

Evaluating the Effectiveness of Cassava Wastewater Treatment in a Low Cost Microbial Fuel Cell

ABSTRACT

The performance of two-chamber low cost microbial fuel cell (MFC) with cassava wastewater was evaluated for the effective treatment of the polluting content. Two 30/it. plastic containers were obtained to serve as anode and cathode chamber. The electrodes were made from readily available carbon papers sew together with naked copper wire while the salt bridge was made of inverted 'U' shaped PVC pipe. Results shows that the removal efficiency for magnesium and cyanide were low while BOD₅ and COD removal were 65% and 53% respectively. Increase in voltage and power was observed at the beginning of the degradation which later decreases with time. The maximum current generation of 0.76 mA was observed at external load of 1000 Ω with maximum voltage of 0.75 V while power obtained was 5.63×10^{-4} Watt. The coefficient of determination (R^2) obtained was 0.9875, 0.9878 and 0.9926 for voltage, current and power respectively which indicate a good fit to the data obtained. MFC can provide a sustainable and cheap means of treating cassava wastewater in developing countries with dual advantage of power production instead of indiscriminate disposal on land and water.

Keywords: Cassava wastewater, Wastewater treatment, Microbial fuel cell, energy generation

1. INTRODUCTION

Amidst various agricultural product processing, cassava processing generates a lot of wastewater. Volume of water consume and wastewater generated depend on the quantity of cassava tubers been processed and the mass of the end product (1). Cassava wastewater constitutes a major environmental concern especially in Africa due to indiscriminate disposal. Not only the volume of wastewater generated but the contents of the wastewater and offensive odour generated from its unplanned disposal over time. Most of the medium and small scale cassava processing industries dispose the cassava peels and wastewater indiscriminately.

Globally, more than 228 Tg of cassava is produce annually. African countries produce over 103 million metric tons per annum with Nigeria accounting for about 35 million metric tons from the total figure with possible increase to 40 million tons as the call to embrace indigenous agricultural farming increases (2). Recently, production figures ranked Nigeria as the leading producer of cassava in the world. By implication, the quantity and quality of cassava wastewater generation in Nigeria is high.

The deleterious effects and adverse impact of indiscriminate disposal of cassava wastewater is not limited to public health but it also has negative impact on crops and plants, soil, surface and groundwater resources, property values, ecological impact and social life of a community (3)(4). Recent research work (5) highlighted the negative impact on receiving water body and aquatic life while another work (6) emphasized the effect of cassava effluent on Okada environs in North East Local Government Area of Edo State, Nigeria and revealed the negative impact on selected animals and impairment to plant growth in addition to air pollution. Cassava wastewater should be treated to produce effluent water of moderate quality that can be disposed to the natural water surface or land with little or no adverse impact on human health or the environment.

Cassava (*Manihot esculenta* 'crantz') is a very significant food crops in Nigeria and much of the tropics. It provides about 40% daily calorie in Sub Saharan Africa and about 70% of the daily Calorie intake of over 50million Nigerians (7). Cassava is used to produce a wide range of industrial products such as ethanol, glue, glucose syrup extensively used by pharmaceutical and confectionary industries, for starch production and for production of consumables like bread as well as for African delicacies like fufu and gari production. Cassava wastewater often becomes putrid with main pollutant as cyanide, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved and

suspended matters amidst others. The disposal of cassava wastewater is a great concern in developing countries where adequate legislation, policy and standards are not strictly adhered to, and where they are followed, there are limited space for land based treatment and disposal.

Primary treatments methods for treating wastewater involves screening, grit chamber, sedimentation and sedimentation, while secondary treatments utilizes activated sludge or trickling filters or lagoons to convert the non-settle-able solids to settle-able solids. In the last century activated sludge process has been the major technique for the treatment of wastewater but the method is expensive and energy consuming, instead of energy producing. Typical treatment method for starchy wastewater like that of cassava wastewater is the aerobic biological treatment. But recently, the microbial fuel cell (MFC) has proven to be a promising and sustainable technology for the treatment of wastewater by removing or treating the pollutants in wastewater before discharge into the environment accomplish by energy generation to meet increasing energy needs (8)(9)(10). Other advantages of MFC is that it reduces the operational cost of treating wastewater (11), it is a clean technology, safe with low emissions, permit the reuse of wastewater and easy to operate.

The MFC cell make use of the bacterium already present in wastewater as catalysts to generate electricity while simultaneously treating the wastewater (12)(13)(14). In MFC, microorganisms in the wastewater oxidize organic matter in the anode chamber (through anaerobic conditions) producing electrons and protons. Electrons transfer via the external circuit to the cathode chamber where electrons, protons and electron acceptor (mainly oxygen) combine to produce water (15). In a two-chamber set up, the anode and cathode compartments are separated by an ion-selective membrane, allowing proton transfer from anode to cathode and preventing oxygen diffusion to the anode chamber. Although MFCs generate a lower amount of energy than hydrogen fuel cells, a combination of both electricity production and wastewater treatment would reduce the cost of treating primary effluent wastewater. Cassava mill wastewater in a single celled MFC inoculated with mixed culture sludge was analyzed to generate energy (16). However, in this study, the effectiveness of treating cassava wastewater was determine in a double chamber MFC made with locally available material. The materials were selected so that both the local and industrial cassava processors would find it economical, easy and safe to use while processing on-site instead of the usual indiscriminate discharge on land and water. The outcome of this work is also significant for public health workers, environmentalists, water resources analyst and engineers.

2. MATERIAL AND METHODS

2.1 Building the anode and cathode chamber

Two medium sized plastic containers were obtained to serve as anode and cathode chamber. Connection openings were made at 13cm to the top and 5cm to the bottom of each of the two chambers as passage to link the chambers. Nuts were fixed to the interior and exterior opening of the tank and tightened. 9cm PVC pipes were connected to the exterior nuts with the means of adaptor and another 9cm PVC pipe was fixed to the other edge of the adaptor for further connection of the ball gauge.

Salt bridge made of elbow PVC pipes in an inverted "U" shape was connected to the ball gauge to reduce the rate of flow of the solution into the opposite chamber.

The ball gauge and the salt bridge were connected together with union connector to allow for disconnection when needed. The lids of the chambers were perforated to obtain tiny openings at the top of the two chambers to serve as openings for copper wires connecting the electrodes in the anode and cathode chambers while the openings to the cathode chamber also allow passage of air in and out of the chamber, Plate 1(a - d).

2.2 Making the Electrodes

The electrodes were made from readily available carbon paper. 100 pieces of carbon papers were collated together in the regular rectangular shape of 30 cm by 20cm ($\approx 25 \text{ cm}^2$). Flexible copper wire was obtained, one end of the flexible copper wire was prepare by stripping off the insulator around it using wire stripper. The stripped or naked copper wire was carefully wound and sew round the collated carbon papers in and out of each layer while the unstrapped end was left for connection to the external circuit, this forms the electrode for the anode chamber. The procedures were repeated for making the electrode for the cathode chamber Plate 1 (e & f).

2.3 Making the salt bridge solution

One end of the inverted 'U' shaped PVC pipe already prepared was securely sealed with aluminum foil to prevent leakage, and kept in a secured petri dish. 60g of Agar agar (agar powder) was added to 300ml of clean water and stirred with glass rod for proper dissolution before adding 12g of table salt. The solution in the flask was properly mixed and placed in an auto clave to boil for one hour. The warm solution was carefully poured into the open end of the inverted 'U' shape PVC pipe over the petri dish and observe for leakages (where leakages was observed, aluminum foil was added to tube opening and refilled). In the absence of any leakage, the tubes over the petri dish were moved to the refrigerator for cooling. After cooling, the aluminum foils were removed from the bridge and the salt bridges were used immediately to prevent drying out of the solution in the tubes (Plate 1g).

2.4 The fuel cell assemblage

The experiment was performed at room temperature. The two chambers were coupled together with the salt bridge in between. The cathode chamber was filled with conductive salt solution (2500g of salt dissolved in 25 litres of clean water). The anode chamber was carefully filled with 25 litres of cassava wastewater observing all safety precaution. The prepared electrodes made of collated carbon paper with copper wires were tied to the lid opening of each chamber and the electrodes were submerged into the anode and cathode solution of each of the chamber. The set- up is as shown in Plate 1h. The hydraulic retention time (HRT) was 24 - 48 h. The voltage of the cell were monitored and measured using a precision multimeter.

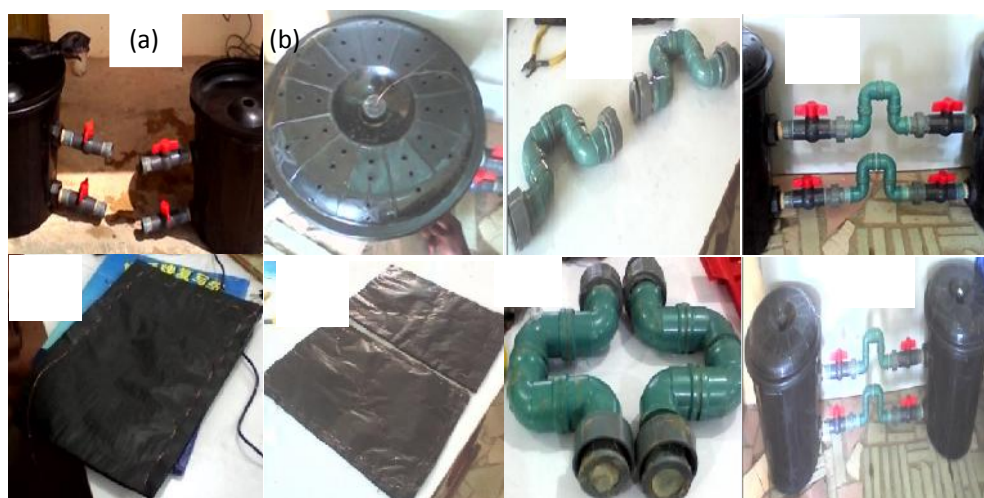


Plate 1: (a) Chambers with adaptor, ball gauge and union connection (b) Perforated lid (c) Salt bridge connections (d) Inverted "U" shape double salt bridge connection (e) Sewed electrode (f) Anode and cathode electrode (g) Salt bridge (h) MFC set up

2.5 Cassava wastewater collection and characterization

Fresh cassava wastewater was obtained from the drain at the processing yard. The composition of the wastewater such as pH, Turbidity, Total suspended solids (TSS), Total dissolved solids (TDS), Hardness, Conductivity, Iron, Magnesium, Lead, Cyanide, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were determined using APHA (17) standard methods before and after retention in the cell chamber.

The pH, conductivity and turbidity were determined using the pH meter, conductivity meter and turbidity meter respectively. The TSS, TDS, hardness were determined by the UV absorption spectrophotometer.

The potential was measured using a digital multimeter and converted to power (P) using equation 1.

$$P = IV \quad \text{Eq. 1}$$

Where I = Current (A) and V = Voltage (V)

The treatment efficiency (E_T %) representing the fraction of the original concentration that was removed in the process was calculated as shown in equation 2. Where C_i represents the initial concentration of the wastewater and C_f represents the final concentration of the wastewater.

$$E_T \% = 100. \frac{C_i - C_f}{C_i} \quad \text{Eq. 2}$$

3. Results and discussion

3.1 Wastewater characterization

The initial and final concentrations of the cassava wastewater is shown in Table 1. The initial average concentration before treatment was denoted as A while the final average concentration after degradation was denoted as B against the permissible limit for effluent discharge.

The initial hydrogen ion concentration (pH) of the cassava wastewater was strongly acidic, the acidic content was slightly reduce after retention in the cell but not within the recommended discharge value of 6.0-9.0. Mean turbidity value of the wastewater was initially 212 NTU but reduced to 68 NTU after degradation in the cell, the final concentration was higher than the recommended value for discharge which should be less than 10 NTU. Cassava wastewater is high in turbidity due to large amount of cassava peel particles, starch residue and organic matter generated during processing for the effluent. The initial values for TSS and TDS were also higher than the allowable threshold due to high level of starch dissolution of the cassava roots in water. The continuous fermentation of the carbohydrate rich starchy wastewater within the cell also result to high values of TSS and TDS than the recommended level for discharge even after degradation. The wastewater hardness was slightly reduced in the degradation process, from an initial values of 95.5 mg/l against the final values of 97.3 mg/l. The conductivity of the wastewater was slightly reduced from an average value of 1921 to 1129 μ S/cm.

The concentration of iron at the influent was at a low level of 0.03mg/l which increased to 1.0 mg/l after continuous retention in the cell. Magnesium as dissolved inorganic substance was slightly reduced from an average value of 217.5mg/l to 210.5 mg/l. Change in concentration of other heavy metals like lead (Pb) and cyanide (Cn) were insignificant.

The BOD test measures the oxygen demand of biodegradable pollutants whereas the COD test measures the oxygen demand of oxidizable pollutants. The BOD and COD as a measure of the relative oxygen-depletion effect of the waste contaminant were degraded from 495 mg/l and 985 mg/l to 173 and 462 mg/l respectively. Both have been widely adopted as a measure of pollution effect. Both the BOD and COD were significantly reduced in the microbial cell but not within the permissible threshold for disposal. BOD and COD removal efficiency between 62 – 91% has been reported (18)(19) from cassava wastewater under different conditions of experimental set-up.

Table 1: Performance of the MFC for cassava wastewater treatment

Parameter	Initial concentration		Final concentration		*Discharge standard
	A1	A2	B1	B2	
pH	3.81 $\pm$ 0.4	3.78 $\pm$ 0.4	5.18 $\pm$ 0.01	5.12 $\pm$ 0.01	6.0 -9.0
Turbidity (NTU)	212.6 $\pm$ 0.1	212.5 $\pm$ 0.3	68.45	68.42	10 NTU
TSS (mg/l)	1399 $\pm$ 2.25	1401 $\pm$ 0.15	123	122	50 – 100
TDS (mg/l)	1842.3	1841.7	979	978.6	500
Hardness (mg/l)	95 $\pm$ 0.5	95 $\pm$ 0.3	97 $\pm$ 0.3	96 $\pm$ 0.4	
Conductivity (μ S/cm)	1921.2	1920.9	1129.5	1129.5	
Iron (mg/l)	0.03	0.03	1	1	0.3/ 1.0
Mg(mg/l)	218	217	210	211	
Lead (mg/l)	0.05 $\pm$ 0.01	0.05 $\pm$ 0.01	0.08 $\pm$ 0.2	0.08 $\pm$ 0.1	0.05 / 0.1
Cyanide (mg/l)	33 $\pm$ 0.5	33.0 $\pm$ 0.3	32 $\pm$ 0.86	32 $\pm$ 0.84	0.05 / 0.1
BOD5 (mg/l)	494.65	495.1	173 $\pm$ 0.25	173 $\pm$ 0.2	50
COD (mg/l)	984 $\pm$ 1	984 $\pm$ 1.2	462 $\pm$ 0.95	462 $\pm$ 0.34	100

**Malaysian Environmental quality (industrial effluent) regulation, 2009. Applicable to discharge into waters within catchment area.*

3.2 Treatment efficiency

The removal efficiency of the parameters tested is shown in Figure 1. The pH content of the wastewater was slightly increased while remaining acidic. Maximum removal of turbidity, TSS, TDS were 68%, 80% and 46% respectively. The removal efficiency for magnesium and cyanide were low while BOD and COD were 65% and 53% respectively.

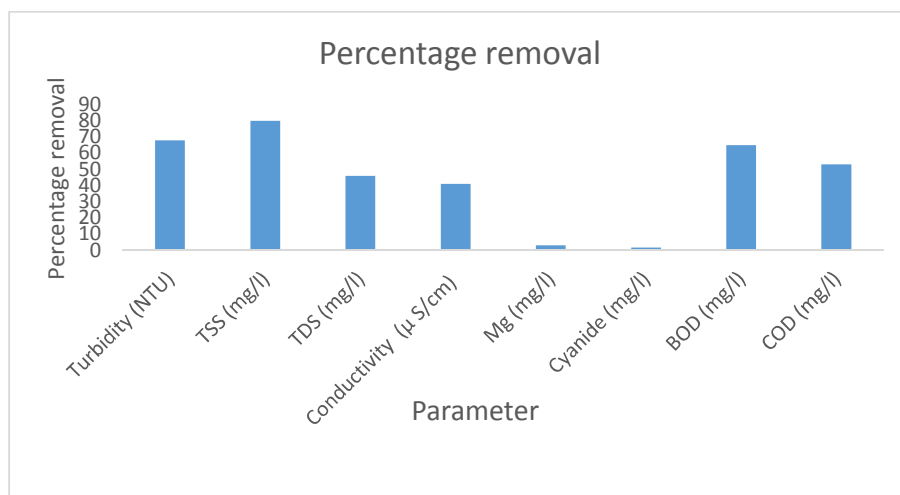


Figure 1: Removal efficiency

3.3 Energy generation

The MFC inoculated with cassava wastewater was operated in a continuous mode at external load of 1000Ω. The variation of voltage, current and power generation with time were recorded and shown in Figure 2.

Within the first minutes of operating the cell, the potential was low. The initial output was 0.35 V which gradually increased to 0.65 V after an hour. It remained stable between 150 – 250 minutes of operation giving rise to an output of 0.70 V. Voltage readings increased from 0.70 to 0.74 volts at 2 and 3 hours respectively, yielding a maximum output of 0.75V between 4.3 and 4.5 hours of operating the set-up after which gradual decrease began at approximately 4.7 hours. The drop in voltage generated continued till the 23rd hours which became negative through the second day of operating the MFC.

The corresponding initial electric current (10^{-4} A) production was also low, at 3.5 to 5.40×10^{-4} A in 10 minutes. Gradual increment of the current ($5.80, 6.10, 6.30, 6.50 \dots\dots\dots 7.6 \times 10^{-4}$ A) were observed up to 270 minutes. Maximum current generated was 0.76 mA observed at 272 minutes. Thereafter the generated current began to decrease ($7.6, 7.3, 7.2, 7.1, 7.0, 6.9, 6.8 \dots\dots\dots 0.1 \times 10^{-4}$ A) at 1360 minutes to the starting time, negative current of -0.1, -0.2, -0.3, -0.2 was recorded at 1370 minutes up to the second day.

As the molecules in the nutrient of the wastewater are broken down, electrons were released which facilitates the rise in voltage, current and power generated. But as these are used up the output decreases.

This decrease is attributed to the growth of methanogens (microorganism that produces methane as a metabolic byproduct in anoxic condition) in the anode chamber, reducing the availability of electron and proton, hence reducing current. The higher the nutrient in the cassava wastewater the better the effective performance of self-produced bacterial which in turn affect the performance of the MFC in producing energy. Hence, variation in enrichment of the bacteria affected the generation of voltage, current and power. In the present study high external resistance could also be attributed to low energy production because it is widely report that larger current production at lower external resistance is usually envisaged. The production of current decreases with increase in resistance at same concentration of wastewater. Hence, the low current obtained in this set up. Power generated was

2.92 x 10⁻⁴ W within the first 10 minutes, these increases to a maximum value of 5.63 x 10⁻⁴ W at a retention time of 270 minutes before a gradual decrease to 0.009 x 10⁻⁴ W at 1440 minutes.

A maximum voltage output of 275 mV and a corresponding current output of 2.75 mA within 240 min (4 h) was obtained from a cassava mill effluent operated in a two cell chamber, with anode chamber inoculated with artificial wastewater containing glucose of different concentration as carbon source (20) while a maximum voltage output and power density of 450 ± 20 mV and 29 mW/m³ was obtained from a single chamber MFC with cassava peel and extract with anode consisting of carbon graphite brushes, while the cathode was a membrane electrode assembly (MEA) carbon cloth assembly, consisting of a gas diffusion layer coated with 60% PtC at 0.5 mg/cm² (10). A maximum voltage of 687 mV was later obtained from aqueous filtrates of microbial hydrolyzed cassava peels operated at different pre-treatment methods (3).

A linear relationship between voltage generated and time was observed in a MFC inoculated with rice washing water also rich in starch with higher voltage in micro-volt recorded in the first day of the operation which decreases to the fifth day irrespective of adding slurry or vermicompost (21). On the other hand, maximum voltage of 490.8 mV was obtained from a starch processing wastewater of 4900 mg/l COD (11).

Another research work (22) obtained a voltage of 0.116 in the first fifteen days of operating a membrane-less microbial fuel cell inoculated with septic tank sludge, the voltage increased to 0.188, 0.175 and 0.151 V between 35, 55 and 78 days of operation with corresponding current generation of 0.175, 0.148 and 0.121 mA. Here, the maximum current and voltage obtained were 0.175 mA and 0.19 V respectively at external load of 10 Ω while higher voltage were generated by using mixed cultures.

From Figure 2, A-B is the initial stage called the exponential stage, at this stage, the set-up is in operation and the microbes have started decomposing the complex waste nutrient to liberate electron at the anode chamber which later find their way through the external circuit to the cathode, whereby voltage is generated.

B-C is the stationary stage where the microbes has been able to decomposed all the substrate and therefore maximum and stable voltage is noted, at this stage the microbes performed up to their maximum efficiency because of the availability of food.

C-D displays the lagging stage where the substrate is almost been exhausted by the microbes gradually and it show the fall in voltage, current and power generated. At this stage the microbe in anode chamber is more than the substrate available in the waste water therefore there is reduction in the performance of MFC.

E is called the death stage which is the stage at which all the substrate has been exhausted therefore it leads to death of some microbe which cannot survive the current condition of the substrate.

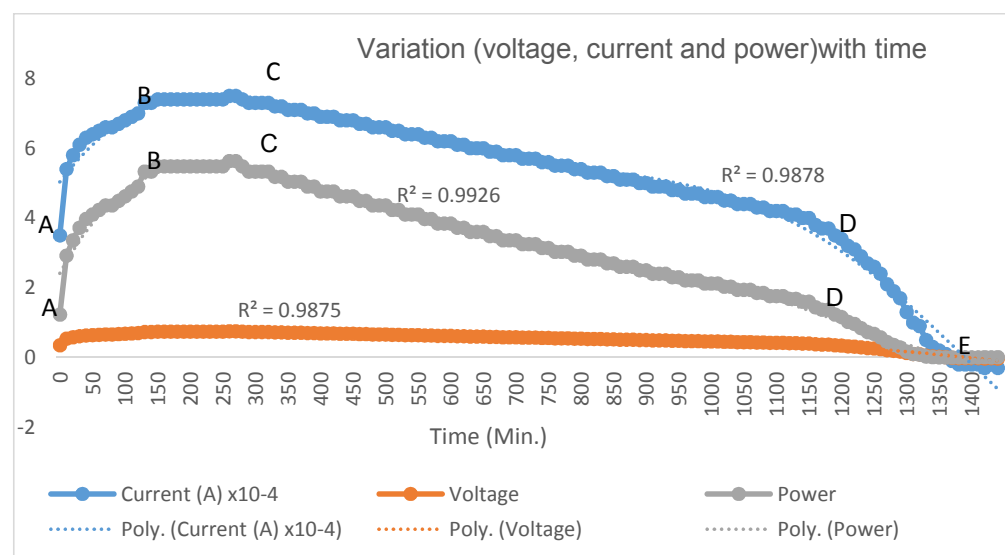


Figure 2: Variation of voltage, current and power with time

3.3 Mathematical modeling for the outputs

The best fitted curve for the voltage generated is a polynomial equation of the fifth order. The mathematical model for voltage is given in equation 3. The best fitted curves for the current and power generation are also polynomial equations of the sixth and fifth order respectively while the mathematical equations obtained are given in equation 4 and 5 respectively. This reflects that voltage, current and power generated with respect to time did not follow a linear order. The decrement in voltage and power is not only dependent on time alone but on many other parameters involved in the process (type of bio-waste or substrate, type of inoculum, concentration, type of chamber, cell volume, anode and cathode material, cell type, electrode material etc.). The coefficient of determination (R^2) as a regression analysis that describes the relationship between the variables employed for the evaluation of degradation process within the cassava wastewater gave the respective values of (R^2) as 0.9875, 0.9878 and 0.9926 for voltage, current and power respectively which indicate a good fit to the data obtained.

$$\text{Voltage (V), } y = 2\text{E-}10x^5 - 9\text{E-}08x^4 + 1\text{E-}05x^3 - 0.0011x^2 + 0.0304x + 0.4621 \quad \text{Eq.3}$$

$$\text{Current (A), } y = 1\text{E-}11x^6 - 4\text{E-}09x^5 + 2\text{E-}08x^4 + 8\text{E-}05x^3 - 0.008x^2 + 0.2646x + 4.7691 \quad \text{Eq.4}$$

$$\text{Power (W), } y = 3\text{E-}09x^5 - 1\text{E-}06x^4 + 0.0002x^3 - 0.0132x^2 + 0.3725x + 2.0458 \quad \text{Eq.5}$$

The terms of the equations, voltage with time, current with time and power generation with time indicate that retention time significantly influenced the removal efficiencies of the organic and inorganic matter in the wastewater. Significant terms are kept in the representative mathematical model equations.

4. CONCLUSION AND RECOMMENDATION

This study revealed that organic, inorganic and heavy metals can be degraded from cassava wastewater in a MFC system. The removal efficiency for magnesium and cyanide were low while BOD₅ and COD removal were 65% and 53% respectively. Increase in voltage and power was observed at the beginning of the test which later decreases with time. The maximum current generation of 0.76 mA was observed at external load of 1000 Ω with maximum voltage of 0.75 V while power obtained was 5.63×10^{-4} Watt. MFC can provide a sustainable and cheap means of treating cassava wastewater in developing countries with dual advantage of power production instead of indiscriminate disposal on land and water. Consortium of bacteria and isolation of potent microorganism could be used to improve electron transfer and power density respectively during degradation process.

REFERENCES

1. Sangyoka S, Reungsang A, Samart M. Repeated batch fermentative for bio - hydrogen production from cassava starch manufacturing wastewater, *Pak J Biol Sci*; 2007 :10: 1782–1789
2. FAOSTAT (2009). Online statistical Database. Rome, Italy. Accessed 29 January, 2018, website: www.fao.org.
3. Adekunle A., Yvan Gariepy, Darwin Lyew and Vijaya Raghavan. Energy recovery from cassava peels in a single –chamber microbial fuel cell, *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, 2016, 38:17, 2495 - 2502.
4. Okunade D.A. and Adekalu K.O. Characterization of cassava – waste effluents contaminated soils in Ile-Ife, Nigeria, *European International Journal of Science and Technology*, 2014: 3(4) 173 - 182
5. Oghenejoboh K.M. Effects of cassava wastewater on the quality of receiving water body intended for fish farming, *British Journal of Applied Science and Technology*, 2015: 6 (2) 164 – 171

- 315 6. Ehiagbonare, J.E, Enabulele, S.A, Babatunde B.B. and Adjarhore R. Effect of cassava effluent
316 on Okada denizens, *Scientific Research and Essay*, 2009: 4 (4): 310-313
- 317 7. FAO. The state of food insecurity in the world (SOF/2003). Rome: Food and Agriculture
318 Organization. Federal Ministry of Agriculture (2004); Annual reports. 2003:pp 36.
- 319 8. Fleck Leandro, Maria H. F. Tavares, Eduardo Eyng, Minéia A. De M. De Andrade, Laercio M.
320 Frare. Optimization of anaerobic treatment of cassava processing wastewater, *Journal of the*
321 *Brazilian Association of Agricultural Engineering*, 2017:37(3)574 – 590
- 322 9. Chaturvedi V. and Verma P. Microbial fuel cell: a green approach for the utilization of waste for
323 the generation of bioelectricity, *Bioresources and Bioprocessing*, 2016: 3:(38) 1-14
- 324 10. Adekunle Ademola. Cassava peels and extracts: Performance in a single chamber air cathode
325 microbial fuel cell, Published MSc project, McGill University, Montreal,(December 2014, 1-104
- 326 11. Lu, N., Zhou, S.-G., Zhuang, L., Zhnag, J.-T., Ni, J.-R. Electricity generation from starch
327 processing wastewater using microbial fuel cell technology. *Biochem. Eng. J.*, 2009: 43, 246–251.
- 328 12. Lui, H., Logan, B.E. Electricity generation using an air-cathode single chamber microbial fuel cell
329 in the presence and absence of a proton exchange membrane. *Environ. Sci. Tech.*, 2004:38,
330 4040-4046
- 331 13. Lui, .H, Ramnarayanan, R.; Logan, B.E.; Production of electricity during wastewater treatment
332 using a single chamber microbial fuel cell. *Environ. Sci. Tech.*, 2004:38, 2281-2285
- 333 14. Min, B.; Logan, B.E.; Continuous electricity generation from domestic wastewater and organic
334 substrates in a flat plate microbial fuel cell. *Environ. Sci. Tech.* 2004: 38, 5809-5814
- 335 15. Li, Z., Zhang, X., Zeng, Y., Lei, L. Electricity production by an overflow-type wetted microbial fuel
336 cell. *Biores. Technology*, 2009:100, 2551–2555.
- 337 16. Kaewkannetra P, Chiwes W. and Chiu T.Y. Treatment of cassava mill wastewater and production
338 of electricity through microbial fuel cell technology, *Fuel*, 2011: 90 : 2746 - 2750
- 339 17. APHA, Standard methods for the examination of water and wastewater. American Public Health
340 Association, American Water Works Association and Water Environment Federation (AWWA),
341 (21st ed.), Washington,USA, 2005
- 342 18. Prasertsung .N. and Ratanatamskul .C. Effects of organic loading rate and operating temperature
343 on power generation from cassava wastewater by a single-chamber microbial fuel cell,
344 *Desalination and Water Treatment*, 2013, DOI: 10.1080/19443994.2013.826405
- 345 19. Y. Mohan, D. Das. Effect of ionic strength, cation exchanger and inoculum age on the
346 performance of microbial fuel cells, *Int. J. Hydrogen Energy*, 2009: 34 7542–7546.
- 347 20. Agarry S.E, Oghenejoboh K.M and Solomon B.O. Bioelectricity production from cassava mill
348 effluents using microbial fuel cell technology, *Nigerian Journal of Technology*, (2016):35 (2) : 329
349 – 336
- 350 21. Barua P.K and Deka .D. Electricity Generation from Bio -waste Based Microbial Fuel Cells,
351 *International Journal of Energy, Information and Communications*, 2010: 1(1) 77 – 92.
- 352 22. Ghangrekar, M.M., & V.B. Shinde. Performance of membrane-less microbial fuel cell wastewater
353 and effect of electrode distance and area on electricity production. *Bioresource Technology*, 2007:
354 98, 2879-2885.