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# Cow Dung to Kilo Watt using Double Chamber Microbial Fuel Cell

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## ABSTRACT

In the current study, voltage is generated from cow waste at varying time duration of 6 to 11 days. PVC pipe was used to make a salt bridge using agarose and potassium chloride and Sodium chloride. The performance of microbial fuel cells was evaluated by characterizing the generated voltage, current, power and surface power density. It was observed that despite the high impedance of the substrate, all the generated parameters have shown maximum values at day 6 and then a decline in trend was observed on 7 days onwards. The highest values of voltage, current, power, current density and power density obtained were 0.5090V, 0.28μA, 0.0093μW, 0.05181mA/m$^2$ and 0.0000006 W/m$^2$ respectively. The study concluded that microbial fuel cells technology can be used to generate electricity from cow dung.

**Keywords:** Microbial Fuel Cells, Voltage, Current, Power Density

## I. INTRODUCTION

Microbial fuel cells (MFCs) technology is considered in the conversion of organic waste to clean and green energy in the form of electricity. This conversion utilizes microbes in the anodic chamber. Previous research on MFC's indicates that the anodic chamber is completely anaerobic with some employing facultative aerobic microbes. Organic substrates e.g. glucose, sewage sludge and petroleum hydrocarbon are oxidized to carbon dioxide, protons and electrons (Park and Zeikus, 2003; Min *et al.*, 2005; Rabaey *et al.*, 2005; Cheng *et al*., 2006; Morris and Jin, 2008).

Although MFCs generate a lower amount of power than hydrogen fuel cells, a combination of both electricity production and wastewater treatment could reduce the cost of treating primary effluent wastewater. Currently, most of the research performed on MFCs is concerned with increasing the power density of the system with respect to the peripheral anode surface area, while little research has been done on determining the effects of voltage output in comparison to varying fuel cell components. (Eric A. Zielke (2005)

Cow dung is rich in methanogenic bacteria as well as minerals that cow eat from herbs and other plants. Its color ranges from greenish blackish and sometimes it turns yellow due to chemical changes, fastened by sunlight. It is largely used for gobar gas plant, biogas plant, production of fertilizers, manures and many other organic products and cooking fuels. The biogas
From cow dung is rich in methane and is used in rural areas providing a renewable and stable source of electricity (Thatoi, 2011). It is a cheap alternative source of fuel for cooking and production of electricity. It is also used as a plaster in rural areas. Biologically, it has anti-bacterial properties and therefore a vital source of organic fertilizer. Despite having plethora properties, Chakraborti et al., (2007) have exposed the arsenic poisoning by cow manure that has affected many in India. They have found a significant amount of arsenic's presence in the air, water etc. The poisoning leads to respiratory problems like chronic bronchitis, coughing, X-ray abnormalities etc. This adds to environmental disadvantages (Henrian, H *et al.,* 2008). Still, many researchers have worked on the application of cow manure in microbial fuel cell, biogas plants, fuel production etc, keeping aside its demerits.

Jiannajia *et al*. (2013) employed microbial fuel cells technology to dispose food wastes (FWs) and process them into a waste-to-energy form. The maximum power density of ∼18

W/m3 (∼556 mW/m2) at COD of 3200 ± 400 mg/L and the maximum columbic efficiency

(CE) of ∼27.0% at COD (Chemical Oxygen Demand) of 4900 ± 350 mg/L was obtained.

COD of the pretreated FWs was 50,000–80,000 mg/L. They used a single chamber and air cathode MFC with anode volume of 28 ml and electrodes of carbon clothes of 7cm2 and nickel catalyzed. The voltage was measured across 500 ohms. Reactions were carried out in fed-batch (Liu, 2004)

Yokoyama *et al*., (2006) measured the capacity of dairy cow waste slurry in generating electricity.

They used the cow slurry of COD 1g/L for treating MFC that produced 0.34 $mW/m^2$ of power density. It was found that after using 84% biological oxygen demand (BOD), nitrogen, phosphorous and potassium were retained. Zheng *et al*. (2010) developed a new 21 scale MFC was to treat cattle dung. The device was able to produce 0.5V in open circuit and 0.4V under the resistance of 470 ohms.

Khare and Bundela (2013) via the application of Single chamber MFC, have generated electricity using different waste water mixed with vermicomposting from Jabalpur. Carbon electrodes were used as both the anode and cathode along with salt bridge having 3% agar and 1M KCl solution for proton transfer to the cathode. MFC used was a single chamber mediated device. Methylene blue served as an electron shuttle. Maximum generated voltage was 232 mV over a period of 7 days.

Lee et al. (2011) made two different MFCs to treat solid waste that includes cow manure and was run in the batch mode. One was of single compartment type and another one was of twin compartment type. A voltage of 0.38 was recorded across a 470-ohm resistance. The power density was measured as 36.6 mW/m 2. Electrodes used had 20% platinum catalyst and Nafion 117 was used as proton exchange membrane. Zhang.G et al. (2011) tested the electricity generating potential of cow manure by three chambered MFC and bio-cathodes. He was able to produce a maximum voltage of 0.502 V with an external resistance of 100 ohms. The volumetric power density of 8.15 W/m3 was obtained throughout the process of production of electricity.

**Energy in Kenya**

Most Kenyans depend on hydro-power and petroleum products for their energy needs. Rural and some urban dwellers rely heavily on trees for firewood and charcoal. The use of fuel for both lighting and cooking has reduced the forest cover significantly. This has resulted in continued cutting down of trees for direct use as a source of fuel and charcoal preparation. 65.3% of energy consumed in Kenya is wood fuel and biomass while petroleum, electricity and other sources account for 32% (GTZ, 2007, PAC, 2010). Since 2014, the number of Kenyans connected to electricity has increased from 1, 041, 576, to 3,300 467 which is a 46% increase. The number of primary schools connected has also increased from 8, 203 in 2013 to 22, 175 schools in 2016 (MOE, 2016). The launch of the last mile connectivity project by the Kenyan government and the cut-down of electricity connection fee to KShs. 15000 is aimed at ensuring that 70% of the households are connected by 2017. Liquefied petroleum gas (LPG) consumption in Kenya was 15000 tons in 2015. The Kenyan Government is targeting to withdraw kerosene from the market to reduce household emissions (Wachira, 2016). Use of LPG is expected to increase until 2020 (Githiomi, 2012).

## II. METHODS AND MATERIAL

A double chamber MFC was fabricated using inexpensive materials. They include 16.3cm to 15.3cm diameter and 7.4cm to 9.4cm long plastic containers, PVC pipes, adhesive glue, scissors, wicks, driller, masking tape and pipes joiners. The following materials were also used copper wires, graphite rod electrodes, 1Ω-33kΩ resistors, and digital multi-meters. The substrate used in this work is fresh cow dung with sucrose as bacteria food.

MFC construction

Two 1.2 L containers were prepared as an anode chamber and a cathode chamber. Two small holes were made in the caps of the bottles as to insert a wire through. One end of the copper wire was attached to

5.7cm long and 0.7cm diameter graphite rod electrodes. The anode chamber was filled with the substrate (0.1kg of cow dung mixed with 1 L of water) while the cathode chamber was filled with plain water of 1 L. Other two ends of wires were attached to a digital multi-meter for open circuit voltages and different 1kΩ to 33 kΩ resistors.

Salt bridge

Salt bridge was prepared using 1.5 liters of 1M KCl and NaCl solution and lamp wicks. The wicks were boiled in the KCl and NaCl solution for 10 minutes after which it was kept in the freezer at -4°C for solidification. The solidified salt bridge was passed through PVC pipes and attached to the chambers using Araldite adhesive which makes them leak proof.

Circuit Assembly

The assembly of the H-shaped MFC was done as shown in figure 1.

**Figure 1:** Set-up of H-shaped microbial fuel cells (a) open circuit with gas collection syringe (b) open circuit voltage

### Experimental Variations

To investigate the effect of sucrose concentration on voltage and current, 250g of sugar was dissolved in 1.2l of distilled water as the stock solution. 5Ml, 10ml, 15ml and 20ml was drawn from the bulk and topped to 25ml.Voltage and current were monitored in open circuit and across a 1kΩ resistor. Other solutions were made by dissolving 10, 20, 30 and 40g of the sugar in 25ml distilled water. The solutions were added to 600ml of cow dung in water via a pipette in the anodic chamber and stirred. The chamber was then sealed tightly after which current and voltage were monitored.

To study the relationship between the amount of current and voltage produced with cow dung, 250 and 500g of dung was mixed with 500ml of distilled water. The fluid was stirred thoroughly and loaded into the anodic chamber before sealing tightly.

### Data collection and observation

The generated voltage and current was recorded from the digital multi-meter at an interval of 24 hours for 9-10 days. The corresponding power, current density and power density was calculated by using formula

$$P = VI \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (1)$$

$$CurrentDensity = \frac{I}{A_{area}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . . (2)$$

$$PowerDensity = \frac{Power}{A_{area}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

## III. RESULTS AND DISCUSSION

The microbial activities in the anodic chamber affect the voltage, current and power produced in a microbial fuel cell. In the anodic chamber, substrate is broken down resulting in production of voltage, electrons, protons and carbon dioxide according to equation (4)

$$C_{12}H_{22}O_{11} + 13H_2O \rightarrow 12CO_2 + 48H^+ + 48e \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . . (4)$$

The protons pass through the proton exchange membrane/salt bridge to the aerobic cathodic chamber where they combine with oxygen to form water according to equation (5).

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$…………………………………………………… …………………. (5)

On the other hand, the electrons are transferred via a conductive wire to the cathodic chamber. The potential difference between the cells results in voltage.

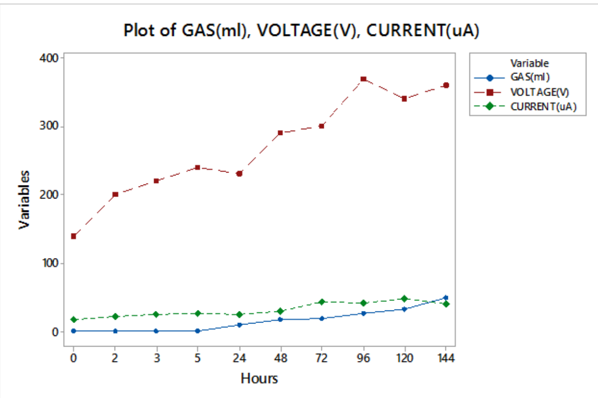
Double chamber MFC were operated for 9-11 days where direct current voltage and current were measured using DT92 series multi-meter. The gas produced from the anodic chamber was measured using graduated syringe. The data obtained were interpreted graphically using Minitab 17 and Microsoft Excel 2013 statistical software's.

When 500g cow dung was loaded to the anodic chamber and distilled water to the cathodic chamber and 25ml of 200g sugar dissolved in 500ml water added as microbes food to the anodic chamber with sodium chloride as the salt bridge, the characteristic voltage, current and gas produced are shown in figure 2. Voltage, gas and current produced increased with increase in time. This is attributed to microbial activities of breaking down the substrate resulting in carbon dioxide and electrons production. The maximum voltage of 0.37V was reached in 96 hours where gas production was maximum. Kumar in 2012used different concentration of normal cow dung and different salt as salt bridges in an open circuit. He observed a voltage of 150.9mV at 40 minutes using cow dung and 3.2mV using sterilized cow dung. This indicates that cow dung can be used as a fuel in MFC with the bacteria metabolism generating electricity.

Figure 2 : Plot of gas, voltage and current generated against time for 500g cow dung.

The voltage increased from 0.14V to 0.36V from 0 to 144 hours. Gas production also increased with time and voltage. For the first 24 hours, no gas production took place. Gas production was noted to be high when the voltage was high. Current also was noted to also increase with time from 0 to 120 hours and dropped at the $144^{th}$ hour. This is consistent with what was reported by Thatoi (2011) who observed the same trend using cow dung as a substrate. The maximum generated voltage at day 5 was 0.804V and the minimum generated voltage of 0.478 V was observed on day 1 in an open circuit. In another study, Zheng et al.,(2010) developed a new 21 scale MFC was to treat cattle dung by The device was able to produce 0.5V in open circuit and 0.4V under the resistance of 470 ohms. Later on, Zhang.G et al. (2011) tested the electricity generating potential of cow manure by three chambered MFC and biocathode. He was able to produce a maximum voltage of 0.502 V with an external resistance of 100 ohms. Yokoyama et al (2006) measured the capacity of dairy cow waste slurry in generating electricity. The research revealed that the cow slurry of 1g/L COD produced a power density of 0.34 mW/m2. Khare and Bundela(2013) using waste water mixed with vermicomposting from Jabalpur and Carbon electrodes were used as both the anode and cathode along with salt bridge having 3% agar and 1M KCl solution for proton transfer to cathode produced 232mV over a period of 7 days.

Calculations of power, power density and current density also increased with time. The maximum power was 0.016.51mW at 120hours with power density of $12.44mW/m^2$ and current density of $36.59\ mA/m^2$ as illustrated in figure 3. The maximum gas production was 50ml during the $6^{th}$ day



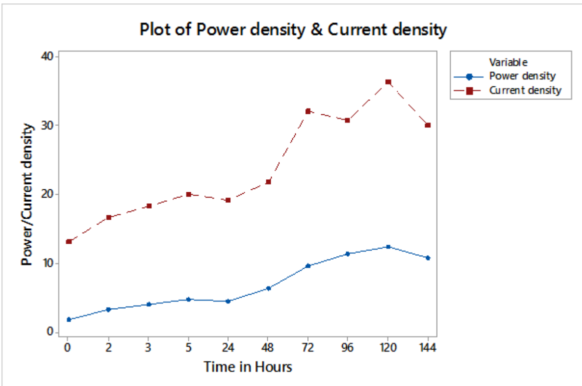



Figure 3: Plot of power and current density against time for 500g cow dung.

From figure 2, power density and current density increased with time with a subsequent decline from 96th hours. The maximum power and current density were 12.407mW/$m^2$ and 36.492mA/$m^2$ respectively observed on day 7. Yokotama et al (2006) observed a power density of 0.34 mW/$m^2$ using cow dung slurry while Zhang et al (2010) recorded a power density of 8.15W/$m^2$. A plot of power density against current density is shown in figure 4

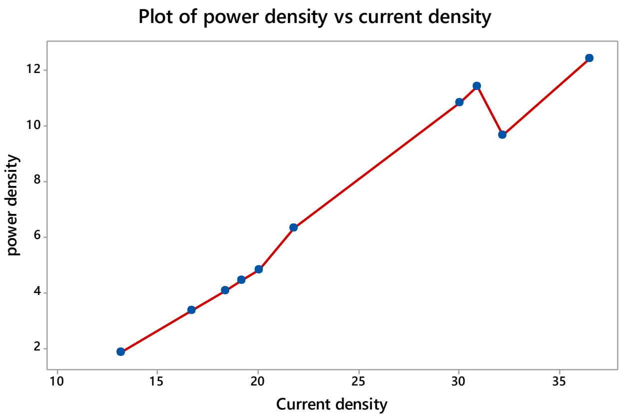



Figure 4: Plot of power density versus current density.

The generated voltage, current and gas produced when 250g cow dung with 300ml was used as the substrate with sugar as the microbe food and potassium chloride as the salt bridge are shown in figure 5. The voltage generated ranged from 0.13 to 0.5V, while current was in the range of 146 to 280uA. The characteristic voltage increased linearly with the gas produced stagnating after the 8th day. Voltage of 0.019, 0.069 and 0.039 was recorded for rice water, sewage water and kitchen waste water respectively on the 144th hour in a study by Sandeep 2015 using Escherichia coli while voltages of 0.106, 0.169 and 0.108 were obtained for the same substrates using Clostridium Sporogenes. 350ml of the substrates were used with 3% NaCl agar as the salt bridge.

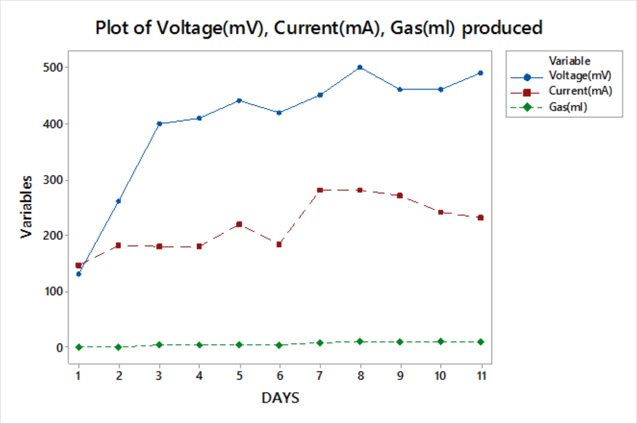



Figure 5: Plot of gas, voltage and current generated against time for 250g cow dung.

The power, power and current densities are shown in figure 6. From the plots, it's evident that power ranged from 18 to 113.3 * $10^{-3}$mW while power and current densities were in the range of 14.25mW/m2 and 0.109 to 0.210mA/m 2 respectively as shown in figure 6.

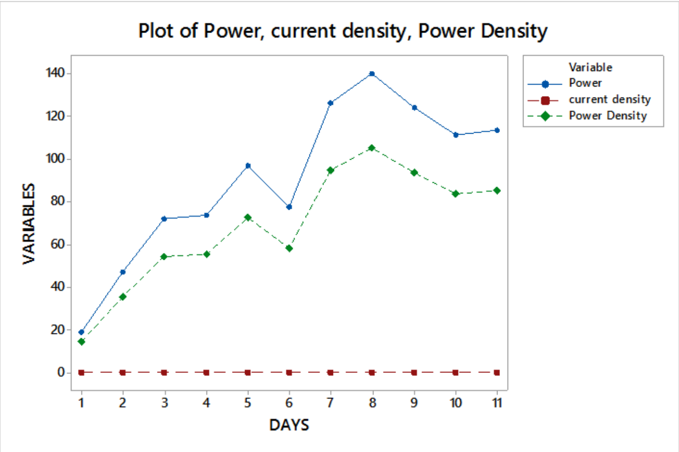



Figure 6: Plot of power and current density against time for 250g cow dung.

A plot of power density versus current density is shown in figure 7. The power density increases with increase in current density from day 1 to 8 and drops thereafter.

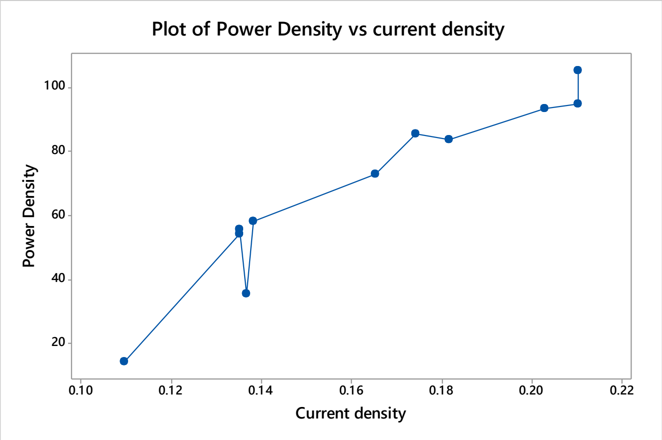



Figure 7: plot of power density against current density for 250g cow dung.

In a study by Kumar (2010), the open circuit voltage generated by 50% was 179.7mV after 40 minutes of study. The voltage increased with time for all the concentration. In this study, the voltage generated was highest in 500g cow dung with OCV of 0.27V on day 5 which started declining thereafter. This implies that 500g of cow dung has sufficient nutrient for microbe's consumption for 5 days.

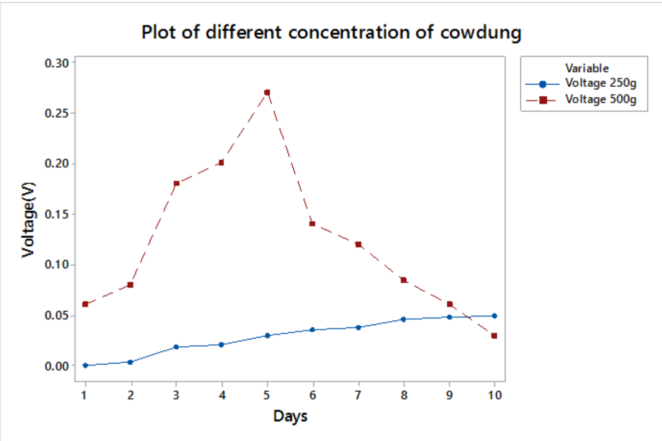



Figure 8: OCV generation from different concentrations of cow dung.

When NaCl and KCl were compared in salt bridge, the results obtained are shown in figure ……. 0.63V was noted in day 8 when NaCl was used compared to 0.50V for KCl. The upward trend was recorded from day 1 to 8 in both salts with a decline thereafter. In a study by Kumar, use of 2.5% NaCl as salt bridge yielded a 0.1849V at 40 minutes using cow dung. Further studies indicated that 15% of NaCl gave a 0.1995V with constant increment. The recommended concentration is 10% NaCl to facilitate easy ion flux (Kumar et al., 2011). The good OCV in NaCl is explained by good electrolytic property (Liu et al.2005)

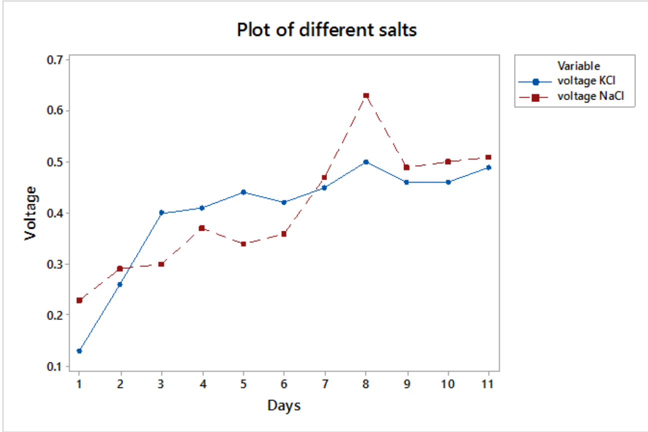



Figure 9: Plot of different salts used in salt bridge.

Comparison of glucose and sucrose were made as the bacteria food. The results obtained from feeding the bacteria with glucose and sucrose solutions are discussed

## Glucose solutions

When 50g of glucose in 250ml of distilled water solutions was used as food, the resulting voltage, current, gas and internal resistance are shown in figure 8 and 9. The internal resistance measured using a multi-meter remained at 0.008μΩ for both 250g and 500g of cow dung. The maximum amount of carbon dioxide produced was 5ml and 11ml for 250g and 500g of cow dung respectively at day 7. The high amount of gas for the 500g is attributed to the high concentration of microbes and substrates to be broken down. Maximum voltage was achieved in day 8 for 500g and day 10 for 250g. The high concentration of microbes meant degrading the substrate more rapidly and hence the observation. The maximum voltage was 0.084V for 500g and 0.049V for 250g.

The current density was 3.76 to 9.77 mA/$m^2$ and 0.75 to 90.15 mA/$m^2$ 250g and 500g cow dung respectively. The power and power density are as shown in figure 7.

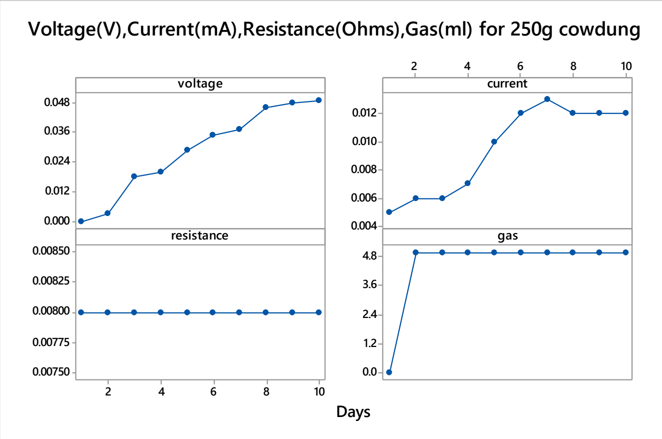



Figure 10: Plot of gas, voltage and current generated against time for 250g cow dung in glucose.

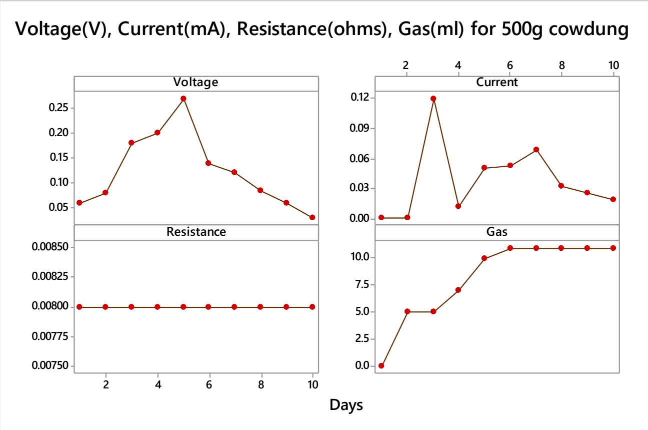



Figure 11: Plot of gas, voltage and current generated against time for 500g cow dung in glucose.

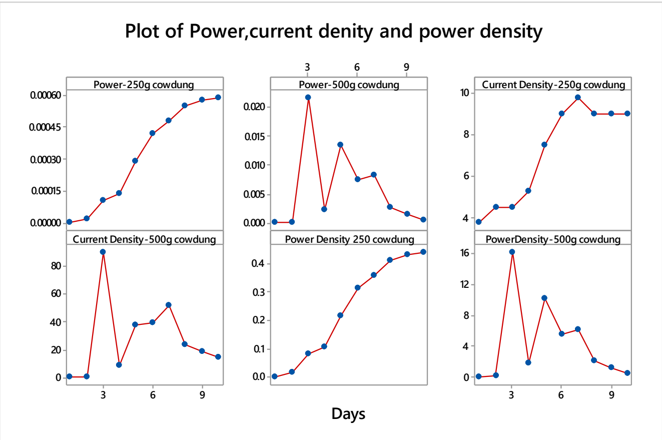



Figure 12: Plot of power, current and power density against days for 250g and 500g cow dung in glucose.

Power density against current density is shown in figure 11. The figure shows that the power density versus current density for 250g was minimal compared to that one of 500g.

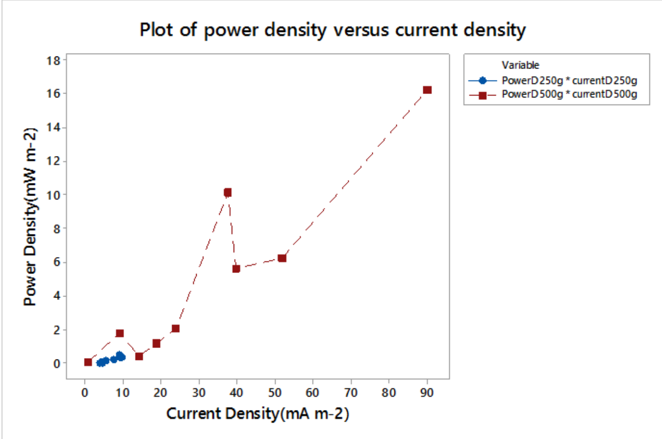



Figure 13: Power density versus current density for 250g and 500g cow dung for glucose solution.

## Sucrose solutions

In this case, 5ml, 10ml, 15ml and 20ml of 250g dissolved in 1.5L of distilled water was drawn and topped to 25ml. The solution was introduced to the dung in the anodic chamber with a pipette and resultant voltage and current recorded across a 1kΩ resistor and in an open circuit. The daily voltage across 1kΩ resistor ranged from 0.0015 to 0.049V for 20ml sugar solution which increased during the first 5 days and started to decrease thereafter as shown in figure 12. Lower voltages were recorded for 5ml to 15ml sugar solutions compared to the 20ml solutions. In an earlier study by Parkash (2016), a range of 0.487 to 0.825V was observed from day 1 to 6 using cow dung as the substrate. The Voltage increased from day 1 onwards and started declining from day 5 as observed in the current study.

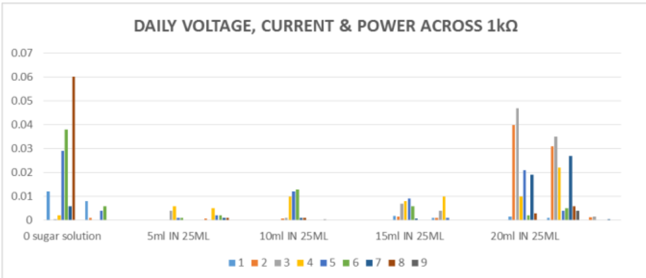



Figure 14: Graphs of voltage, current and power generated against days for 500g cow dung in sucrose across a 1kΩ resistor.

The resulting power and current densities are shown in figure 13. The current density was highest in 20ml sugar solutions in day 3 and lowest in day 1. Low power density was witnessed in the anodic cell with zero sugar solution with the same extending to 5, 10, 15ml solutions.

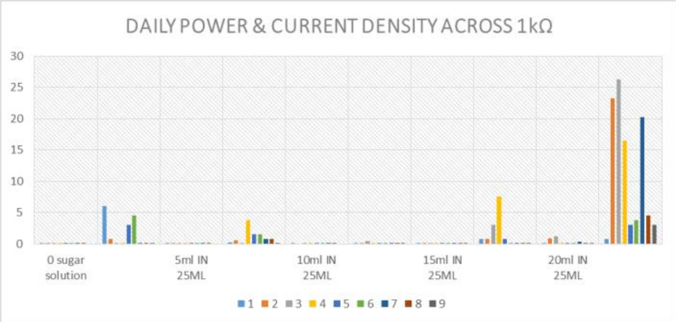



Figure 15: Graphs of power and current density against days for 500g cow dung in sucrose across a 1kΩ resistor.

On characterizing voltage and current in an open circuit with the same solutions, a high voltage was observed in 20ml sugar solution with a voltage of 0.131V. The voltage was higher compared to when it was taken across a 1kR resistor as shown in figure 14. Figure 15 illustrates the power and current density in an open circuit.

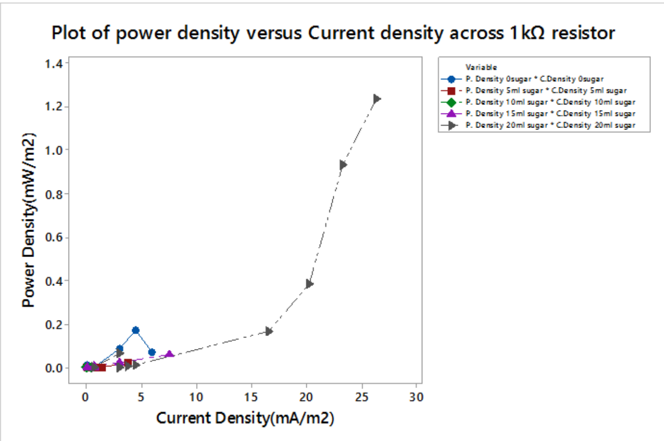



Figure 16: plot of power density versus current density across a 1kΩ resistor.

On varying the concentration of sugar solutions, the results indicate that during the first days, the voltage derived from the substrate is high as microbes degrade the dung. The colony is maintained by the sugar solution introduced as food after the dung is fully depleted. On introducing high-concentration sugar solution to the microbes, the resulting voltage, current and power are shown in figure 17. High characteristic voltage is observed where no sugar solution was introduced especially for day 8 with 0.06V. The voltage decreases with increase in time while for the ones with the sugar solutions it increases with time.

**Open Circuit**

Lower concentrations of sugar were used compared to the ones used in figures 10 and 11. In this case, 5ml, 10ml, 15ml and 20ml of 250g dissolved in 1.5L of distilled water was drawn and topped to 25ml. The solution was introduced to the dung in the anodic chamber with a pipette and resultant voltage and current recorded in an open circuit. The current observed in this study is consistent with what was observed by Parkash in 2016. In his study, a current of 0.009 to 0.0113µA was recorded for the 6 days of his study using cow dung as the substrate and 1M KCl as the salt bridge. The current increased with time and with a downward trend being observed on day 6. This is in agreement with what we observed in this study in an open circuit.

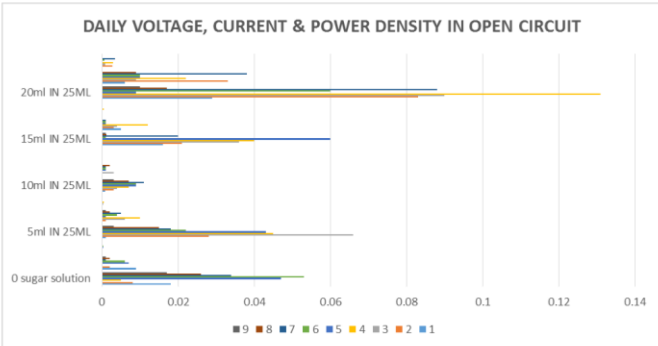



Figure 17: Graphs of voltage, current and power generated against days for 500g cow dung in sucrose in open circuit.

Similar results were observed by Priyabrata in 2011 using cow dung who observed that there was a definitive increase in the generated power density from day 1 to day 5 and then a decline in trend is observed on day 6. The maximum generated power density at day 5 was 0.000000938W/m$^2$ and the minimum generated a power density of 2.69111E-07W/m2 was observed on day 1. Power density measured was open circuit voltage since the external resistance is not used. Hence the power density generated was due to internal impedance, which seemed to be very high in the range of mega ohms. Parkash in 2016 recorded a maximum power of 0.009223µW on day 5 of his study in an open circuit.

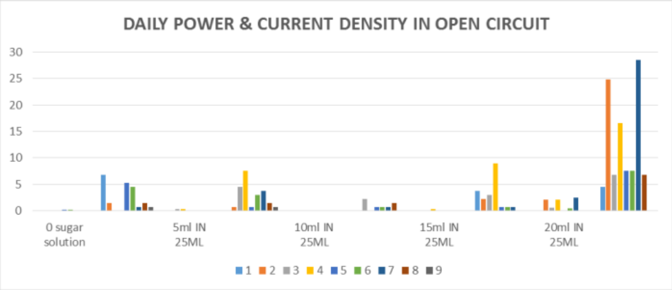



Figure 18: Graphs of power and current density against days for 500g cow dung in sucrose in open circuit.

Parkash 2016 using cow dung as substrate recorded an increase in power density from day 1 to 5 with a decline in day 6. In his study, maximum power density generated was 0.000000947W/m$^2$ on day 5 and a minimum on day 1 of 2.69211E$^{-07}$W/m$^2$ on day 1.

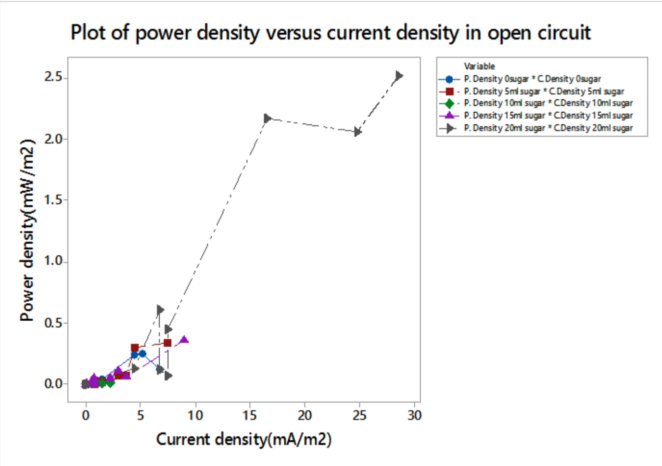



Figure 18: Plot of power density against current density in open circuit.

## IV. CONCLUSION

Alternative sources of renewable energy need to be sought due to the rapid depletion of fossil fuels. Microbial fuel cells technology is a promising energy source which requires optimization studies. Energy generated from MFC is clean and sustainable. Characterization of generated voltage, current, power, current and power density was done. The maximum values of these parameters obtained were 0.5090V, 0.28µA, 0.0093µW, 0.05181mA/me and 0.0000006 W/m2.

**Ongoing Research :** optimization of MFC parameters for maximum power output

## V. REFERENCES

[1]. Parkash A (2016) Characterization of Generated Voltage, Current, Power and Power Density from Cow Dung Using Double Chambered Microbial Fuel Cell. J Phys Chem Biophys 6: 208. doi:10.4172/2161-0398.1000208
[2]. GTZ (2007): Eastern Africa Resource Base: GTZ Online Regional Energy Resource Base: Regional and Country Specific Energy Resource Database: IV - Energy Policy: 1-36.
[3]. PAC (2010), Practical Action Consulting Bioenergy and Poverty in Kenya: Attitudes, Actors and Activities. PISCES Working Paper, Nairobi, Kenya.
[4]. Ministry of Energy, Kenya (2016): Last mile connectivity projects report.
[5]. Henrian, H et al., harvesting electrical energy from cellulose using cow manure microorganisms as biocatalysts in a two-chamber, 4th national science and mathematics Congress of regional science high schools, 2008
[6]. H. Liu, B.E. Logan, Electricity generation using an air–cathode single chamber MFCin the presence and absence of a proton exchange membrane, Environ. Sci. Technol., 2004, pp. 4040–4046
[7]. Yokoyama.H et al, treatment of cow-waste slurry by a MFC and the properties of the treated slurry as a liquid manure, animal science journal, Animal Science journal, 2006, volume 77, issue 6, pp. 634– 638,
[8]. X. Zheng et al, cattle wastes as substrates for bioelectricity production via microbial fuel cells, biotechnology letters, 2010, volume 32, issue 12, pp 1809-1814
[9]. Khare. A et al., Generation of electricity using vermicompost with different substrates through single chamber MFC approach, the international journal of engineering trends and technology, 2013, vol 4. lee.Y et al., electricity production in membrane-less MFC fed with livestock organic solid waste,
[10]. Bioresource technology, volume 102, issue 10, May 2011, pages 5831–5835.
[11]. Zhang.G et al, Biocathode Microbial Fuel Cell for Efficient ElectricityRecovery from Dairy Manure, Biosensors and Bioelectronics, 2011.
[12]. Arup Pal, Bishwajit Nayak, Bhaskar Das, M. Amir Hossain, Sad Ahamed and Dipankar

Chakraborti* "Additional danger of arsenic exposure through inhalation from burning of cow dung cakes laced with arsenic as a fuel in arsenic affected villages in Ganga–Meghna–Brahmaputra plain" J. Environ. Monit., 2007, 9, 1067–1070.
[13]. Priyabrata Thatoi (2011); Characterization of generated Voltage, Current, Power and Power Density from Cow Dung using Double Chamber Microbial Fuel Cell
[14]. Cheng, S., Liu, H., and Logan, B.E. (2006) Increased power generation in a continuous flow MFC with adjective flow through the porous anode and reduced electrode spacing. Environ Sci Technol 40: 2426–2432.
[15]. Min, B., Kim, J.R., Oh, S.E., Regan, J.M., and Logan, B.E. (2005) Electricity generation from swine wastewater using microbial fuel cells. Water Res 39: 4961–4968.
[16]. Morris, J.M., and Jin, S. (2008) Feasibility of using microbial fuel cell technology for bioremediation of hydrocarbons in groundwater. J Environ Sci Health A 43: 18–23.
[17]. Park, D.H., and Zeikus, J.G. (2003) Improved fuel cell and electrode designs for producing electricity from microbial degradation. Biotechnol Bioeng 81: 348–355.
[18]. Rabaey, K., Boon, N., Hofte, M., and Verstraete, W. (2005) Microbial phenazine production enhances electron transfer in biofuel cells. Environ Sci Technol 39: 3401–3408.
[19]. Morris, J.M., and Jin, S. (2008) Feasibility of using microbial fuel cell technology for bioremediation of hydrocarbons in groundwater. J Environ Sci Health A 43: 18–23.
[20]. Eric A. Zielke (2005) Design of a single chamber Microbial Fuel Cell
[21]. Priyabrata Thatoi (2011); Characterization of generated Voltage, Current, Power and Power Density from Cow Dung using Double Chamber Microbial Fuel Cell
[22]. Sandeep. S 2015, Microbial Fuel Cell for Electricity Production, International Journal of Bio-Technology and Research (IJBTR) Vol 5, Pp 23- 30
[23]. Parkash Anand (2016) Characterization of generated Voltage, Current, Power and Power Density from Cow Dung using Double Chamber Microbial Fuel Cell. J Phys Chem Biophys 6: 208. Doi: 10.4172/2161-0398.1000208.
[24]. Shiv Kumar, Harsh Dev, Gireesh Babu K (2012). A study on the electricity generation from the cow dung using microbial fuel cell. J Biochem Tech. Vol 3(4); 442-447
[25]. Liu et al (2005) production of electricity from acetate or butyrate using a single-chamber microbial fuel cell. Environ Sci Technol 39: 658-662