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Conversion of Animal Waste (Cow dung) into Electricity using MFC Technology

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A B S T R A C T

Increased anthropogenic activities and consumption of natural resources have led to the decline in fossil fuel. To resolve an increasing global demand in energy, a source of sustainable and environmentally friendly energy is needed. Microbial fuel cells (MFCs) represent the latest advancement in bioelectricity production. This technology harnesses the electrons released by microbes as they metabolize organic substrates, transferring them from the anode to the cathode through an external circuit to generate energy. In our study, we investigated the efficacy of organic substrate cow dung, as electron donors in the presence of microorganisms for bioelectricity generation. A salt bridge was employed between the anode and cathode chambers to facilitate proton transfer. Our findings indicate that MFCs constructed in this manner can effectively produce electricity from organic waste, offering a potential solution to the ongoing global energy crisis. The experimental readings from this substrate were monitored over a period of 5 days, with the performance being evaluated based on the voltage generated. The highest recorded values for the generated parameters were 1.31mV. These Dual chamber microbial fuel cells as a promising technology for future energy solutions.

Introduction

The world faces a serious energy crisis as traditional energy sources like coal and oil continue to deplete (Kumar *et al.,* 2012). Their continued use contributes to global warming, the reduction of fossil fuel reserves, energy supply security risks, and environmental pollution. As a result, there is an urgent need to replace conventional energy sources with unconventional ones that promote a healthy environment and enhance human well-being (Rahimnejad *et al.,* 2012). In the developing industrial world, the lack of energy drives scientists to seek alternative energy sources. Industrialization and modern lifestyles have exploited the environment, leading to significant sanitary problems for people and ecosystems (Li *et al.,* 2014). While industrial expansion boosts the economy, it also creates substantial waste management challenges. Governments are increasingly focusing on utilizing renewable energy sources, such as solar, wind, biofuels, and other forms of energy. Renewable energy is crucial in addressing the global energy dilemma (Lee *et al.,* 2014; Oliveira *et al.,* 2013). MFCs have attracted attention because they can operate under different environmental conditions, such as low temperatures, and because they use different biodegradable substrates as fuel (Kumar *et al.,* 2012). MFCs were first proposed for water treatment in the late 1900s and have been continuously developed to increase productivity (Siegert *et al.,* 2019). These are biochemically catalyzed systems where electricity is produced by oxidizing organic matter in the presence of bacteria or enzymes. In this process, electrons move from anode to cathode through an external circuit and protons diffuse through a proton exchange membrane (Rahimnejad *et al.,* 2009). The main factors that improve MFC efficiency are microorganism metabolism, electron transport, proton exchange membrane efficiency, and cathodic oxidation. Conventional MFCs typically have two chambers—an aerated cathode and an anaerobic anode—separated by an ion exchange membrane such as Nafion or a salt bridge, allowing hydrogen ions to move from the anode to the cathode (Rahimnejad *et al.,* 2009; Najafpour *et al.,* 2010). MFCs produce renewable energy from organic waste and help remove organic pollutants from the environment. MFCs use electroactive bacteria to form biofilms on the anode that act as biocatalysts for substrate oxidation. The generated electrons move through the external circuit to the cathode, where they work, while the protons pass through the proton exchange membrane into the cathode chamber and complete the reduction reaction with oxygen (Siegert *et al.,* 2019). Considering the different wastes generated worldwide, special attention is given to recent developments in MFCs using wastes as substrates from different sources. Different substrates, whether simple organic and inorganic substrates or wastewater as a mixed combination of several materials, can be used in MFCs as electron donors (Kumar *et al.,* 2012). Microbial fuel cells (MFCs) use the biocatalytic properties of microorganisms to convert organic fuels into electricity. Unlike traditional fuel cells based on metal catalysts, MFCs use bacteria to generate electricity from organic matter, including wastewater. During the biodegradation of domestic sewage and other biodegradable products, these microorganisms produce electrons that generate electricity (Lovley, 2006).

Cow dung is emerging as a highly promising source of organic waste for bioenergy extraction. Solid waste, such as organic matter in cow dung, serves as an excellent source of carbon and energy for the microbial communities within microbial fuel cells (MFCs). These microorganisms break down organic compounds through biochemical processes, releasing electrons as a byproduct (Bharadwaj and Kumar, 2012). MFCs have been the subject of recent research due to their potential for producing sustainable energy (Oliveira *et al.,* 2013). Advances in low-cost and MFC-compatible components show promise for sustainable power generation (Gunkel, 2009). Electricity production from renewable sources is on the rise, with researchers actively exploring various alternatives to address the future energy crisis (Khare *et al.,* 2016). Cow dung manure, in particular, has proven to be an effective substrate for MFCs. In this study, the experiment were conducted with the cow dung as substrate to identify how the pH, EC, TS, OC and microbial population have its direct influential on current production.

Materials and Methods

Materials collection and processing

MFC's are the new biochemical process that aims to produce electricity by using the electrons derived from biochemical reactions catalysed by microorganisms in the substrate. In this study, organic waste conversion to electricity through microbial fuel cell is done. This experimental study carries,

- Collection of bio waste (Cow dung)
- Analysis of substrates (pH, EC, Microbial population, TS)
- Construction of MFC
- Current production

Collection of bio waste

The substrate used for this experiment is cow dung is collected from the cattle shed of Imayam Institute of Agriculture and Technology, Thuraiyur. The cow dung is collected made to slurry by 2:1 ratio and kept it for fermentation for 5 days.

Character Analysis

The substrates were subjected to analysis at various stages of current production (Fresh sample (FS), After fermentation (AF) and during current production (DCP)).

The pH of the substrate was analysed with buffers 4.0, 7.0 and 9.2, EC calibrated with KCL solution. Total solids were determined on material residue left in the crucible after evaporation of the sample and its subsequent drying in a laboratory oven at 105°C for a period of one hour, then cooled in a desiccator to prevent moisture entry. The final weight was recorded. Equation was used to calculate the percentage total solids.

$$\%TS = \frac{W_1 - W_2}{W_3 - W_4} \times 100$$

Where,

%TS = Percentage total solid

W1 = Weight of dried crucible + dried residue

W2 = Weight of crucible

W3 = Weight of wet sample (Cow dung) + crucible

To calculate the C/N ratio, the organic carbon content was measured using the loss-on-ignition method in a muffle furnace at 550°C for 2 hours. Total Kjeldahl nitrogen was determined through distillation followed by titration with sulfuric acid. Nitrate content was assessed via distillation.

Microbial population Analysis is made through Serial Dilution Technique. A small measured volume of each dilution is used to make a series of pour or spread plates.

Begin by preparing serial dilutions from a cow dung sample in sterile water, creating dilutions from 10^{-2} to 10^{-6}. For each dilution, transfer 1 ml to a Petri plate and add the appropriate agar medium: Ken Knight's Agar for 10^{-2}, Martin's Rose Bengal Agar for 10^{-4}, and Nutrient Agar for 10^{-6}.

Medium was dispensed evenly, allowed to solidify, and plates were incubated. Bacterial colonies were counted after 1-2 days, fungal after 3-5 days, and actinomycetes after 7 days. Colonies were isolated and examined microscopically.

Calculate the populations of fungi, bacteria and actinomycetes in the original sample and express as number per g of the soil sample.

No. of colony forming units

$$= \frac{\text{Total no. of colonies x Dilution factor}}{\text{Quantity of soil sample taken on dry wt. basis}}$$

Construction of MFC

The materials used in microbial fuel cell construction are the anode, cathode, salt bridge, plastic bottles (bottles), Multimeter, wire, aluminium mesh.

Conductivity is another critical feature of the electrodes for the effective transport of electrons. Anode and cathodes are materials through which the conventional current enters into a polarised electrical device. In this study, aluminium mesh is used as electrode because of its non-reactive and non- corrosive properties. The anode and cathode are separated by a proton exchange membrane (PEM); in this case it is a salt bridge. This ensures flow of anions in the salt bridge towards the anode and cation in the salt bridge flow toward the cathode which is the primary goal in maintaining electrical neutrality within the cell. The Salt bridge is made using NaCl solution (14.61 g of NaCl in 1lit of distilled water). The salt bridge is left in the prepared solution and left dried for some time. The containers of capacity 3 L were taken for anode and cathode chamber, connected through the salt bridge and sealed to avoid leakage. The anode was filled with substrates which is made slurry (2:1) and cathode with conductive water. The level of the fluid in both the containers was kept the same (1.5 L). Electrodes, connected with copper wire are placed in the chambers and a multimeter is connected with the copper wire to complete the circuit.

To measure the energy generation, the electrodes were carefully inserted into the chambers, with the wires threaded through the holes in the lid. Electrodes, which are present in anodic and cathodic chamber are connected with copper wire and a multimeter is connected with this to complete the circuit. The anode was filled with substrates and cathode with a conductive water. The level of the fluid in both the containers was kept the same the initial reading was recorded, and subsequent readings were taken over a period of 5 days.

Results and Discussion

It was determined how productive cow dung from the IIAT farms could be in terms of producing voltage and current. The cow dung that was collected from the farms of IIAT had a semi-solid, dark green colour with the characters shown in Table 1. The results showed the initial cow dung sample has neutral pH while Electric conductivity (EC) was recorded as 1.02 ds m-1, Total solids (TS) as 44.1%, Organic carbon (OC) as 19%, C: N ratio as 35:1 and Microbial population were recorded as 41 x 10^6 for bacteria, 7x10^3 for Fungi and 3.9x10^2 for actinomycetes.

The initial cow dung sample was subjecting to the fermentation process for 5 days and subjected to current production analysis with the following results (Table 2) of substrate characteristics were recorded in three stages (Fresh sample (FS), After fermentation (AF)and During the current production (DCP)). In the fresh sample the characteristics were observed with the following parameters pH, EC (dS m^{-1}), TS (%), Microbial Population (Bacteria, Fungi and Actinomycetes) were 7.01, 1.02 dS m^{-1}, 44.1%, 41x10^6 CFU/ml, 7x10^3 CFU/ml, 3.9x10^2 CFU/ml respectively. The same characters were observed to be 6.02, 0.96 dS m^{-1}, 28%, 64x10^6 CFU/ml, 2x10^3 CFU/ml and, 4.3 x10^2 CFU/ml, after the fermentation of sample stage respectively. Similarly, the sample of DCP was recorded as 7.46, 1.89 dS m^{-1}, 9.8%, 59x 10^6 CFU/ml, 5.6x10^3 CFU/ml and 4.1x10^2 CFU/ml respectively. There was a change in the pH from neutral to slightly acidic and back to Alkaline. EC were observed to be change from 1.02 dS m^{-1}, 0.96 dS m^{-1} to 1.89 dS m^{-1}. TS were observed to change from 44.1% of fresh sample to 28% of after fermentation stage and 9.8 %of DCP stage. The Bacterial count tends to change from 41x10^6 CFU/ml increased to 64x10^6CFU/ml and declined to 59x 10^6CFU/ml. Fungi population changed from 7x10^3 CFU/ml to 2x10^3 CFU/ml then increased to 5.6x10^3 CFU/ml while the actinomycetes followed the same trend to that of bacterial population. It recorded 3.9x10^2 CFU/ml increased to 4.3 x10^2 CFU/ml and declined to 4.1x10^2 CFU/ml respectively. Highest value of pH (7.46) and to that of EC (1.89 dS m^{-1}) was recorded during current production stage. Similarly, TS (44.1%) also recorded highest count during current production stage.

The Current Production was recorded after fermentation process of 5days. The readings were recorded with following results as shown in the graph 1. After fermentation first day of current production registered as 0.06 mV, while the second day showed the slight increase in the voltage produced with 0.40mV. The third day of the current production was recorded to be the highest as 1.31mV. The subsequent 4th and 5th day showed the decline trend with the recorded value of 0.87 mV and 0.26 mV respectively.

The present study clearly shows that change in the characteristics of the substrate were similar to that of other research carried on current production using Cow dung. According to a study by Gil *et al.,* (2003), the optimal pH for all of the isolates of cow dung was 7.0, which is the highest bioelectricity generation recorded to date. The pH displayed an abrupt increase, followed by a slow decline, in line with Agho *et al.,* (2018) study. It was found that the voltages obtained were affected by the pH which was recorded 7.46. This is due to the pH's capacity to influence microbial activity and impede the processes that produce electrons and protons.

The quantity of voltage generated was influenced by Electrical conductivity. The outcome demonstrated that voltage generated increase with EC and vice versa., which found that EC affects microbial activity and metabolic efficiency. Reduced EC was the outcome of excessive ions leaching due to organic matter (Rahman *et al.,* 1996).

The MFC process's performance is influenced by the substances' total solid (TS). A variation in the total solids content will result in MFC' microbial morphology. Therefore, it is essential to comprehend the impact of total solid content on the behaviour of the microbial activities (Sajeena *et al.,* 2013). The result obtained for total solid is 9.8% for higher electricity generation which is agree with work of Orhorhoro *et al.,* (2017) obtain the total solid of 10.16% for higher bioelectricity generation.

At the initial stages of current production, the microbial load of the cow dung sample from IIAT farm was found to be larger amount. The microbial load of the cow dung decreased after electricity was generated compared to the initial microbial load prior to electricity generation.

This could be because the substrate became less nutrient-rich or exhausted, or because metabolic waste products were produced, which increased the rate at which organisms died. The findings of Adesiji *et al.,* (2020), which indicated that microorganisms play a significant role in the release and transfer of electrons, which results in the generation of voltage and current, are agreeable with this finding. Prior to the production of electricity, the microbial load of the cow dung sample from IIAT farm was found to be larger amount.

Table.1 Characteristics of Substrate

Analysis	pH	EC (ds/m)	TS (%)	OC (%)	C:N Ratio	Microbial Population		
						Bacteria	Fungi	Actinomyctes
Cow dung	7.01	1.02	44.1	19	35:1	$41x10^6$	$7x10^3$	$3.9x10^2$

Table.2 Parameter analysis of Substrate at different stages of current production

Parameters		F	AF	DCP
pH		7.01	6.02	7.46
EC (dS m-1)		1.02	0.96	1.89
TS (%)		44.1	28	9.8
Microbial Population	Bacteria	$41x10^6$	$64x10^6$	$59x 10^6$
	Fungi	$7x10^3$	$2x10^3$	$5.6x10^3$
	Actinomycetes	$3.9x10^2$	$4.3 x10^2$	$4.1x10^2$

*F – Fresh Sample, AF – After Fermentation, DCP – During Current Production

Figure.1

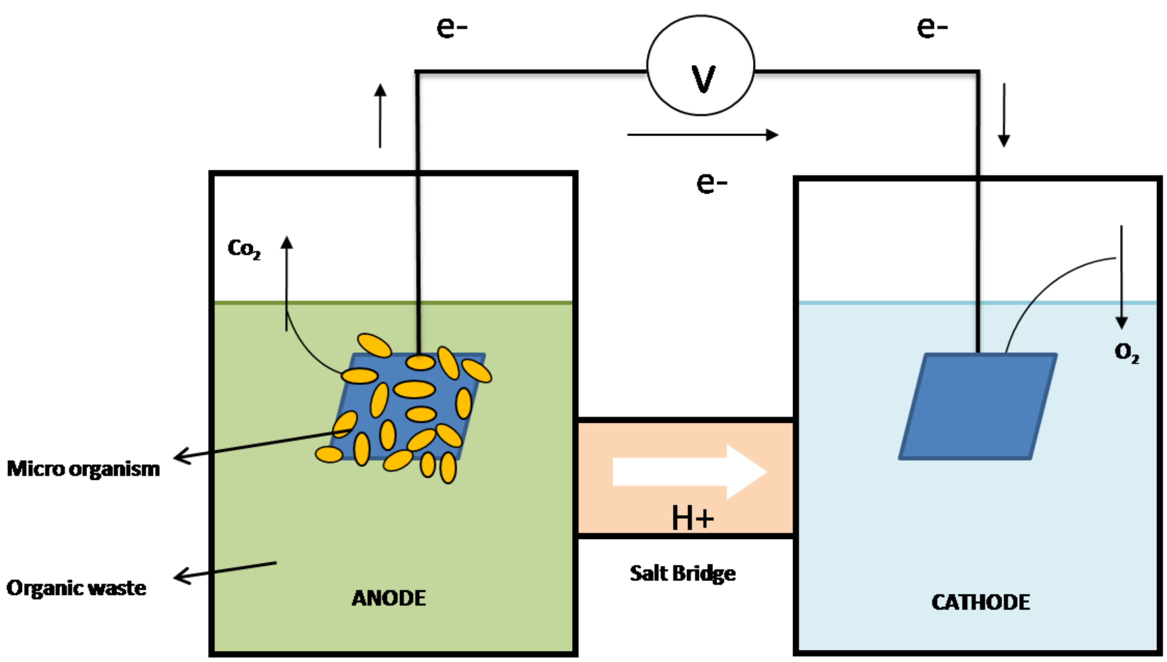
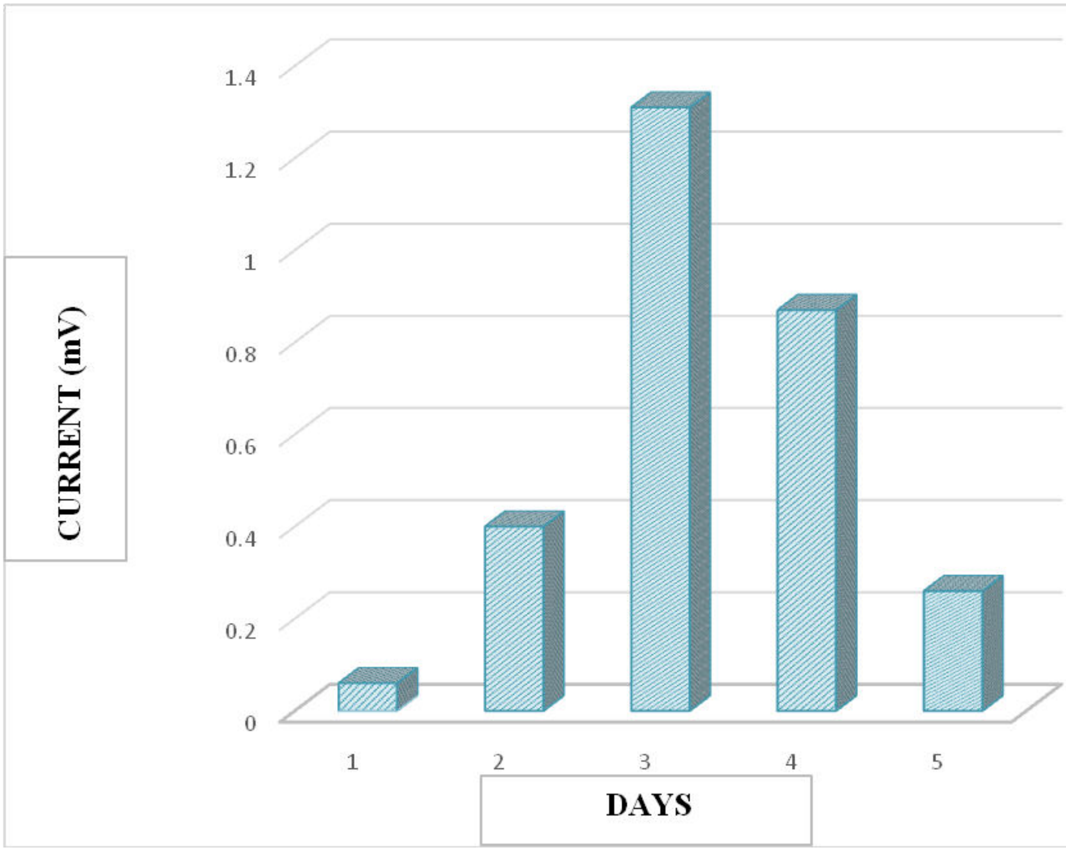


Figure.2



The microbial load decreased after electricity was generated compared to the initial microbial load prior to electricity generation. This could be because the substrate became less nutrient-rich or exhausted, or because metabolic waste products were produced, which increased the rate at which organisms died. The findings of Adesiji *et al.,* (2020), which indicated that microorganisms play a significant role in the release and transfer of electrons, which results in the generation of voltage and current, are agreeable with this finding.

In this study, during the course of the observation time, there was a gradual increase in the voltage created, followed by a sharp surge and a slow fall which was consistent with the (Parkash, 2016). A higher microbial activity, the development of biofilm, and sufficient nutrient availability may be the causes of the gradual rise in voltage generated, whereas a decrease in microbial activity, the build-up of metabolic by-products, and a reduction in nutrient availability may be the causes of the gradual decline. The purpose of this study is to determine whether cow dung can be an effective biomass for producing voltage in a dual chamber MFC and to fabricate an MFC using affordable and locally available materials. According to Prakash (2016), findings he validated that cow dung is an effective biocatalyst for producing voltages, and they also demonstrated that the highest voltage produced by the MFC was produced at a concentration of 50% cow dung which was onpar with our study.

The results of this study encourages to produce electricity using backyard animal waste (cow dung) using microbial fuel cells technology. Similarly, more research can be done to improve MFC technology further by employing cow dung as a biocatalyst, which will help India, a developing nation, solve its energy crisis. It is also required researchers work to enhance the research to set MFC in large quantity to get more voltage and on its components.

This study shows that the MFC using cow dung has potential to produce electric current. This substrate is influenced by pH, EC and activities of several microbes such as bacteria, fungi, actinomycetes which results in the highest electricity generation and hence this experiment shows that the feasibility of cow dung used to produce the electric current through MFC. This also recommended that the scientist and student researchers work to improve the components and set up MFC used in the experiment. Using this manure is preferable to use consumable resources because it not only reduces environmental pollution but also aids in the preservation of natural resources.

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Author Contributions

L. Meena: Investigation, formal analysis, writing—original draft. S. Keerthana: Validation, methodology, writing—reviewing. N. Sivapriya:—Formal analysis, writing—review and editing. R. Sowmiya: Investigation, writing—reviewing. A. Sethu Mathavan: Resources, investigation writing—reviewing. E. Prem Kumar: Validation, formal analysis, writing—reviewing. C. Siva: Conceptualization, methodology, data curation, supervision, writing—reviewing the final version of the manuscript. S. Aglin Sherin: Investigation, formal analysis, writing—original draft. S. Suba Mohana: Validation, methodology, writing—reviewing. B. Bhavani:—Formal analysis, writing—review and editing. A. Kishore: Investigation, writing—reviewing. T. Sibiarasu: Resources, investigation writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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