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Research Article

USE OF BIOWASTE FOR ELECTRICAL ENERGY PRODUCTION THROUGH MICROBIAL FUEL CELL

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Abstract: Waste is a common term for all kind of unwanted materials generated during the extraction and processing of raw materials to get intermediate and final products. A major portion of the total solid waste in developing countries is an organic waste, and it is not properly treated for resource recovery. Organic waste treatment is also a top priority in the developing countries. Microbial fuel cells (MFCs) are an alternative energy technology that has the capacity to simultaneously treat organic waste and generate electricity. MFCs are used to generate electricity while accomplishing the biodegradation of organic matters by microbes. The objective of present work was generation of electricity by mixture of different biowaste as a substrate in MFC. The experimental study was carried out by using biowaste (Kitchen waste, cow dung and poultry waste), zinc and copper plates of dimension length=15 cm and width 4.5 cm with potassium ferricyanide used as an oxidizing agent. In all the setup maximum electricity generation was measured between 321 to 736.66 mV by using mixture of kitchen waste with cow dung waste and poultry waste. In all setup maximum electricity generation of 736.66 mV was recorded by using only 100% poultry waste. Overall, this study has shown that the fabricated microbial fuel cell can be used for the generation of electricity from different kinds of biowaste at a larger scale in series with continuous feeding of biowaste and it can be considered as eco-friendly system for solid waste management.

Keywords: *Solid waste, Microbes, Microbial Fuel Cell and Energy Production*

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Introduction

Rapid industrialization and population explosion in India have leads to the migration of people from villages to cities, which generate thousands of tons of municipal solid waste (MSW) daily. It has been estimated that urban India is generating approximately 1, 88,500 tonnes of municipal solid waste per day (68.8 million tonnes per year). The capital of India, Delhi generates approximately 11,558 tonnes of municipal solid waste daily [1].

There are different sources of solid waste generation, which includes agriculture, industrial, mining, domestic waste, municipal solid waste, commercial and institution *etc*. About 10% of the collected MSW is openly burnt and is caught in landfill fire. MSW and landfill fires together release tons of pollutants into the atmosphere in open burning. These pollutants include carbon monoxide (CO), nitrogen oxides (NOx) and sulfur dioxide (SO_2) carcinogenic hydrocarbons (HC) (includes dioxins and furans), particulate matter (PM). Wastes are classified into solid, liquid and gaseous on the basis of their physical state. Solid wastes are the organic and inorganic in nature.

Energy crisis as result of increased depletion of fossil fuels has led to a serious search for alternate and sustainable energy resources. Energy is a vital area of research in the World, and currently a range of energy sources are in use. However, more focus is on renewable and sustainable energy solutions [2]. The non-renewable resources of energy are depleting at a faster rate. A various approach with highly efficient energy transformations and ways to utilize the alternate renewable energy sources is needed to mitigate the energy crisis. New approach of electricity production from renewable resources without a net carbon dioxide emission is much desired [3].

Microbial Fuel cells are one of the most important areas of research for the sustainable production of electricity. The main aspect of MFC research is to reduce the cost and simplify the utilization conditions.

Microbial fuel cells (MFCs) are bio electrochemical systems (bioreactors) that convert the chemical energy in organic matter into electricity by means of metabolic activity (catalysis) of the aerobic and anaerobic microbes. MFCs are used to generate electricity while accomplishing the biodegradation of organic matters. Mostly biowaste can be used inside the anodic chamber as feed for microorganism, however cow dung is observed as rich nutrient source for microorganism and hence mixing of cow dung with biowaste can enhance the production of electricity through MFC.

Food waste (both precooked and leftover) is a biodegradable waste and comes from various sources including hotels, restaurants, supermarkets, residential blocks, cafeterias, airline caterers, food processing industries and some portion of a municipal solid waste, *etc*. Food waste including fresh vegetables, fruits, meat, bakery and dairy products are lost along the food supply chain. As a promising anaerobic waste treatment device, the microbial fuel cell (MFC) can use microorganisms as catalyst to recover electricity from organic wastes. The MFC could efficiently achieve safe, clean and direct electricity production and simultaneous organic matter removal. Therefore, using food waste as a substrate in MFC for electricity generation could be a promising approach for food waste treatment and energy recovery.

Poultry waste is a solid waste and it is a nutrient-rich litter was used as a soil fertilizer in crop production, cattle feed and as a potting medium in growing ornamental plants. Use of poultry waste can be good option for energy production. Poultry waste (litter) is a mixture of manure and bedding material like wood shavings, sawdust, shredded sugar cane, peanut hulls, straw, and other dry absorbent low-cost organic materials. The potentials of poultry waste for generation of electricity using microbial fuel cell is required to be studied in details by communication with other municipal solid waste and kitchen waste.

Material and Methods

This study was conducted in G. B. Pant University of Agriculture and Technology Pantnagar, Uttarakhand. Biowaste such as kitchen waste, cow dung and poultry waste were used for generating the electricity through MFC. Kitchen waste was collected from hostel mess of Yamunotri Bhawan girl's hostel, Cow dung and poultry waste were collected from Instructional Dairy and Poultry Farm Nagla, respectively situated in University campus. The materials used for this study include poultry waste, kitchen waste, cow dung, distilled water, plastic containers, polyvinylchloride (P.V.C.) pipes, potassium fericyanide, sodium chloride, copper wires, multimeter, glass wares, zinc and copper plates.

The basic design of the microbial fuel cell consists of two distinguished compartments: Aerobic and Anaerobic compartments. For making these compartments two plastic container of same size and same volume (2 litre) were used as a cathodic and anodic chamber separately. A hole of same size at the same place on both the container was made for inserting the salt bridge, which connected both the container. In the cathodic and anodic container, a small hole was made on the cover of the containers for fitting the zinc and copper plates (length= 15cm, width= 4.5cm). The salt bridge required to connect anodic cathodic chamber, were made up by using agar and NaCl solution and after its proper boiling and mixing this solution was placed in the PVC plastic pipe which were used to work as a salt bridge between both the chamber. This solution was made up by adding 10g agar with 20g NaCl in beaker and heated at temperature of 100°C for 20 min. After cooling it was poured in the PVC pipe which is used as salt bridge. For making the salt water with conductivity of 31.3 mS/cm, 250 milli molar salt solution was required. By dissolving the 15g of NaCl in 1L of distilled water we achieved salt solution of 250 mM. It has been reported by Wang *et al*. [4] that at conductivity of 31.3mS/cm performance of plate was found optimum.

Result and Discussion

The present work mentioned the results along with discussion. Performance of different experimental Setup

Setup-1

For carrying out this study potassium ferricyanide (50g/L) which is used as an oxidizing agent and zinc or copper plate of same length =15 cm and width= 4.5 cm in both the chambers of cathode and anode of MFC were used. The further experiment was carried out by taking mixture of biowaste 25 % kitchen waste along with 75% cow dung waste which is used as a substrate in microbial fuel cell for utilizing electron through the degradation by microbes of kitchen waste and cow dung. On 3rd day from the starting of experiment the maximum voltage generation of 321 mV and on 7th day of the experiment minimum voltage generation 94 mV was recorded. From mixture of kitchen waste with cow dung waste, electricity generation was lowly raised and due to maximum utilization of organic waste present in mixture of biowaste it starts decreasing after 3 days. The details of result obtained from this experimental setup are given in [Table-1] and same is also shown in [Fig-1]. Moqsud *et al*. [5] have reported that the generation of bioelectricity from kitchen waste and bamboo waste and founded by kitchen waste 620 mV was generated and 540 mV voltage was generated by bamboo waste.

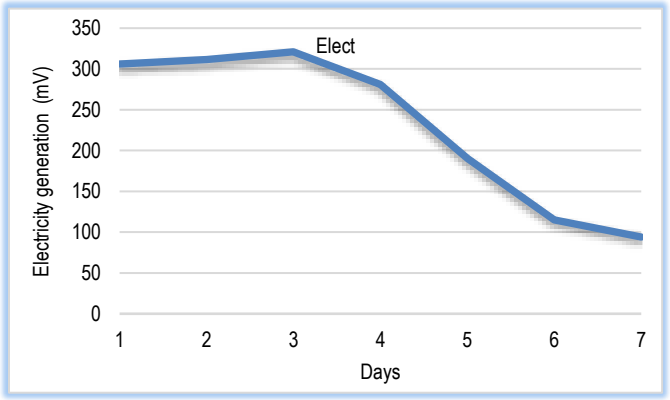

Fig-1 Average electricity generation in mV through MFC Setup-1 by using (25% kitchen waste and 75% cow dung waste) substrate

Setup-2

In this experimental setup potassium ferricyanide (50g/L) was used as an oxidizing agent and keeping zinc and copper plates of same length =15 cm and width = 4.5 cm in both the chambers of cathode and anode of MFC were placed. The further experiment was carried out by taking mixture of biowaste 50 % kitchen waste along with 50% cow dung waste which is used as a substrate in microbial fuel cell for utilizing electron through the degradation by microbes of kitchen waste and cow dung waste. On 4th day from the starting of experiment the maximum voltage generation of 422.66 mV and on 7th day of the experiment minimum voltage generation 96.06 mV was recorded. From mixture of kitchen waste with cow dung waste, electricity generation was lowly raised and due to maximum utilization of organic waste present in mixture of biowastes it starts decreasing after 4th day. The details of result obtained from this experimental setup are given in [Table-2] and same is also shown in [Fig-2]. Kumar and Das [6] have reported the generation of 462 to 1652 mVelectricity from sewage sludge, Cow dung and kitchen waste by using single chamber single electrode MFC.

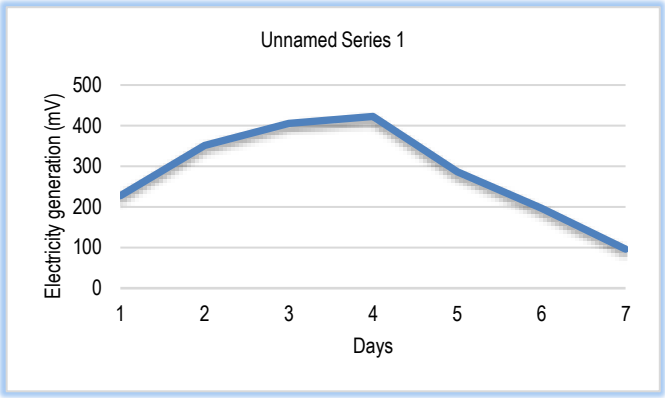

Fig-2 Average electricity generation in mV through Microbial fuel cell Setup-2 by using (50% kitchen waste and 50 % cow dung) substrate

Setup-3

In this experimental setup potassium ferricyanide (50 g/L) was used as an oxidizing agent and keeping zinc and copper plates of same length =15 cm and width = 4.5 cm in both the chambers of cathode and anode of MFC were used. The further experiment was carried out by taking mixture of biowaste such as 75 % kitchen waste along with 25% cow dung waste which is used as a substrate in microbial fuel cell for utilizing electron through the degradation by microbes of kitchen waste and cow dung waste. On 2rd day from the starting of experiment the maximum voltage generation of 418 mV and on 7th day of the experiment minimum voltage generation was 188.66 mV was recorded. From mixture of kitchen waste with cow dung waste, electricity generation was lowly raised and due to maximum utilization of organic waste present in mixture of biowastes it starts decreasing after 3 days. The details of result obtained from this experimental setup are given in [Table-3] and same is also shown in [Fig-3].

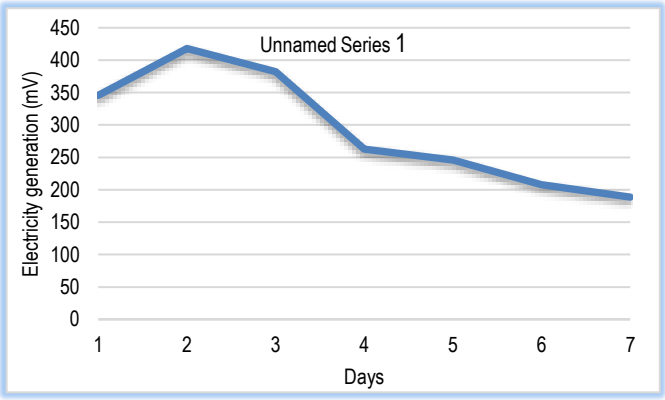

Fig-3 Average electricity generation in mV through Microbial fuel cell by Setup-3 using (75% kitchen waste and 25% cow dung waste) substrate

Table-1 *Electricity generation in mV through MFC in Setup-1 by using (25% kitchen waste and 75% cow dung) substrate*

Substrate	No. of observation	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
25% Kitchen waste & 75% Cow dung	1	306	312	322	280	190	120	96
	2	305	311	320	282	192	115	95
	3	307	312	321	281	189	110	91
Average		306	311.66	321	281	190.33	115	94
S.E.		±0.57	±0.33	±0.57	±0.57	±0.88	±2.88	±1.52

Table-2 *Generation of electricity in mV through Microbial fuel cell Setup-2 by using (50 % kitchen waste and 50 % cow dung waste) substrate*

Substrate	No. of observation	Day 1	Day 2	Day 4	Day 5	Day 6	Day 7	Day 7
50% kitchen waste & 50 % cow dung waste	1.	223	350	406	425	289	196	98.2
	2.	225	348	408	420	285	198	96
	3.	235	355	404	423	286	196	94
Average		227.66	351	406	422.66	286.66	196.66	96.06
S.E.		±3.71	±2.08	±1.15	±1.45	±1.20	±0.66	±1.21

Table-3 *Generation of electricity in mV through Microbial fuel cell Setup-3 by using (75% kitchen waste and 25% cow dung waste) substrate*

Substrate	No. of observation	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
75% Kitchen waste & 25% Cow dung	1.	345	416	385	268	250	209	190
	2.	347	420	382	265	242	210	191
	3.	344	418	380	255	245	205	185
Average		345.66	418	382.33	262.66	245.66	208	188.66
S.E.		±0.88	±1.15	±1.45	±3.92	±2.33	±1.52	±1.85

Table-4 *Generation of electricity in mV through Microbial fuel cell Setup-4 by using 100% kitchen waste*

Substrate	No. of observation	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 7
100% Kitchen waste	1.	285	354	377	258	120	96	70
	2.	286	343	370	260	121	99	72
	3.	280	350	365	265	120	94	71
Average		283.66	349	370.66	261	120.33	96.33	71
S.E.		±1.85	±3.21	±3.48	±2.08	±0.33	±1.45	±0.57

Table-5 *Electricity generation in mV through MFC Setup-5 by using (50 % kitchen waste and 50 % poultry waste) substrate*

Substrate	No. of observation	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
50% kitchen waste & 50% poultry waste	1	243	281	331	224	192	92	85
	2	255	286	325	222	190	91	83
	3	270	290	303	223	193	92	82
Average		256	285.66	319.66	223	191.66	91.66	83.33
S.E		±7.81	±2.60	±8.51	±0.57	±0.88	±0.33	±0.88

Table-6 *Electricity generation in mV through MFC Setup-6 by using (75% kitchen waste and 25 % poultry waste) substrate*

Substrate	No. of observation	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
75% kitchen waste & 25 % poultry waste	1	543	453	367	226	183	158	94
	2	549	438	366	224	180	156	93
	3	555	425	364	225	182	157	93
Average		549	438.66	365.66	225	181.66	157	93.33
S.E.		±3.46	±8.09	±0.88	±0.57	±0.88	±0.57	±0.33

Table-7 *Electricity generation in mV through MFC Setup-7 by using (100% poultry waste) substrate*

Substrate	No. of observation	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
100% Poultry waste	1	692	730	450	220	195	85	70
	2	690	750	440	222	190	80	72
	3	700	730	444	223	192	82	73
Average		694	736.66	444.66	221.66	192.33	82.33	71.66
S.E.		±3.05	±6.66	±2.90	±0.88	±1.45	±1.45	±0.88

The same trend of bio-electricity generation from organic waste has been reported by Moqsud and Omine [7] by using 120g kitchen waste, 120g leaf mold and 15 gm microorganism. They observed that the maximum power density 682 mW/m^2, when kitchen waste used as a substrate.

Setup-4

For carrying out this study potassium ferricyanide (50 g/L) was used as an oxidizing agent and keeping zinc and copper plates of same length =15 cm and width = 4.5 cm in both the chambers of cathode and anode of MFC were used. The further experiment was carried out by taking biowaste such as 100 % kitchen waste which is used as a substrate in microbial fuel cell for utilizing electron through the degradation by microbes of kitchen waste. On 3rd day from the starting of experiment the maximum voltage generation of 370.66 mV and on 7th day of the experiment minimum voltage generation was 71. mV was recorded.

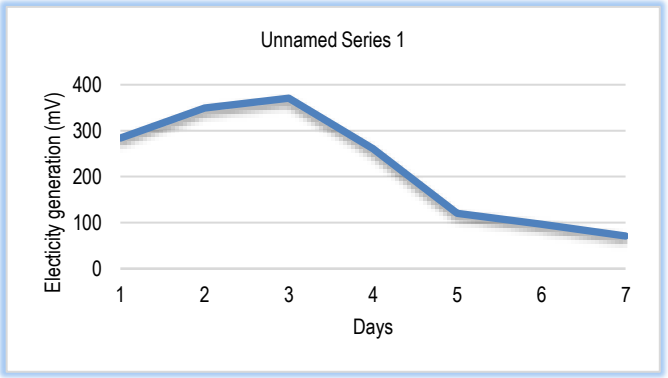

Fig-4 Average electricity generation in mV through Microbial fuel cell Setup-4 by using 100% kitchen waste

From 100% kitchen waste, electricity generation was lowly raised and due to maximum utilization of organic waste present in kitchen waste it starts decreasing after 3 days. The details of result obtained from this experimental setup are given in [Table-4] and same is also shown in [Fig-4]. Jia *et al*. [8] used food waste as an energy source using it in a MFC as a substrate and the maximum power density of 180 Wm^{-3} at COD OF 3200 ± 400 mg/L and the maximum output of 27% in form of columbic efficiency at COD 4900 ± 350 g/L was obtained.

Setup-5

In this experimental setup potassium ferricyanide (50 g/L) was used as an oxidizing agent and keeping zinc and copper plates of same length =15 cm and width = 4.5 cm in both the chambers of cathode and anode of MFC. The further experiment was carried out by taking mixture of biowaste 50 % kitchen waste along with 50 % poultry waste is used as a substrate in microbial fuel cell for utilizing electron through the degradation by microbes of kitchen waste and poultry waste. On 3rd day from the starting of experiment the maximum voltage generation of 319.66 mV and on 7th day of the experiment minimum voltage generation 83.66 mV was recorded. From mixture of kitchen waste with poultry waste, electricity generation was lowly raised and due to maximum utilization of organic waste present in mixture of biowastes it starts decreasing after 3rd days. The details of result obtained from this experimental setup are given in [Table-5] and same is also shown in [Fig-5]. Uzoejnwa *et al* [9] Investigated the potential of poultry and piggery waste for electricity production in the term of current (0.96 mA), voltage (1.22 V) and power generation (1.12 mW) by using two configuration of double-chambered microbial fuel cell.

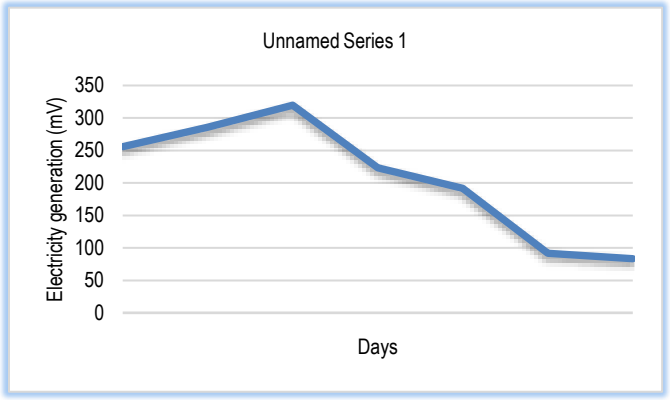

Fig-5 Average electricity generation in mV through MFC Setup-5 by using (50% kitchen waste and 50 % poultry waste) substrate

Setup-6

In this experimental setup potassium ferricyanide (50 g/L) was used as an oxidizing agent and keeping zinc and copper plates of same length =15 cm and width = 4.5 cm in both the chambers of cathode and anode of MFC were placed.

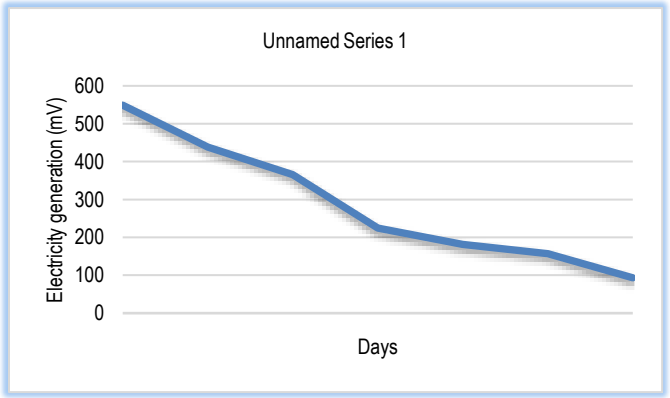

Fig-6 Average electricity generation in mV through MFC Setup-6 by using (75% kitchen waste and 25% poultry waste) substrate

The further experiment was carried out by taking mixture of biowaste 75 % kitchen waste along with 25 % poultry waste which is used as a substrate in microbial fuel cell for utilizing electron through the degradation by microbes of kitchen waste and poultry waste. On 1st day from the starting of experiment the maximum voltage generation of 549 mV and on 7th day of the experiment minimum voltage generation 93.33 mV was recorded. From mixture of kitchen waste with poultry waste, electricity generation was lowly raised and due to maximum utilization of organic waste present in mixture of biowastes it starts decreasing after 1 days. The details of result obtained from this experimental setup are given in [Table-6] and same is also shown in [Fig-6]. Nyoyoko and Ibuot [10] have reported the generation of electricity from the mixture of cow, swine and poultry wastewater by using phosphate buffer solution with a concentration of 0.002 and found maximum power density of 480.187 mW/m^2.

Setup-7

In this experiment setup potassium ferricyanide (50 g/L) was used as an oxidizing agent and zinc or copper plates of same length =15 cm and width = 4.5 cm in both the chambers of cathode and anode of MFC were placed. The further experiment was carried out by taking biowaste such as 100 % poultry waste which is used as a substrate in microbial fuel cell for utilizing electron through the degradation by microbes of poultry waste. On 2nd day from the starting of experiment the maximum voltage generation of 736.66 mV and on 7th day of the experiment minimum voltage generation 71.66 mV was recorded. From 100% poultry waste, electricity generation was lowly raised and due to maximum utilization of organic waste present in poultry waste it starts decreasing after 3 days. The details of result obtained from this experimental setup are given in [Table-7] and same is also shown in [Fig-7]. Uzoejinwa *et al* [9]) investigated the potential of poultry and piggery waste for electricity production in the term ofcurrent (0.96 mA), voltage (1.22 V) and power generation (1.12 mW) by using two configuration of double-chambered microbial fuel cell.

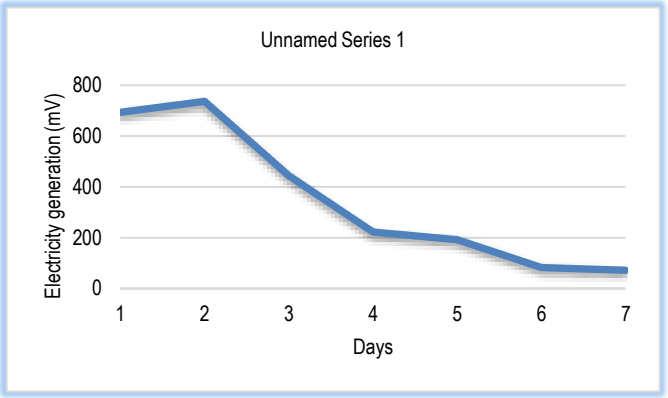

Fig- 7 Average electricity generation in mV through MFC Setup-7 by using (100% poultry waste) substrate

Conclusion

Based on the result and observation, it was noted that the maximum electricity generation 321 mV was obtained by the mixture of 25% kitchen waste mixed with 75 % cow dung waste, maximum electricity generation was recorded 422.66 mV, when 50% kitchen waste mixed with 50 % cow dung waste and 418 mV electricity was generated by the mixture of 75 % kitchen waste and 25 % cow dung waste. The observation and results obtained during the study envisaged that when 100 % kitchen waste used as substrate separately the maximum electricity generation was only 370.66 mV and when 50 % kitchen waste mixed with 50 % poultry waste the maximum electricity generation was recorded 319.66 mV, the maximum electricity was recorded 549 mV by the mixture of 75 % kitchen waste mixed with 25 % poultry waste and 100% poultry waste used as substrate separately the maximum electricity generation was 736.66 mV. The MFC was run up to one week and the electricity was recorded on daily basis in the presence of zinc or copper plates and potassium ferricyanid used as an oxidizing agent.

Application of research: To study the different solid waste substrate utilization in electricity production by Microbial fuel cell.

Research category: Environmental Science

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Research project name or number: MSc Thesis

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Instructional Dairy and Poultry Farm Nagla

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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