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Comparative Analysis on Bioelectricity Generation From Cow Dung, Vegetable and Fishery Waste Using Laboratory Designed Microbial Fuel Cell

KEYWORDS Microbial fuel cell, Electricity generation, Waste

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ABSTRACT *Electrical energy demand in India has increasing, that makes there are researches about innovative technologies that more effective, efficient, and green environment. Environmentally friendly and sustainable energy production is coming to the forefront of both research and world issues. Water and wastewater treatment are also a top priority in the developing global community. Microbial fuel cells (MFCs) are an alternative energy technology that has the capacity to simultaneously treat wastewater. This is focused because it is easy to operate, economic, stable and effective in use. In a country like India where tons of waste is generated daily can be used as such for this purpose without any modification or with little modification. The report comprises introduction to MFC, its materials used for construction and different designs which can helps to build MFC. This work explores the feasibility of replacing or supplementing methanogenesis with the emerging technology of microbial fuel cell (MFC). The research focused on the utilization of cow dung, fishery and vegetable waste that produce liquid and solid waste in large quantities which potentially contaminate the environment. One way to utilize waste from cow dung, fishery and vegetable could be done with MFC (Microbial Fuel Cell).*

INTRODUCTION

The world today is undoubtedly facing a serious energy crisis and energy demand continues to increase at an unsustainable pace. New methods of electricity generation from renewable resources without a net carbon dioxide emission are much desired. Recently, MFC have drawn increasing world-wide attention in generating electricity directly from organic matter. MFC technology helps to treat the organic wastes to produce the bioelectricity. All easily degradable materials including cooked and raw food wastes, fruits and vegetable wastes, fish and meat wastes, excreta of all domestic and wild animals including cow dung and birds and waste water containing bio waste materials can be treated with microbial fuel cell technology. The microbial fuel cell (MFC) is an innovative biological technology that can be used for waste biomass treatment with simultaneous electricity generation [1]. It is important to find an alternative form of energy before the world's fossil fuels are depleted. It is predicted that oil and gas reserves will be depleted by 2032 and 2030 [2].

MFC has garnered significant interest in both basic and applied research due to its sustainable and renewable nature in the contemporary energy scenario and is all set to be the trendsetter in the arena of answers to the complex environmental pollution problems and the energy crisis, with a unified approach. The MFC is essentially a hybrid bio-electrochemical system which directly transforms chemical energy stored in the biodegradable substrate to electrical energy via microbial catalysed redox reactions involving microorganisms as biocatalysts under ambient temperature/pressure [2].

The concept of the MFC is well established in the direction of utilizing wastewater as an anodic fuel making it a sustainable technology for energy generation as well as waste management. Reducing the cost of wastewater treatment and finding ways to produce useful byproducts has been gaining importance in view of environmental sustainability. The organic matter present in wastewater serves as primary substrate for the fermentation process facilitating treatment of wastewater with simultaneous generation of bioelectricity. Wastewater from food waste, electroplating, starch processing, breweries, paper industry, palm oil mill, chocolate industry, domestic sewage, cellulosic waste, vegetable waste, composite chemical wastewater, pharmaceutical wastewater, swine waste, etc. were evaluated at a laboratory scale to understand their potential as anodic fuel and the possibility of power generation from various types of wastewater was evaluated at CSIR-IICT [3].

Traditionally cow dung has been used as a fertilizer, though today dung is collected and used to produce biogas. This gas is rich in methane and is used in rural areas of India/Pakistan and elsewhere to provide a renewable and stable source of electricity. Fish is very important dietary animal protein source in human nutrition. Production of aquatic species through freshwater fisheries and aquaculture for protein supply is being encouraged in developed or developing countries but in under- developed countries, it is declining [4]. Vegetables wastes are contain nutrients that can use in water treatment or other process. In the case of microbial fuel cell (MFC), waste water from potato processing industries have been traditionally treated by a sequence of steps that include the production of methane as the anaerobic one. This work explores the fea-

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sibility of replacing or supplementing methanogenesis with the emerging technology of microbial fuel cell (MFC). The research focused on the utilization of cow dung, fishery and vegetable waste that produce liquid and solid waste in large quantities which potentially contaminate the environment. One way to utilize waste from cow dung, fishery and vegetable could be done with MFC (Microbial Fuel Cell).

MATERIALS AND METHODS

Materials and Equipment

The materials that used include activated sludge, fish waste and chemicals to artificial wastewater analysis. Tools that used among a set of tools comprising MFC digital multimeter, vessel 1500 ml, copper wire was used to connect the circuit containing a 465 Ω load unless stated otherwise., nickel electrode, and digital thermometer and pH as well as the tools used to manufacture and wastewater analysis.

Collection of wastes

The cow dung was obtained from cow farm at Mathakottai, Thanjavur district. Tamil Nadu, South India. The vegetable and fish wastes were obtained from vegetable market and fish market Kelavasal, Thanjavur city, Tamilnadu state. The collected wastes further immediately used for experimental work.

Experimental design

The simplest type of MFC consists of two chambers anode and cathode (Fig 1) are separated by a material that conducts protons between the chambers but not the electrons. A simulation of this type of MFC was designed in the lab using two plastic bottles connected by a tube, containing a separator which is usually a cation exchange membrane (CEM) such as Nafion. (The CEM is also called as proton exchange membrane, PEM) but in this study it was an agar salt bridge that was made by using again a glass tube filled with 10% agar in 2M NaCl to serve the same function as a cation exchange membrane. It was prepared by first dissolving 11.6gm NaCl in 100 ml of Double Distilled Water (DDW) and then using this solvent to make 10 % agar (10 gm of agar in 100 ml of the solvent, first the solvent was heated and then the agar powder was added gradually while the heating continued until a clear suspension was obtained). Agar was poured hot in the tube which was sealed from both ends, once agar solidified on cooling, the seals were removed. The cathode compartment was filled with 1500ml of 100mM phosphate buffer solution (PBS) and 500ml of 50mM potassium ferricyanide solution (24.6gm in 1500 ml of DW) i.e. catalyst in order to accelerate the reduction of oxygen in water [6] , [7]. Resting cell (anode compartment) was suspended cow, fish and vegetable waste in 1500 ml of 50mM phosphate buffer solution. The initial pH was adjusted to 7. The above method followed by [5] . When the CEM is used in an MFC, it is important to recognize that it may be permeable to chemicals such as oxygen, ferricyanide, $K_3Fe\ (CN)_6$ or organic matter used as a substrate. Using the ferricyanide as the electron acceptor in the cathode chamber increases the power density due to the availability of the good electron acceptor at high concentration. While performance of ferricyanide, it must be chemically regenerated and its use is not sustainable in practice. Thus the use of ferricyainde is restricted to fundamental laboratory studies. The simplest materials for anode electrodes are graphite plates or rods as they are relatively inexpensive, easy to handle and have a defined surface area.

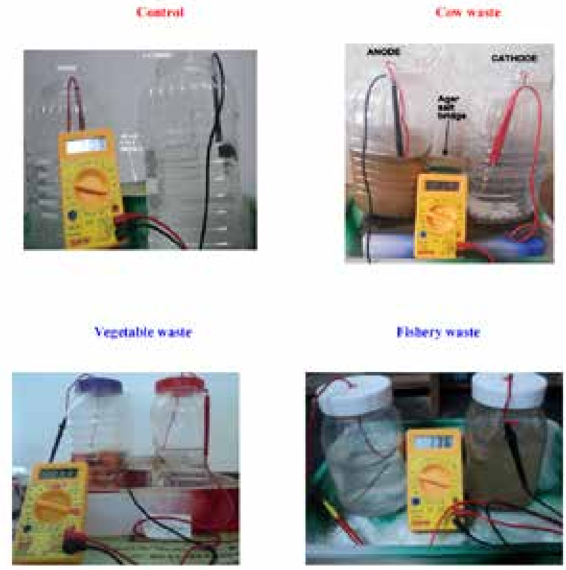

Figure 1. Experimental design of MFC

Methods

The research begins with manufacture of cow dung, fishery and vegetable wastewater. Waste is made by counting the cow dung, fish and vegetable then mix water with a ratio 1: 5 (w/w). Set of tools that will be used MFC prepared the electrode chamber 23x10 cm. Liquid waste that has been made is inserted into a vessel of 1500 ml. Anode chamber was repeatedly filled with organic wastes until bacteria colonize the electrode. Chamber was refilled when voltage decreased to less than 50 millivolts. Electricity was measured every day for 5 days. .

The key to this design is to choose a bridge that allows protons to pass between the chambers, but optimally not the substrate or electron acceptor (typically oxygen) in the cathode chamber. In the study MFC was operated in batch mode carrying different substrate, employing nickel plate electrode 15 cm X 1 cm in size for generation of power and to facilitate the proper electron and proton transfer with its large size. The electrodes were connected by copper wire with all surfaces coated with a non-conductive epoxy [6].

The electrode materials were collected and pretreated before constructing MFC. The electrodes selected should have same surface area. Pretreatment of electrode involves initially washing the electrodes with distilled water and later dipped in the ethanol for 10 mins, finally the electrodes were dried by keeping it in the hot air oven for five minutes.

A key aspect of the MFC design is the environmentally friendly nature of the energy source. The main product of bacterial digestion is carbon dioxide, and the waste from the anode chamber is composed primarily of unused nutrient feed, which contains acetate, table salt, baking soda, ammonium chloride, and sodium phosphate in water. These components are not harmful to the environment, and are suitable for watering plants.

Analyses

The overall performance of an MFC is evaluated in many ways, but principally through power output. Voltage was continuously measured by a multimeter with a data acqui-

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sition system and converted to power according to p = power, I current, and v = voltage. Power was normalized by the total surface of area of the anodes. Power is calculated as

P = IV.

RESULTS

Electricity in the two chambered MFC was generated using two different organic waste as cow dung and vegetable waste in anode chamber. The average voltage among the batches varied between 40 millivolts (mV) to 320mV, depending upon the substrate concentration used in the anode chamber measured for 5 days. The amount of electrical energy generated is determined by the different waste in generating electrons and protons. Measurement results cow dung, vegetable and fishery waste electricity represented in Table. 2 and Fig 2 -5.

Table 2 shows the relationship between voltage and the duration of the MFC. The result can be seen the value of the voltage continues to increase every day except control. The increase was observed in the following order: cow dung, vegetable waste and fish waste. Among the three organic wastes, the cow dung is producing the better bio-electricity as compared with other organic wastes.

Organic wastes	Day (s)				
	1	2	3	4	5
Control	40	43	40	42	40 mV
Cow dung	95	127	196	252	320 mV
Vegetable waste	62	98	176	234	292 mV
Fishery waste	58	101	135	189	210 mV

Table 2. Average voltage (mV) produced by cow dung, vegetable and fishery wastes

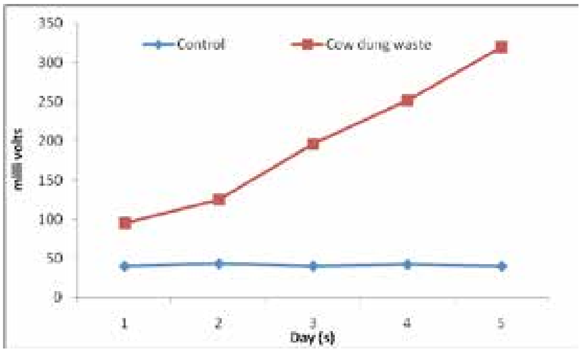

Figure 2. Comparative analysis of Average Voltage generated by cow dung wastes

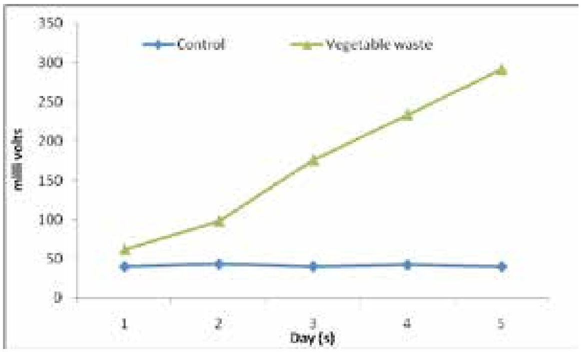

Figure 3. Comparative analysis of Average Voltage generated by vegetable wastes

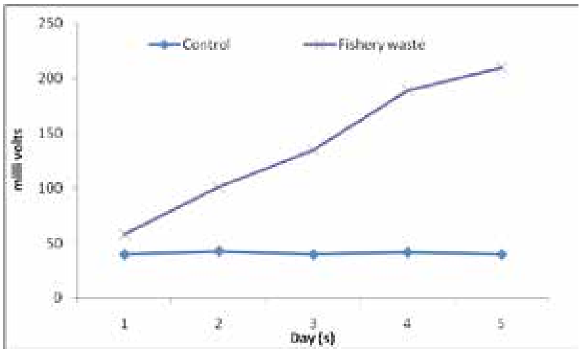

Figure 4. Comparative analysis of Average Voltage generated by fishery wastes

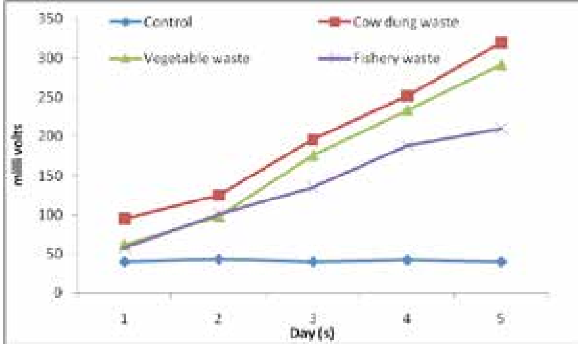

Figure 5. Comparative analysis of Average Voltage generated by cow dung, vegetable waste and fishery wastes

DISCUSSION

Bio-electrochemical systems have recently emerged as an exciting technology to generate the electricity that is considered as the ladder for the development. In accordance with the fast growing population, the demand for energy and the discharge of waste are increasing day by day. To overcome the energy crisis, alternative energy sources are the only remedy. Generation of energy from waste is beneficial in many ways. It is most suitable for eco friendly waste disposal and also for energy generation. The most desirable type of bio-electrochemical system is the microbial fuel cell (MFC), in which power could be generated from electron donors that are present in the form of organic matters[8].

MFC systems have been applied in several fields, including for the treatment of waste water and producing electricity,

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biosensors, and the production of secondary fuels. MFC technology is attractive for waste treatment because it allows the system to extract energy from waste for electricity production. MFC substrate contains a growth promoter that can increase bioelectrychemical microbial growth during the waste processing. MFC system with anaerobic consortium communities that could be replaced can be used as a biosensor for the online monitoring of organic compounds. Through a little modification, MFC can be used for produce secondary fuels like hydrogen as an alternative electricity power [9].

Microbial fuel cells (MFCs) are devices that use microorganisms to covert the energy stored in chemical bonds in biodegradable organic and inorganic compounds to electrical energy. Microbes release electrons to the anodes, and they are transferred through the circuit to the cathode, where they combine with protons and an electron acceptor, such as oxygen, to form water. The characteristic of vegetables waste industrial processing are different from beef, poultry, dairy and marine industry. The waste from fishing industry containing high organic matter that may contains blood and a piece from fish skin and also the entrails. Cow dung, which is usually a dark magenta colour (usually combined with soiled bedding and urine), is often used as manure(agricultural fertilizer). If not recycled into the soil by species such as earthworms and dung beetles, cow dung can dry out and remain on the pasture, creating an area of grazing land which is unpalatable to livestock. In many parts of the developing world, and in the past in mountain regions of Europe, caked and dried cow dung is used as fuel. Dung may also be collected and used to produce biogas to generate electricity and heat. Cow dung has high nitrogen content and due to pre-fermentation in the stomach of ruminant, and has been observed to be most suitable material for high yield of bioelectricity through the study made over the years [10].

Microbial fuel cell (MFC) is a system that directly converts the chemical energy contained in bio-convertible substrate into electrical energy, using the catalyst from bacteria. Generally an MFC consists of an anode, cathode, cation exchange membrane or proton and electrical circuits. Bacteria in anode used substrates such as glucose, acetate also liquid waste into CO_2, protons and electrons. There is no oxygen in anode, so bacteria must alter its electron acceptor into an insoluble acceptor such as anode. Based on the ability of bacteria to transfer electrons to the anode, the MFC can be used to collect electrons from the microbial metabolism. The electrons then flow through an electrical circuit with the charge on the cathode. There are several mechanisms that involve the transfer of electrons from bacteria to the anode is the direct electron transfer through the outer cell membrane protein, the mediator of electron transfer, and electron transfer via bacterial nano wires [9].

The part that can be used in MFC as a electron donor is the result of microbial metabolism of substances or microbes ejected electrons during metabolism. The result of microbial metabolism generally compounds containing of hydrogen, such as ethanol, methanol, or methane gas. These compounds can be used as a source of hydrogen through a series of processes in a reformer to produce electrons and electric current [11].

Based on the study, obtained data on electricity value contained in the waste of cow dung, fish and vegetable waste were observed for 5 days. Electricity value of control without the addition of waste is no remarkable change in every day, with an average number of electricity of 40 mvolts. Cow dung waste electricity value with increased from the first day until the fifth day. Electricity value on fifth day is 320 mvolts. Electricity value from vegetable wastewater with the increased from the first day until the fourth day and then decreased on the fifth day. Electricity value on fifth day is 292 mvolts. Fishery Wastes electricity values increases up to fourth day and slight decrease in fifth day. Electricity value on fifth day is 210 mvolts.

Electricity value is fluctuating every day. This was influenced by the metabolic activity of the microbial consortia that relies on the availability of organic matter (carbon and nitrogen source) contained in the waste. The organic material were oxidized to produce CO_2 as final products and lead a consortium of microbes that live in it actively to metabolize and produce more free electrons. Based on the data obtained, could be concluded that the most effective treatment is with the cow dung waste. Treatment resulted an increasing electricity value every day and shows the highest average value. In addition due to the metabolic activity, fluctuations in potential difference also caused by the interaction between microbes making up the consortium. Cow dung is the source of nutrient for bacteria. Fermentation products (lactate, succinate, and format) from one type of bacteria can be a substrate for the other types of bacteria. Increase or decrease in electrical potential difference correlated with the sheer number of free electrons produced by microbial consortium. Increase in potential difference measured by the multimeter is likely to occur when microbes perform simple substrate solution derivative works, in addition to the activities of anabolism, the possibility can also occur because the microbes are adapted to break down the more complex substrates into simple [11]. One way that can be done to improve the electricity is to press the internal resistance caused by obstacles or resistance given the components that exist in the MFC system, such as electrodes, electrolyte, and membrane. In addition, the increase of electricity can also be done by extending the electrode surface so there are more electrons transferred to the electrode and flow towards the cathode compartment [9].

MFC without membrane is an alternative way to minimize costs. Membrane systems are expensive and can be avoided by utilizing complex biofilm development that occurs on the surface of the cathode. Another benefit is the result of power density could be higher because of the ability of the system to reduce internal barriers. The disadvantages of MFC without using diffusion membrane is vulnerable to such toxic ferisianida electron acceptor in the cathode chamber, vulnerable to diffusion of oxygen, facilitator and there is no facilitator of proton transfer or other cations to the cathode chamber [9].

This experimental setup of MFC with agar salt bridge working as cationic membrane, where three different organic waste as cow dung, vegetable waste and fish waste, showed promising and exciting results. The results of the present study concluded that the maximum voltage generation was observed in cow dung whereas the vegetable waste and fish waste produce minimum voltage. Cow dung as a substrate provided higher voltage output in comparison to vegetable waste and fish waste. The high electricity production of cow dung is might be due to the rich source of bacteria which having high metabolic activity. The MFCs have recently emerged as an exciting and promising technology which can cater to the needs of modern world that is constantly looking towards such replenishable and safe energy generators.

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