International Journal of Hybrid Innovation Technologies
Vol.3, No.1 (2023), pp.41-48
http://dx.doi.org/10.21742/ijhit.2653-309X.2023.3.1.04

Bio-Electricity Generation from Watermelon Fruit Bark (*Citrullus lanatus*) through Single Chamber Microbial Fuel Cell (SC-MFC)

Akpotayire Stephen. I. [1*] and Pepple Omiete E. [2]

[1*, 2] *Department of Biochemistry, University of Port-Harcourt, Choba, P.M.B 5323, Rivers State, Nigeria*

[1*] *Stephenlegacy1@yahoo.com, Peppleomiete704@gmail.com*

Abstract

Fossil fuels used in the generation of electricity pollute the environment as the noxious gases that are expelled have resulted in global warming just as the careless disposal of organic waste materials has destroyed the aesthetic beauty of the environment and caused land pollution. This research therefore is aimed at converting such organic waste into electricity. Watermelon (Citrullus lanatus) fruit barks which were collected from different refuse dumps in Port-Harcourt, Rivers State, Nigeria utilized electricity generation by microbial fuel cell method in a constructed chamber (single) using local materials, watermelon fruit bark of different weights (1kg, 2 kg and 4 kg) were used for the generation of electricity. Voltages generated by the different weight(s) of watermelon fruit bark were obtained through the recordings displayed on the digital multi-meter connected to the constructed microbial fuel cells. This study was done in triplicate for five days. The result showed that 1 kg of watermelon fruit bark generated the following voltages (32.75±5.90, 49.00±8.07, 76.80±9.13, 82.30±9.38 and 97.85±6.04) mV; 2 kg of watermelon fruit bark generated the following voltages (56.80±9.58, 67.50±9.88, 78.00±8.67, 90.10±8.93 and 104.85±4.13) mV and 4 kg of watermelon fruit bark generated the following voltages (72.75±3.23, 91.45±0.98, 111.25±2.83, 123.75±1.78 and 143.15±3.79) mV. The result showed that watermelon fruit bark was capable of generating electricity and the quantity of electricity generated increased with a corresponding increase in the weights of the watermelon fruit bark utilized. It therefore suggests that organic wastes (watermelon fruit bark) which are potential environmental and health risk materials can be recycled and used to generate electricity for homes and industrial use. Proper programs should be put in place to adequately utilize these organic materials for the generation and supply of electricity to developing countries.

Keywords*: Electricity, Watermelon, Fruit, Bark, Single chamber microbial fuel cell*

1. Introduction

The eating habit of individuals around the world has caused a huge worldwide waste problem, especially in Nigeria where organic wastes are indiscriminately disposed of. These wastes are littered in lands that have been converted to dumpsites, landfills, and roadsides thereby depriving the environment of its aesthetic beauty and causing pollution (land and air).

Article Info:

Received (May 25, 2023); Review Result (June 28, 2023); Accepted (August 5, 2023)

The incomplete combustion of fossil fuel for the generation of electricity has been found to generate a lot of 'greenhouse gases such as carbon IV oxide (CO2), sulfur IV oxide (SO2), and nitrogen IV oxide (NO2), these have been shown alarming consequences on the environment, the health of humans [1]. Materials used in the generation of energy around the world come from non-renewable energy sources such as petroleum, coal, oil, and natural gas which are highly depleted at a fast rate [2]. Technologies that utilize renewable energy are being invented globally and they have been postulated to be able to overcome these drawbacks caused by non-renewable energy sources [3][4][5].

Bioelectricity production is the use of organisms particularly that from the microbial world which helps in the production of electrical energy resulting from the liberation of electrons via the breakage of bonds. The liberated electrons are captured which helps to sustain a stable or continuous supply of energy from the microbial cells which can metabolize the components of the organic matter when exposed to suitable substrates, thereby producing electrons that can be harvested and utilized by a constructed organic circuit (MFC) [6].

Energy generation from wastes that are landfill-bound is obtaining heat or electrical energy from manure, feces, and various other organic materials. In addition to the generation of heat or electrical energy, organic wastes can be used in the production of methane, ethanol, methanol, or synthetic fuels. Different techniques are been explored in the transformation of organic wastes into useable forms of energy [7].

Biomass comprising crops, seeds, algae, and bio-waste are seen as major sources of renewable energy since they can be regenerated through natural processes [8][9][10][11]. Citrus are part of what constitutes biomass, they are rich in ascorbic acid [12], citric acid, sugar, and other ingredients with sufficient chemical energy which are converted into electrical energy by redox reaction with specific conditions, this chemical energy can be utilized as batteries to light up LEDs bulbs, power up a clock or calculator, etc. [10][11]. Citric acid contained in citrus fruits could serve as an electrolyte that similarly enables the generation of electricity as the galvanic battery [13].

Microbial fuel cells are bio-electrochemical transducers, that convert chemical energy into electrical energy [14][15][16]. MFCs make use of substrate from renewable sources and convert them into harmless by-products alongside the production of energy [16][17][18]. Within the microbial fuel cell, microbes munch up the sugars and other nutrients in their surrounding environment and release charged particles contained within the food in the form of electricity [19]. MFCs are systems in which microbes convert chemical energy produced by the oxidation of organic/inorganic compounds into adenosine tri-phosphate to generate an electrical current [20][21]. A microbial fuel cell is made up of two chambers which are the anodic (anode) and cathodic (cathode) chamber [6].

MFCs are divided into two main types: single chamber and dual chamber. The MFC containing a cathode and anode in different chambers is called a dual chamber MFC; while an MFC which contains both a cathode and anode in a single chamber is called a single chamber MFC [21].

This research work was aimed at converting organic (watermelon fruit bark) waste into electricity.

2. Materials and methods

2.1. Collection of watermelon fruit bark

A top-loading weighing balance (Model: SP20KG; Capacity: 20kg/44LB) was used to weigh different weights (1 kg, 2 kg, and 4 kg) of watermelon fruit bark collected from different refuse dumps in Port-Harcourt, Rivers- State, Nigeria at an interval of one week. The collected barks of watermelon fruit were bagged and transported to the Biochemistry Research Laboratory of the Department of Biochemistry all in the University of Port-Harcourt, Choba, Rivers State, Nigeria, where they were used with the constructed single chamber microbial fuel cell for the generation of electricity.

2.2. Sample preparation (electrolyte)

The collected watermelon fruit bark was left for three days for microorganisms and enzymatic reactions to take place; this helped to facilitate the breakage of bonds and the release of the electron that was used in the generation of electricity. The watermelon fruit bark was sliced into tiny pieces with the aid of a knife, The sliced watermelon fruit bark was made in a solution form by mixing it with water this was done to enhance the degradation of the watermelon fruit bark which was made possible by microorganisms and enzymes, the watermelon fruit bark was sliced into the tiny piece to create a large surface area for the microorganisms and enzymes to properly and quickly degrade the watermelon fruit bark. The prepared watermelon fruit bark was loaded into the constructed single chamber microbial electrochemical cell and water was added to the solution in the SC-MFC until it got to the 21.00 liters mark (21.00 liters transparent bucket that served as the single chamber microbial electrochemical cell) where electricity was generated.

2.3. Preparation of anode and cathode chambers

The anode and cathode chambers of the single-chamber microbial fuel cell were prepared according to the method described by Logan et al [22]. The anode compartment was anaerobic; the anode was covered with a lid and was properly sealed with 4-minute gum to prevent atmospheric oxygen from entering the chamber. The degrading microorganism hence functioned in an absolute anaerobic condition The diameter of the anode was ¾ inch which is approximately 1.0875 cm while its length was 35.00 cm. The cathode compartment was aerobic as it contained atmospheric oxygen. The diameter of the cathode was ¾ inch while its length was 50cm.

2.4. Construction of single-chamber microbial fuel cells

The method described by Logan et al [22] was followed in the construction of the single-chamber microbial fuel cells used in this research work. The SC-MFC used for this study was constructed from local materials, a 21.00-liter transparent bucket with a lid as the entire volume of the system was employed. The top inner diameter of the single chamber microbial electrochemical cell was 31.60 mm while its base inner diameter was 21.00 mm. The PVC pipes that served as anode and cathode chambers were stacked with graphite rods obtained from 1.5 V dry cell batteries. The base of the cathode and anode compartment was sealed with polyethylene material to avoid the passage of the graphite rods. A hole of diameter 11.00 mm was bored on the lid of the SC-MFC. The anode chamber was inserted completely into the single chamber microbial fuel cells which were sealed with 4-minute gum to avoid the passage of air. 70% of the total length of the cathode was in the solution of watermelon fruit bark while the remaining 30% of its length was exposed to atmospheric oxygen (air). The graphite rod with a diameter of 10.00 mm and length of 57.00 mm was extracted from discarded 1.5 V dry cell batteries. The distance between the electrodes (cathode and anode) was 15.00 mm (1.5 cm). At the top of the cathode and anode, a projected hanging graphite rod of 5.0 mm was placed. The electrodes (anode and cathode) with their projected graphite rods were connected by using copper wire which was glued to the projected graphite rod. A 10,000Ω resistor was connected across the circuit to bridge it. The voltage generated was recorded daily at 1:00 p.m. with a digital Multi-meter (Model: DT9205A).

2.5. Microbial fuel cell test procedure

The microbial fuel cell was monitored for 5 days for each weight of watermelon fruit bark used (1 kg, 2 kg and 4 kg) during which the voltages generated by the watermelon fruit bark and measured by the digital Multi-meter (Model: DT9205A) were recorded for each experimental day. 24 hourly (daily) reading of the voltages generated was measured and recorded at 1:00 pm, the voltages generated, measured, and recorded by the digital multi-meter were in milli-volts (mV).

2.6. Statistical analysis

This study was carried out in triplicate and triplicate readings of voltages generated were obtained. Voltages generated from this study are presented in Mean ± Standard Error of Mean (M ± S.E.M). Statistical analysis was done using SPSS Version 23.0

3. Result and discussion

3.1. Result

The result obtained from this study is presented in the table below showing the voltages generated from different weights (1 kg, 2 kg, and 4 kg) of watermelon fruit bark through a single chamber microbial fuel cell.

The table below revealed that the different weights (1kg, 2kg, and 4kg) of watermelon fruit bark generated voltages that varied from each other, the voltages so generated increased with a corresponding increase in the weight of watermelon fruit waste as can be seen in the table below; 1 kg of watermelon fruit bark generated voltages of (32.75±5.90, 49.00±8.07, 76.80±9.13, 82.30±9.38 and 97.85±6.04)mV for days 1-5 respectively; 2 kg of watermelon fruit bark generated the following voltages (56.80±9.58, 67.50±9.88, 78.00±8.67, 90.10±8.93 and 104.85±4.13) mV and 4 kg of watermelon fruit bark generated the following voltages (72.75±3.23, 91.45±0.98, 111.25±2.83, 123.75±1.78 and 143.15±3.79) mV. The result showed that watermelon fruit bark and by extension organic wastes are capable of generating electricity; the quantity of electricity generated increased with a corresponding increase in the weight of the watermelon fruit bark.

Table 1. Voltages generated from 1 kg, 2 kg, and 4 kg weight(s) of watermelon fruit bark for experimental days

	Experimental Days And Voltages Generated (mV)				
Weights of watermelon fruit bark (Kg)	1	2	3	4	5
1	32.75±5.90	49.00±8.07	76.80±9.13	82.30±9.38	97.85±6.04
2	56.80±9.58	67.50±9.88	78.00±8.67	90.10±8.93	104.85±4.13
4	72.75±3.23	91.45±0.98	111.25±2.83	123.75±1.78	143.15±3.79

Results are Mean ± SEM for n=3
Note: n = Single Chamber Microbial Fuel Cell (SC-MFC)

3.2. Discussion

Harnessing of organic waste material, especially biomass for the generation of electricity or any useful product is a welcome development as it helps in recycling this deleterious material which has the potential to cause health challenges to individuals who are recipients of its noxious gases; also fossil fuel which is presently used for the generation of electricity is constantly posing serious health challenges to humans and plants alike as a result of the greenhouse gases which they have been known to expel, this has therefore led to the carrying out of research by scientist all around to world to design a system that has the capability of recycling these organic waste matter into a useful product that is renewable and not harmful to human and plant and also to create a system that can be used to replace fossil fuel that is currently used in the generation of electricity today and this is where microbial fuel cell also known as microbial electrochemical cell comes in.

The findings obtained from this study indicated that the voltages generated were weight-dependent (increase in weight of watermelon waste causes a corresponding increase in the voltage generated). The results derived from this study are in agreement with that of Moqsud et al [16], who carried out research on bioelectricity generation from kitchen garbage and bamboo waste in a microbial fuel cell and obtained a voltage reading of 620mV from kitchen waste which comprised of vegetable wastes, fruits, and leftover food.

The findings of this study also agree with that of Navinraja et al [23], who reported a maximum voltage reading of 292mV from vegetable waste in their study on comparative analysis of bioelectricity generation from cow dung, vegetable, and fishery waste using laboratory-designed microbial fuel cells. The findings of this research work also agree with that of Gadhamshetty et al [24], who conducted a research work on the generation of electricity from defective tomatoes and obtained a power of 0.3 watts from 10 milligrams of defective tomatoes. Also, the findings of this study is in agreement with that of Javed et al [25], who researched on production of bioelectricity from vegetable waste (cabbage, spinach leaves, potato peels, cucumber peels and carrot of 100 grams each), and obtained a maximum power density of 88990mW/m^2 and a current density of 314.4A/m^2 after the second day of the study with a minimal internal resistance comparatively (123.23**Ω**).

4. Conclusion

Electricity can be generated from organic wastes that litter our environment, the electricity generated was a result of the microorganisms that were present in the watermelon fruit waste that caused the decomposition of the watermelon waste with the release of electrons and energy (breakage of bonds since watermelon is an organic material) which are trapped by the anode chamber of the microbial fuel cell for the generation of electricity. The microbial fuel cell works on the principles of electrolysis. Proper programs should be put in place to adequately utilize these organic materials for the generation and supply of electricity to developing countries.

Conflict of Interest

The authors declare that no conflict of interest exists between them regarding any part of this publication.

Acknowledgment

The authors thank the Management University Of Port-Harcourt Choba, Rivers State, Nigeria for the use of the Research laboratory in the Department of Biochemistry for the entire period of this study.

References

[1] A. M. Khan, S. A. Attaullah, I. Ahmed, F. Malik, and H. A. Shahid, “Correlation of COD and BOD of domestic wastewater with the power output of a bioreactor,” Journal of the Chemical Society of Pakistan, vol.32, no.2, pp.269-274, **(2011)**

[2] A. W. D. Larhum, “Limitation and prospects of natural photosynthesis for bioenergy production,” Current Opinion in Biotechnology, vol.1, no.21, pp.271-276, **(2010)**

[3] M. Goff, S. B. Nicholas, L. Shailesh, R. S. Willian, and J. S. Galen, "Acid-catalyzed alcoholysis of soybean oil,” Journal of the American Chemist’s Society, vol.81, pp.415-420, **(2004)**

[4] Y. Christi, “Biodiesel from algae,” Journal of Biotechnology Advances, vol.25, pp.294-296, **(2007)**

[5] J. H. Ha, N. Shah, M. Islam, and J. Park, “Production of bio-ethanol by simultaneous saccharification and fermentation process using waste from beer fermentation broth,” Journal of Biotechnology, vol.150 no.1, pp.147-148, **(2010)**

[6] D. T. Akshay, S. Namrata, and W. O. Jabez, “Microbial fuel cell in bioelectricity production,” Journal of Frontiers in Life Science, vol. 9 no.4 pp.252-266, **(2016)**

[7] S. Pandey, K. Kalra, P. Singh, and R. Shukla, "Electricity generation from trash 'eliminating the unwanted, while creating the needed", International Advanced Research Journal in Science, Engineering, and Technology, vol.21 no.1, pp. 258-262, **(2015)**

[8] I. Dincer, “Renewable energy and sustainable development,” Renewable and Sustainable Energy Reviews, vol.4 pp.157-175, **(2000)**

[9] A. B. M. S. Hossian, and M. A. Mekhled, “Biodiesel fuel production from waste canola cooking oil as sustainable energy and environmental recycling process,” Australian Journal of Crop Science, vol. 4 no.7, pp.543-549, **(2010)**

[10] T. M. Mata, A. A. Martins, and N. S. Ceatano, “Microalgae for biodiesel production and other applications,” Renewable and Sustainable Energy Reviews, vol.14 pp.217-232, **(2010)**

[11] A. M. Khan and M. Obaid, “Comparative bioelectricity generation from waste citrus fruit using a galvanic cell, fuel cell, and microbial fuel cell” Journal of Energy in Southern Africa, vol.26 no.3, pp.90-99, **(2015)**

[12] M. A. Randhawa, A. Rashid, M. Saeed, M. S. Javed, A. A. Khan, and M. W. Sajid, “Characterization of organic acids in juices in some of the Pakistani citrus species and their retention during refrigerated storage,” Journal of Animal and Plant Science, vol.24, no.1. pp.211-215, **(2014)**

[13] J. Goodisman, “Observation on lemon cells,” Journal Chemical Education, vol.75, no.4, pp.516-518, **(2001)**

[14] B. E. Logan, and J. M. Regan, “Electricity producing bacterial communities in microbial fuel cells,” Trends in Microbiology, vol. 14, pp.512-518, **(2006)**

[15] H. L. Oon, “A simple electric cell, chemistry expression: an inquiry approach,” Panpac Education Pte Ltd: Singapore, vol.1, no.1, pp.236, **(2007)**

[16] M. A. Moqsud, K. Omine, N. Yasufuku, Q. S. Bushra, M. Hyodo, and Y. Nakata, “Bioelectricity from kitchen garbage and bamboo wastes,” Journal of Waste Management Resources, vol. 32, pp. 124-130, **(2014)**

[17] M. A. Moqsud, K. Omine, and N. Yasufuku, "A comparative study of bioelectricity generation by using kitchen garbage and bamboo waste in a microbial fuel cell," In Proceedings of the 27th International Conference on Solid Waste Technology and Management, Philadelphia, USA. pp.1051-1061, **(2012a)**

[18] M. A. Moqsud, J. Yoshitake, Q. S. Bushra, M. Hyodo, K. Omine, and D. Strik, “Compost in plant microbial fuel cell for bioelectricity generation,” Article in Waste Management, vol.36, pp.63-69, **(2015)**

[19] M. A. Moqsud, K. Omine, N. Yasufuku, M. Hyodo, and Y. Nakata, “Microbial fuel cell (MFC) for bioelectricity generation from organic waste,” Journal of Waste Management, vol.33, pp.2465-2467, **(2013)**

[20] C. I. Torres, R. K. Brown, P. Parameswaran, A. K. Marcus, G. Wanger, Y. A. Gorby, and B. E. Rittmann, “Selecting anode-respiring bacteria based on anode potential: phylogenetic, electrochemical, and microscopic characterization,” Journal of Environmental Science and Technology, vol.1, no.43, pp.9519-9524, (2009), DOI: 10.1021/es902165-1

[21] V. Chaturvedi and P. Verma, “Microbial fuel cell: a green approach for the utilization of waste for the generation of bioelectricity,” Journal of Bioresources and Bioprocessing, vol.1, no.3, pp.1-14. (2016), DOI:10.1186/s40643-016-0116-6

[22] B. E. Logan, B. Hamlers, R. Rozendal, U. Schronder, J. Keller, S. Freguia, P. Aelterman, W. Verstraete, and K. Rabaey, “Microbial fuel cell: methodology and technology,” Environmental Science and Technology Journal, vol.40, pp.5181-5192, **(2006)**

[23] P. Navinraja, D. Manimaran, R. Dinesh, S. Sivaramakrishnan, and S. Velavan, "Comparative analysis on bioelectricity generation from cow dung, vegetable, and fishery waste using laboratory designed microbial fuel cell," Journal of Biotechnology, vol.5, no.7, pp.1-5, **(2015)**

[24] V. Gadhamshetty, N. Shrestha, A. Fogg, J. Wilder, D. Franco, and S. Komisar, “Electricity generation from defective tomatoes,” Journal of Bioelectrochemistry, vol.112, pp.67-76, **(2016)**

[25] M. M. Javed, M. A. Nisar, B. Munner, and M. U. Ahmad, “Production of bioelectricity from vegetable waste extract by designing a u-shaped microbial fuel cell,” Pakistan Journal of Zoology, vol.49, no.2, pp.711-716, **(2017)**

Authors

Akpotayire, Stephen Ive

Akpotayire, Stephen Ive is an ardent researcher and is currently undergoing a M.Sc. program in Environmental Biochemistry, from the University of Port-Harcourt, Choba, Rivers State, Nigeria. His research interest includes heavy metal and hydrocarbon analysis in plants, water bodies/aquatic lives, medicinal plants, xenobiotics as well as environmental pollutants. He is the author of "Don't just talk, communicate: A guide to effective communication in Business and relationships". He also has a good number of publications in reputable journals.

Pepple, Omiete Ene

Pepple, Omiete Ene is an M.Sc. student in the Department of Biochemistry (Medical Biochemistry and Immunochemistry option), University of Port-Harcourt, Choba, Rivers-State, Nigeria. Her research interest includes amelioration of infertility in both males and females using medicinal plants. She is an avid reader and a relentless researcher.