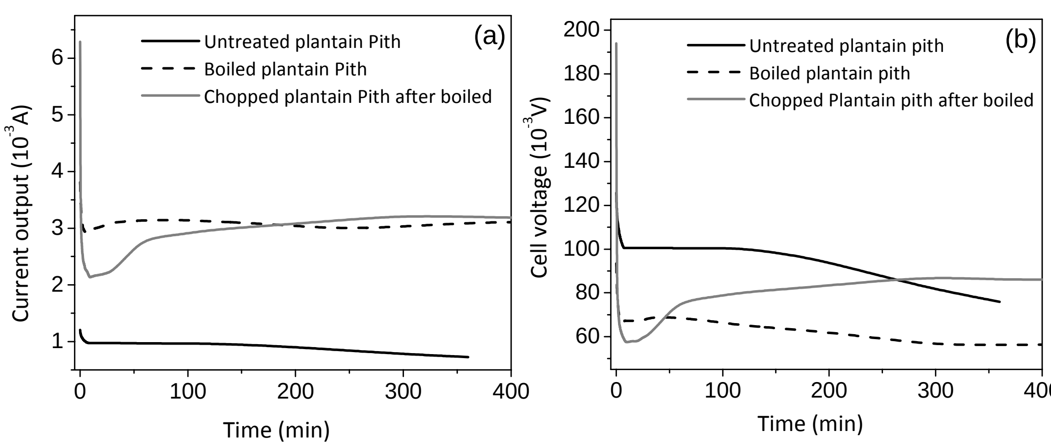

Fig. 4: Variations of (a) discharge current and (b) discharge voltage of the plantain pith battery through a 300 Ω resistor with time.

Fig. 5 shows the comparison of the discharge curves of CAB plantain pith and boiled potato Galvanic cells. CAB plantain pith Galvanic cell produces slightly high cell voltage and low current output at the steady state than the boiled potato Galvanic cell. Results reveal that CAB plantain pith is a competitive candidate as electrolytic material for the Galvanic cell even though it produces slightly lower current output than boiled potato.

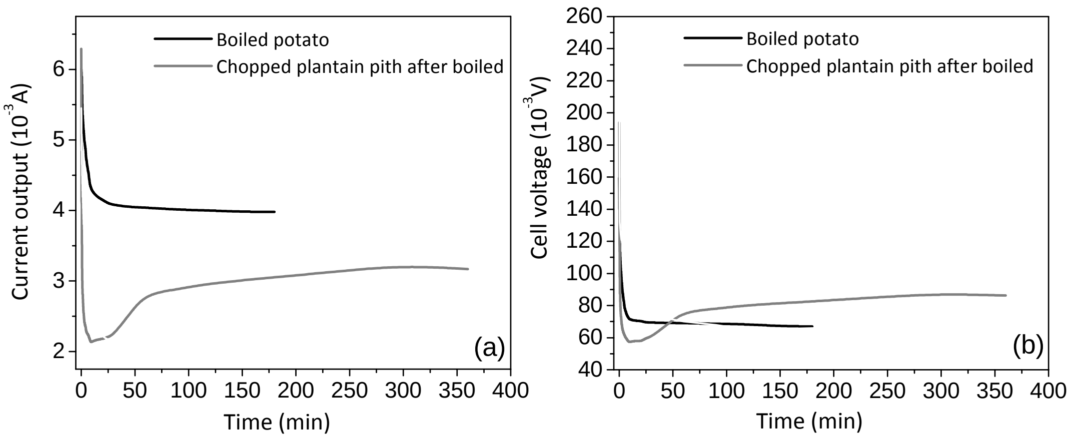

Fig. 5: Comparison of variations of (a) discharge current and (b) discharge voltage of the plantain pith and potato batteries through a 300 Ω resistor with time.

Geometrical optimization of the cell was carried out to enhanced battery performance. A cell parameter called cell constant K_{cell} (cm) which is defined as the surface area of an electrode over distance between electrodes is used to optimize the separation between the electrodes [4].

$$K_{cell} = \frac{area\ of\ a\ electrode\ (cm^2)}{seperation\ between\ electrodes\ (cm)} \quad (01)$$

Table 3: Cell voltage and current values for different K_{cell} values

d (cm)	K_{cell} (cm)	t = 0		t = 120 min	
		Cell voltage (mV)	Cell current (mA)	Cell voltage (mV)	Cell current (mA)
1.8	25.00	447	1.148	177	0.446
2.0	22.50	445	1.125	300	0.740
2.5	18.00	492	1.095	254	0.622
3.5	12.86	507	1.252	289	0.719
4.0	11.25	527	1.258	230	0.446

Initially, the separation between the electrodes was set to 1.0 cm. Cell voltage and current measurements through a 300 Ω resistor were carried out with time using the cells fabricated from CAB plantain pith for K_{cell} values ranging from 25.00 to 11.25. Table 3 shows the cell voltages and currents at t = 0 and t = 120 min for different K_{cell}

Proceedings of the Technical Sessions, 28 (2012) 92-99
Institute of Physics – Sri Lanka

values. Although the initial cell voltage increases as the K_{cell} (cm) decreases (*d* increases), maximum discharge voltage and current at the steady state can be obtained for K_{cell} = 22.50 cm (d = 2.0 cm). Thus the maximum cell performance was obtained for K_{cell} = 22.50 cm, which is related to the electrode separation of 2.0 cm.

The CAB plantain pith is found to be the best environment friendly low cost electrolytic material for Galvanic cell. The ability of producing electrical energy by using the Galvanic cell method should be converted to practical use in day to day life. The stability of the battery fabricated with CAB plantain pith was tested by measuring the light intensity of a normal white LED with time. Results revealed that it is possible to light up LEDs for more than 500 hours provided the electrolyte is prevented from drying.

In order to explain the reactions taking place inside the cell with plantain pith, the mineral composition of plantain pith was determined by colorimetric method, flame atomic absorption spectrometry and titration method and the results obtained are listed in Table 4. The highest anions concentration dominates by PO_4^{3-} in plantain pith. Thus the main contributor of hydrogen ions to the solution is mild phosphoric acid (H_3PO_4) and the net electrical potential of the cell is governed by the following reaction.

$$2H^+ + Zn \longrightarrow Zn^{2+} + H_2\text{ (gas)} : E_0 = 0.76\text{ V}$$

Table 4: Mineral composition of plantain pith

Substance	Concentration $\left(\frac{mg}{kg}\right)$
PO_4^{3-}	121.640
NO_3^-	1.021
Cl^-	24.850
Pb	0.368
Ni	0.660
Zn	104.752
Cu	83.600
Cr	14.360

Right throughout the present investigation Zn and Cu were used as the electrodes hence the OCV is about 0.76 V (potential for the reaction). A normal LED bulb requires a voltage more than 1.6 V to be needed to light LED. Hence three Zn/Cu-CAB plantain pith batteries are needed to light a LED but number of cells can be reduced if it is possible to find a cell arrangement which can give a higher OCV. In this respect different electrodes were tested with CAB plantain pith and results are shown in Table 5.

Proceedings of the Technical Sessions, 28 (2012) 92-99
Institute of Physics – Sri Lanka

Table 5: OCV measurements for different electrodes

Electrode		OCV (V)
Zn	C	1.413
Zn	Cu	0.740
Zn	Ti	0.613
Zn	Pt	0.963
Zn	Pb	0.323
Al	C	0.946
Al	Pt	0.814
C	Ti	0.516
C	Pt	0.309
C	Pb	0.743
Cu	Pt	0.350
Cu	Pb	0.287

According to the results shown in Table 5, highest OCV value can be obtained for Zn and C electrodes and it is around 1.4 V, which is almost the value 1.5 V given by conventional (A, AA) batteries. Hence the Cu electrode in the Zn/Cu-CAB plantain pith Galvanic cell can be replaced by the C electrode to obtain a high OCV.

4. CONCLUSION

Considering the cost and abundance of the material, plantain pith is a very good candidate for the electrolytic medium for Galvanic cells. Electrical performance of the cell can be enhanced by using chopped plantain pith after boiling. Results revealed that it is possible to light up LEDs for more than 500 hours provided the electrolyte is prevented from drying. Thus in conclusion, it is possible to fabricate a battery easily from cheap and environmental friendly material of plantain pith for low power applications.

REFERENCES

1. Daniel J. Swartling and Charlotte Morgan, *Lemon Cells Revisited-The Lemon-Powered Calculator*, Journal of Chemical Education, 75 (1998) 181.
2. Jerry Goodisman, *Observations on Lemon Cells*, J. Chem. Educ., 78 (2001) 516.
3. Kenneth R. Muske, Christopher W. Nigh and Randy D. Weinstein *A Lemon Cell Battery for High-Power Applications* J. Chem. Educ., 84 (2007) 635.
4. Alex Golberg, Haim D. Rabinowitch and Boris Rubinsky, *Zn/Cu-vegetative batteries, bioelectrical characterizations, and primary cost analyses*, J. Renewable and Sustainable Energy, 2 (2010) 033103.
5. Alex Golberg, Haim D. Rabinowitch and Boris Rubinsky, Galvanic apparent internal impedance: An intrinsic tissue property, 386 (2009) 168.