Journal of Fundamentals of
Renewable Energy and Applications

OPEN ACCESS Freely available online

Research Article

Bioenergy from Waste Paw-Paw Fruits and Peels Using Single Chamber Microbial Fuel Cells

Kalagbor Ihesinachi A[1,2*], Nwosu Lois N[2], Akpotayire Stephen I[3]

[1]*Research & Development Centre, Ken Saro–Wiwa Polytechnic,Bori, Rivers State, Nigeria*

[2]*Department of Science Laboratory Technology, School of Applied Sciences, Ken Saro–Wiwa Polytechnic,Bori, Rivers State, Nigeria*

[3]*Department of Biochemistry, University of Port-Harcourt, Choba, Rivers State, Nigeria*

ABSTRACT

The generation of electricity from waste paw-paw fruits and peels is one of the approaches to meet the population demand for energy. We have employed the use of single microbial fuel cells (SMFC) as an alternative source of generating electricity using microorganisms. The graphite used for the electrodes were obtained from discarded finger batteries. The waste paw-paw fruits and peels were weighed in varying quantities of 5kg, 10kg, 15kg and 20kg. The results obtained showed that the voltage and current produced from the 20 kg paw-paw waste were capable of lighting a 2V bulb continuously for one week. The decrease in voltage and current with time was as a result of decrease in the organic matter contents of the substrates used. The linearity relationship between voltage, current density and power density showed r2 values of 0.906 to 0.994 across the various weights of paw-paw waste used. The steady increase in conductivity values showed that the medium was capable of conducting electricity. A decreasing trend was observed in the results obtained for biochemical oxygen demand (BOD), dissolved oxygen (DO) and chemical oxygen demand (COD) for all the substrates. In this research, we achieved the conversion of paw-paw biomass to bio-energy using a simple and cheap method. The use of discarded finger batteries was an opportunity to convert waste to wealth.

Key words: Biomass; Bioelectricity; Voltage; Finger batteries; 2V bulb; Paw-paw; Microorganisms; Daily readings.

INTRODUCTION

Most of the energy around the world comes from non-renewable sources, including coal, petroleum, oil and natural gases which are being depleted at a higher rate [1]. Energy is a prime requirement of all sectors of an economy. This includes the industry, transportation, agriculture, hospitals as well as domestic uses without which advancement of technology and survival of life is not possible [2]. Despite having abundance of both renewable and non-renewable energy resources notably hydro, biomass, fossil fuels coal and natural gas, Nigeria is still being plagued with electricity crisis. The electricity crisis has hampered the socio-economic and technology of the nation and has compelled many industries to either shut down or relocate to neighboring countries thereby reducing job availability and national product. The development and deployment of waste-to-energy (WTE) technology in Nigeria was proposed [3] following the Swedish WTE model. It is expected that this will improve the epileptic power supply in the country as well asreduce the huge quantities of municipal solidwaste generated annually. The microbial fuel cell (MFC) technology provides the opportunity to generate electricity from a wide range of substrates. It is a biological system in which electrons produced from the microorganisms are transported over an anode, conducting wire and a cathode, thereby converting the energy directly into electrical energy [4,5]. In microbial fuel cells, microbes play crucial roles in energy production and the removal of organic contaminants. The single-chamber microbial fuel cell (SMFC) with an air-cathode has great advantages in terms of the structure, power density and aeration and is has been considered the most anticipated mode for practical application [6].The generation of bioelectricity has been achieved over the years using biomass[7-11]which includes agricultural crops, seeds and bio waste. It has been reported [12-15] that these are major sources of bioelectricity. Paw-paw contains sugar and other ingredients with sufficient chemical energy that can be converted into electrical energy by means of a redox reaction. Its high content of glucose and fructose and polysaccharides which are easily hydrolyzed makes it a viable source for bioenergy. The purpose of this research is to carry out a biotransformation of paw-paw waste into clean bioenergy and reduce the environmental pollution that arises from the accumulation of this organic waste.

***Correspondence to:** Kalagbor Ihesinachi A, Research & Development Centre, Ken Saro–Wiwa Polytechnic, P.M.B. 20 Bori, Rivers State Nigeria, Tel: 08033098983; E-mail: kalagbor.ihesinachi@kenpoly.edu.ng

Received: November 05, 2020; Accepted: December 26, 2020; Published: January 02, 2021

Citation: Ihesinachi KA, Lois NN, Stephen AI (2021) Bioenergy from Waste Paw-Paw Fruits and Peels Using Single Chamber Microbial Fuel Cells. J Fundam Renewable Energy Appl 11:1. doi: 10.4172/2090-4541.1000282

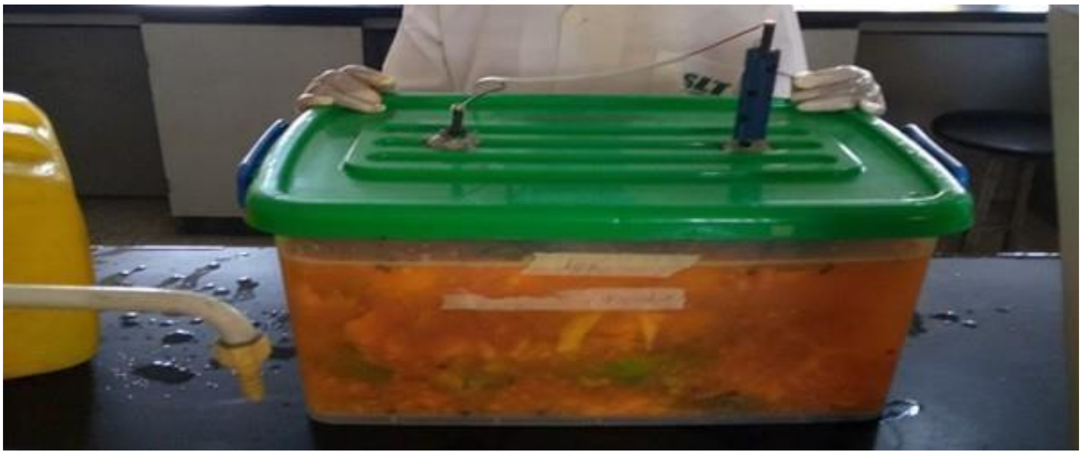

Figure 1: The SMFC set up ready and running.

METHODOLOGY

Construction of the Single Chamber Microbial Fuel Cells

The single chamber microbial fuel cell (SMFC) was constructed using a 25litre rectangular plastic container. The electrodes were constructed with 10mm diameter PVC (poly vinyl chloride) pipes filled with graphite extracted from discarded 1.5V finger batteries. The heights of the cathode and anode electrodes were 40cm and 25cmrespectively. The anode is not aerated while the cathode is porous and aerated (exposed directly to the air). The terminals of the electrodes were connected by a copper wire to 10,000 Ω resistor and digital multimeter was connected to the positive and negative terminals of the electrodes for current and voltage readings. This is shown in Figure 1.The SMFC was constructed and used in the laboratory at room temperature.

Collection of Sample Materials

Waste paw-paw fruits and peels were collected from different market dump sites and taken to the laboratory. The required quantity for the week's study was weighed out using a digital top-loading weighing balance (Model: SP20kg; capacity: 20kg/40lb) and were kept in the chamber to decompose for 3 days leaving it open to prevent heat from destroying the microbes.

Microbial fuel cell Procedures

The waste paw-paw fruit and peels which had been weighed on a scale were poured into the 25litre plastic container and reduced to pulp by hand. Water was added to the sample to make up the volume to 25litres. The SMFC container was properly secured by clamping the sides with the side handles to maintain an anaerobic environment throughout the seven (7) days of study for each batch. The copper wire was connected to the electrodes and a 10,000Ω resistor.Voltage and current output across the 10,000Ω resistor was recorded daily, using the digital multimeter (DT 9205A). This procedure was carried out for 5kg, 10kg, 15kg and 20kg of the waste each week.

Physicochemical analysis

The physicochemical parameters; conductivity, pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD) and dissolved oxygen (DO) were analyzed. The pH and conductivity parameters were measured using a digital hand-held portable HANNA instrument (HI 9813-6N).

RESULTS AND DISCUSSION

Voltage and Current

The plot of the readings obtained for voltage and current from this research are presented in Figures 3 and 4 respectively. The voltage and current decreased daily for all the weights studied are shown in Tables 1-6. This can be attributed to the decrease in the organic matter contents of the substrate as the microorganisms decomposed the biomass daily. The highest voltage and current recorded for the 5kg paw-paw waste was 1.9V and 1.6A respectively. These values increased as the weight of the substrates increased. Better output values were obtained with the20kg waste. Voltage and current readings were 4.5V and 4.2A respectively on Day 1. There was a gradual decrease of these values as the study progressed to Day 7 with final readings of 2.3V and 2.0A. These were found to generate enough electricity that kept a 2V bulb lit for seven (7) days during the experiment as shown in Figure 2.This is in agreement with the findings [15] that this technology enables the supply of energy to small devices.

The results obtained from the polarization curves for the different weights shows that the relationship between voltage and power density as well as its relationship with current density is significant.

pH

Average pH values obtained were 4.90 ± 0.15, 4.70 ± 0.33, 3.70 ± 0.40 and 3.80± 0.37 for 5kg, 10kg, 15kg and 20kg respectively. These values were observed to decrease as the study days progressed. The values for the 5kg and 10kg were relatively in the same range of 4.3 – 5.3. The values for the 15kg and 20kg were also found to have a common range of 3.6 – 4.4. The plot for these pHreadings from all four weights is presented in Figure 5. The medium was mostly acidic for all the batches.

Conductivity

Conductivity values recorded in this experiment are shown in the plot presented on Figure 6. They were observed to increase daily with increasing quantities of the substrate. The average values obtained were 1.60 ± 0.21 S/cm, 3.02 ± 0.57 S/cm, 3.30 ± 0.46 S/cm and
3.47 ± 0.46 S/cm for 5kg, 10kg, 15kg and 20kg respectively. The 5kg substrate recorded the least conductivity readings. However, the results obtained showed that conductivity was proportional to the quantity of waste paw-paw fruits and peels used. The steady increase in values also showed that the medium was capable of

Table 1: Mean value for voltage and current readings

Parameters	5kg	10kg	15kg	20kg
Voltage (V)	0.90±0.62	1.91±0.91	2.57±0.45	3.26±0.84
Current (A)	0.84±0.54	1.50±0.90	2.54±0.99	3.17±0.76

Table 2: Mean values for physicochemical parameters

Parameters	5kg	10kg	15kg	20kg
pH	4.90±0.15	4.70±0.33	3.70±0.40	3.80±0.37
Conductivity (S/cm)	1.60±0.21	3.02±0.57	3.30±0.46	3.47±0.46
BOD (mg/L)	3.60±0.26	3.27±0.19	2.99±0.31	3.49±0.24
DO (mg/L)	5.49±0.28	5.19±0.78	4.99±0.46	4.66±0.26
COD (mg/L)	7.37±0.37	6.47±0.41	6.04±0.55	6.63±0.63

Table 3: Polarization data for 5kg with 10000Ω resistor.

Experimental days	Current (A)	Voltage (V)	Current density (A/m²)	Power (W)	Power density (W/m²)
1	1.6	1.9	789.34	3.04	1499.75
2	1.3	1.4	641.34	1.82	879.88
3	1.1	1.1	542.67	1.21	596.94
4	0.9	0.8	444.01	0.72	355.20
5	0.6	0.7	296.00	0.42	207.20
6	0.3	0.2	148.00	0.06	29.60
7	0.1	0.2	49.33	0.02	9.87

Table 4: Polarization data for 10kg with 10000Ω resistor.

Experimental days	Current (A)	Voltage (V)	Current density (A/m²)	Power (W)	Power density (W/m²)
1	2.7	2.9	1332.02	7.83	3862.85
2	2.4	2.7	1184.02	6.48	3196.84
3	1.9	2.5	937.35	4.75	2343.36
4	1.4	2.1	690.68	2.94	1450.42
5	1.2	1.7	592.01	2.04	1006.41
6	0.7	1.1	345.34	0.77	379.87
7	0.2	0.4	98.67	0.08	39.47

Table 5: Polarization data for 15kg with 10000Ω resistor.

Experimental days	Current (A)	Voltage (V)	Current density (A/m²)	Power (W)	Power density (W/m²)
1	3.6	3.1	1776.00	11.16	5505.67
2	3.5	2.9	1726.69	10.15	5180.07
3	3.4	2.8	1677.36	9.52	4696.60
4	2.5	2.7	1233.35	6.75	3330.04
5	2.1	2.5	1036.01	5.25	2590.03
6	1.5	2.2	740.01	3.30	1628.02
7	1.2	1.8	592.01	2.16	1065.61

Table 6: Polarization data for 20kg with 10000Ω resistor.

Experimental days	Current (A)	Voltage (V)	Current density (A/m²)	Power (W)	Power density (W/m²)
1	4.2	4.5	2072.03	18.90	9324.12
2	3.8	4.1	1874.70	15.58	7686.24
3	3.5	3.6	1726.69	12.60	6216.08
4	3.3	3.1	1628.02	10.23	5036.88
5	2.9	2.8	1430.69	8.12	4005.92
6	2.5	2.4	1233.35	6.00	2960.04
7	2.0	2.3	986.68	4.60	2269.36

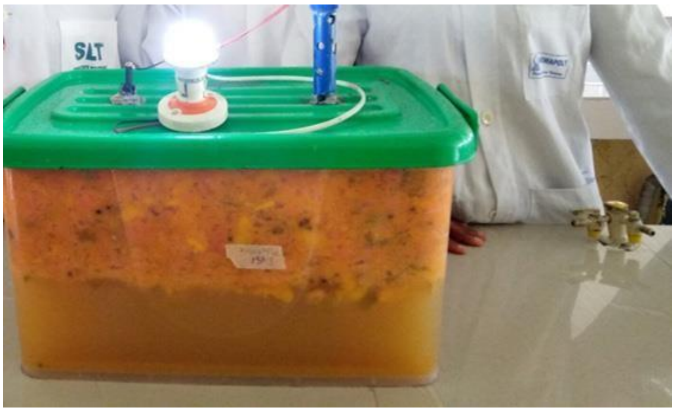

Figure 2: The bioelectricity lights up a 2V bulb.

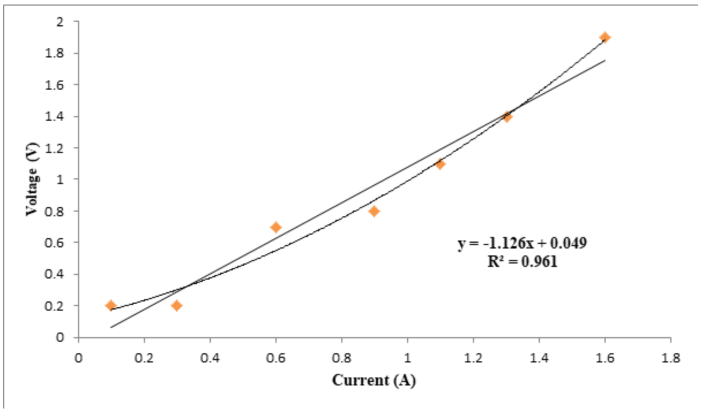

Figure 3: Polarization curve of voltage against current for SMFC with a 10000Ω resistor for 5kg.

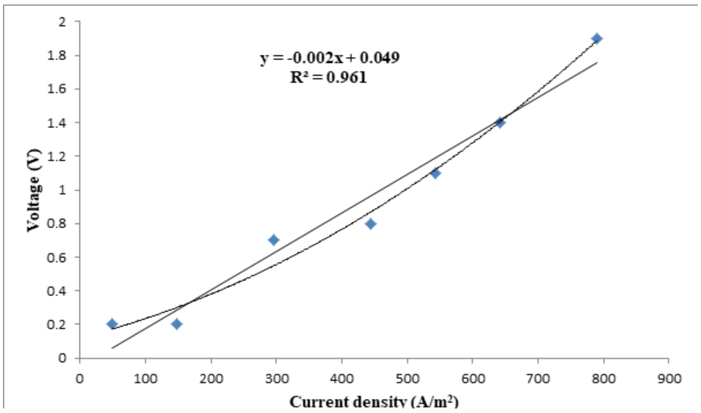

Figure 4: Polarization curve of voltage against current density for SMFC with a 10000Ω resistor for 5kg.

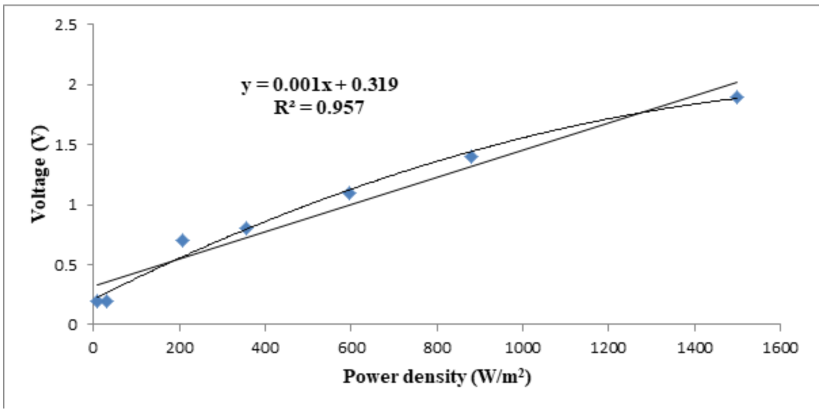

Figure 5: Polarization curve of voltage against power density for SMFC with a 10000Ω resistor for 5kg.

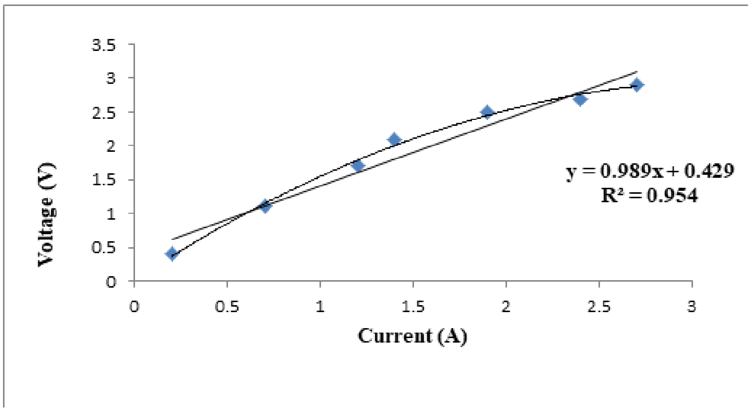

Figure 6: Polarization curve of voltage against current for SMFC with a 10000Ω resistor for 10kg.

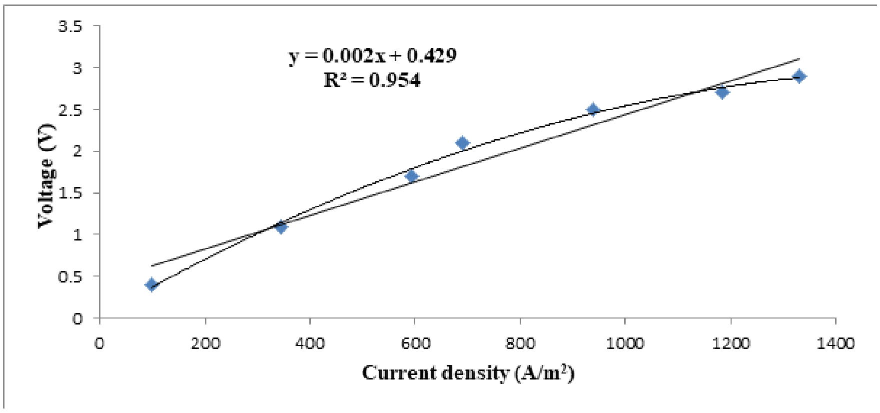

Figure 7: Polarization curve of voltage against current density for SMFC with a 10000Ω resistor for 10kg.

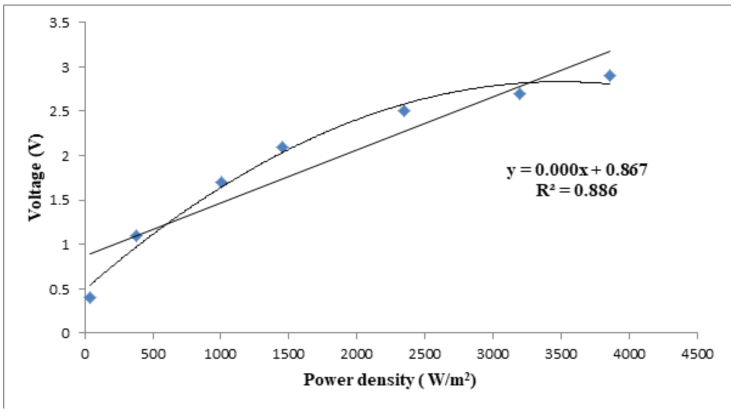

Figure 8: Polarization curve of voltage against current density for SMFC with a 10000Ω resistor for 10kg.

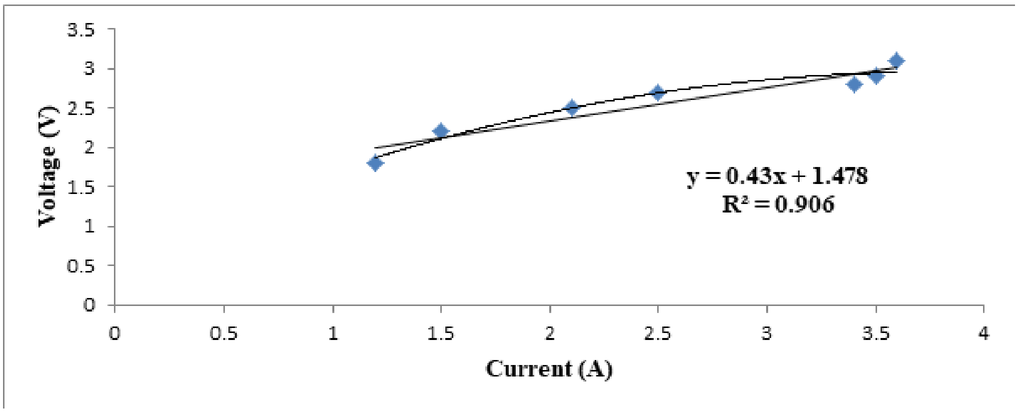

Figure 9: Polarization curve of voltage against current density for SMFC with a 10000Ω resistor for 15kg.

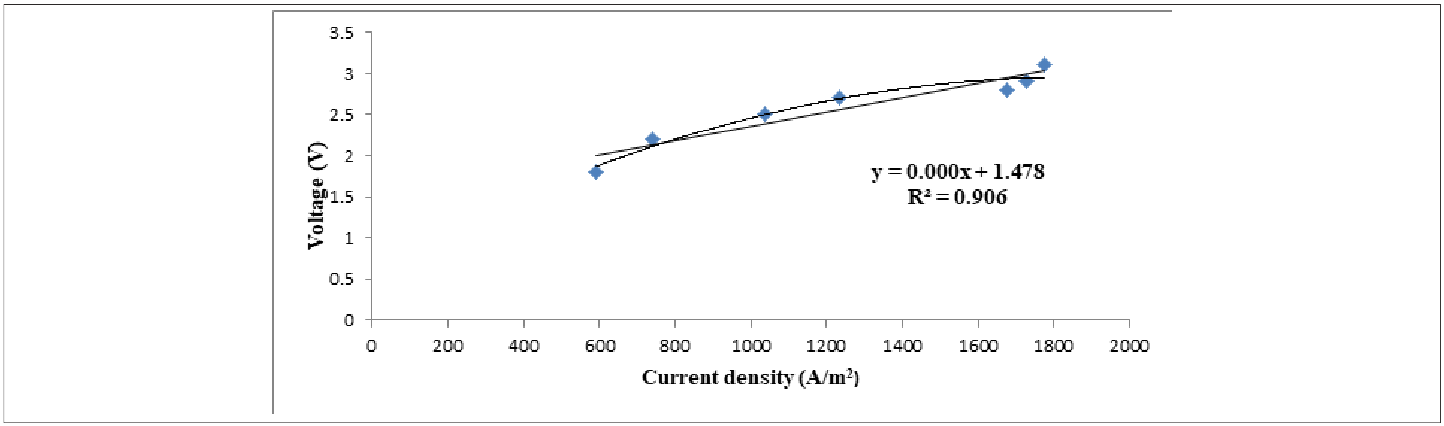

Figure 10: Polarization curve of voltage against current density for SMFC with a 10000Ω resistor for 15kg.

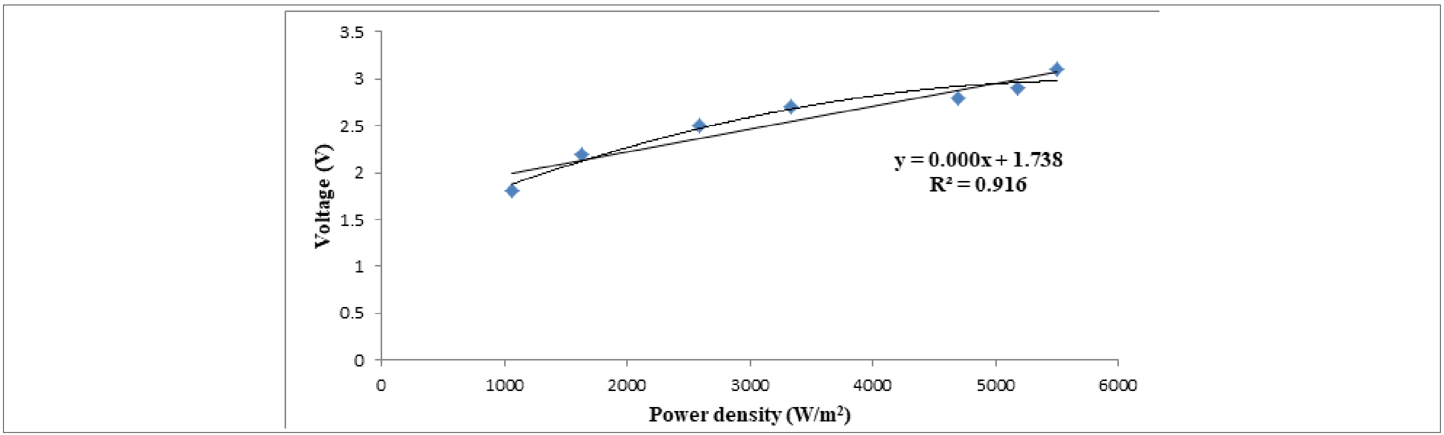

Figure 11: Polarization curve of voltage against current density for SMFC with a 10000Ω resistor for 15kg.

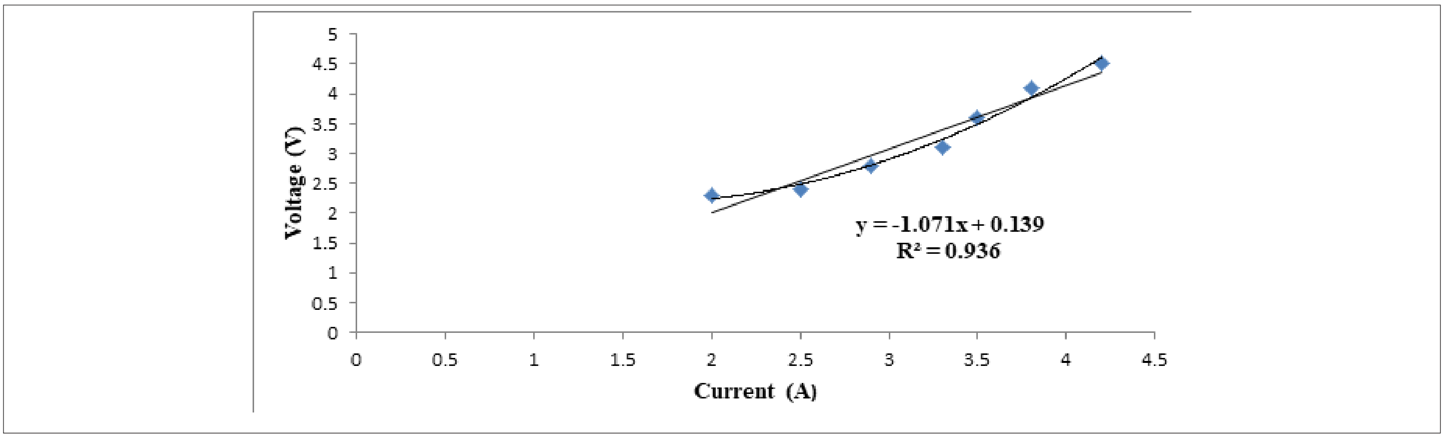

Figure 12: Polarization curve of voltage against current for SMFC with a 10000Ω resistor for 20kg.

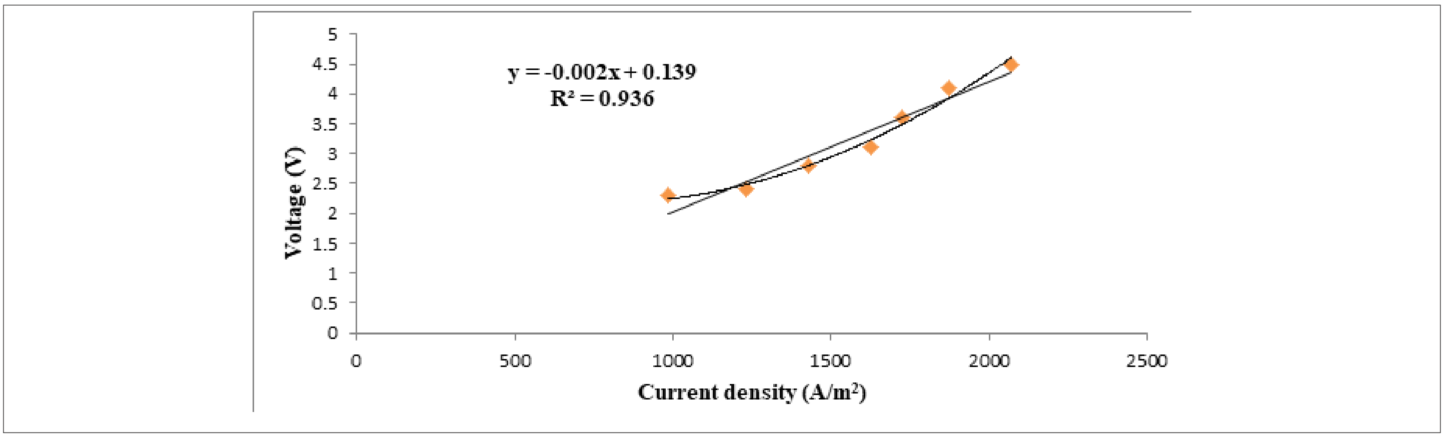

Figure 13: Polarization curve of voltage against current density for SMFC with a 10000Ω resistor for 20kg.

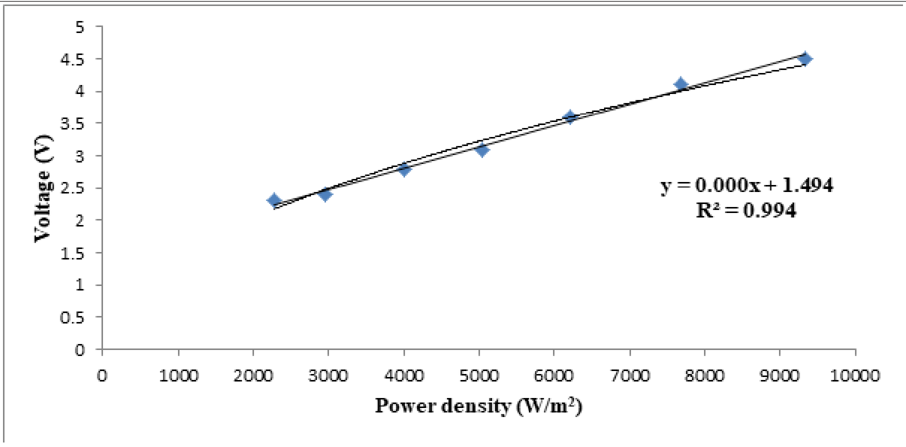

Figure 14: Polarization curve of voltage against current density for SMFC with a 1000Ω resistor for 20kg.

conducting electricity. This is confirmed in the voltage output recorded in which a 2V bulb was lit from day 1 to day 4, day 6 and day 7 from the10kg, 15kg and 20kg substrates respectively.

BOD, DO and COD

The average biochemical oxygen demand(BOD) for 5kg, 15kgand 20kg paw-paw waste was 3.61 ± 0.26 mg/L, 3.27 ± 0.19 mg/L, 2.99 ± 0.31 mg/Land 3.49 ± 0.24 mg/L respectively. The 15kg substrate had the lowest BOD values of 3.4 – 2.6 mg/L as well as the lowest mean values. This decrease in the BOD values shows that the microorganisms were able to decompose the paw-paw waste efficiently thereby releasing enough electrons to sustain the generation of the bioelectricity. A decreasing trend was observed in the results obtained for dissolved oxygen (DO).The mean values recorded for 5kg, 10kg, 15kg and 20kg substrates were 5.49 ± 0.28 mg/L, 5.19 ± 0.78 mg/L, 4.99 ± 0.46 mg/L and 4.66 ± 0.26 mg/L respectively. A similar trend of decrease in values was also observed for chemical oxygen demand (COD) with average values of 7.37 ± 0.37 mg/L, 6.47 ± 0.41 mg/L, 6.04 ± 0.55 mg/L and 6.63 ± 0.63 mg/L for 5kg, 10kg, 15kg and 20kg paw-paw waste respectively are shown in Figures 7-14.

CONCLUSION

The bioelectricity generated from paw-paw fruits and peels waste using the single microbial fuel cells (SMFC) was capable of powering a 2V bulb. We have been able to achieve the conversion of paw- paw fruit and peels waste that cause environmental pollution into bioenergy. The real potential of MFCs in electricity generation has not been fully practiced in Nigeria and this is an opportunity to explore. It is therefore recommended that green chemistry technology be employed to boost the generation of bioelectricity through the use of single chamber microbial fuel cells (SMFC) which is a simple and cheap source. We recommend that more study be carried out on a large scale for bio-energy production from other fruit wastes.

REFERENCES

1. Larhum A.W.D. Limitation and Prospects of Natural Photosynthesis for Bioenergy Production. Current Opinion in Biotechnology. 2010; 1:21:271-276. DOI:10.1016/j.copbio.2010.03.004
2. Carvalho J, Ribeiro A, Castro J Biodiesel Production by Microalgae and Macroalge from North littoral Portuguese Coast In: 1st International Conference held by Centre for Waste Valorization (CVR)-Wastes: Solutions, Treatments and Opportunities, Guimarpes, Portugal, CVR. 2011. September 12th – 14th.
3. Akhator E. P, Obanor A. I, Ezemonye L. I. Electricity Generation in Nigeria from Municipal Solid Waste using the Swedish waste-to-Energy Model.J. Appl. Sci. Environ. Manage. 2016; 20:635-643. DOI: 10.4314/jasem.v20i3.18
4. Rabaey K, Boon N, Siciliano S. D, Biofuel cell select for microbial consortia that self-mediate electron transfer. Appl. Environ. Microbiol. 2004; 70:5373–5382. DOI: 10.1128/AEM.70.9.5373-5382.2004
5. Pham T. H. Microbial Fuel Cells in Relation to Conventional Anaerobic Digestion Technology.Engr. Life Sci. 2006; 6:285 - 292. Doi: 10.1002/elsc.200620121.
6. Logan B. E, Regan J. M. Electricity-Producing Bacterial communities in microbial fuel cells.Trends microbial. 2006; 14:512-518. DOI: 10.1016/j.tim.2006.10.003
7. WangX, Liao FY,Liu KS. Bioaugumentation for Electricity Generation from Corn Stover Biomass using Microbial Fuel Cells.Environ. Sci. Technol. 2009; 43:6088–6093. DOI: 10.1021/es900391b
8. Logrono W, Ramirez G, Recalde C Bioelectricity Generation From Vegetables and Fruits Waste by using a Single Chamber Microbial Fuel Cells with High Andean Soils. Science Energy procedia. 2016; 1:75:2009-2014. DOI: 10.1016/j.egypro.2015.07.259
9. Provera M, Han Z, Liaw BY Communication – Electrochemical Power Generation from Culled Papaya Fruits. J. Electro. Soc. 2016; 163:A1457– A1459. DOI: 10.1149/2.0051608jes
10. Ghazali N. F,Mahmood N. A. B. N, Ibrahim KAElectricity Generation from Palm Oil tree empty fruit bunch (EFB) using Dual Chamber Microbial Fuel Cell (MFC). IOP Conference Series: Materials Sc. Engr. 2017; 206:012025. Doi:10.1088/1757-899x/206/1/012025.
11. Azouma Y. O, Jegla Z, Reppich M Using Agricultural Waste for Biogas Production as a Sustainable Energy Supply for Developing Countries. Chem. Engr. Trans. 2018; 70:445-450. Doi:10.3303/CET 1870075.
12. Dincer I. Renewable Energy and Sustainable Development. Renewable and Sustainable Energy Reviews 4:157-175.RePEc:eee:rensus:v:4:y:2000:i:2:p:157-175
13. Hossain A. B,Mekhled M. A. Biodiesel Fuel Production from Waste Canola cooking oil as Sustainable Energy and Environmental recycling process. Austral J Crop Sci. 2010; 4:543-549. DOI: cropj.com/sharif233_4_7_2010_543_549
14. Mata T. M, Martins A. A, Ceatano N. S. Microalgae for biodiesel production and otherapplications.Renewable and Sustainable Energy Reviews. 2010; 14:217-232. doi.org/10.1016/j.rser.2009.07.020
15. Moqsud M. A, Omine K, Yasufuku N. Microbial fuel cell (MFC) for bioelectricity generation from organic wastes.Waste Management. 2013; 33:2465-2469. DOI: 10.1016/j.wasman.2013.07.026.