ENERGY GENERATION FROM DAIRY EFFLUENT USING MFC TECHNOLOGY AND PIEZO ELECTRIC TRANSDUCER

Beena Puthillath
Department of EEE, SCMS School of Engineering & Technology, Ernakulam

ABSTRACT: Today the world is facing so many challenges regarding the energy crisis. As the population increases the demand for energy also get elevated. There is increase in energy demand for portable electronic devices and harnessing of alternative renewable source of energy is of interest as it is eco-friendly. This made us think about harnessing energy from different sources like from a microbial fuel cell utilizing dairy waste and vibrational energy from footsteps. For this the use of Piezo-electric crystals are being used for absorbing the pressure energy from the footsteps and converting the corresponding mechanical energy to electrical energy. Another method adopted for energy generation is the use of Microbial Fuel Cell (MFC). This uses the bacterial action to derive bio-electricity from waste. The MFC can generate electricity as well as it contributes to the effective waste management on a large scale. The electricity produced is of low power.

KEYWORDS: Microbial Fuel Cell, Dairy byproduct, Whey, Renewable energy, Piezo-electric sensor

Introduction

The world we are seeing today is facing a lot of undeniable setbacks. For thousands of years we have been relying on fossil fuel for power generation to meet the demand. As the fossil fuels acts as the primary means of energy generation it also causes many complications as well. Climate change is one of the serious issues caused by the over dependence on fossil fuel. The abundant usage causes hike in the pollutants concentration in the atmosphere which will leads to massive increase in temperature on the earth's surface. This is a huge threat to the environment. This is what led us to make us look into the greatly and rapidly developing fields of renewable energy.

The use of Piezo electric modules for the application on footpath can contribute to the vast generation of electricity by installation. Basically, we don't require any expensive machinery and it widely uses the pressure generated from the footsteps of the pressure from the moving vehicles as in advanced applications.

The Piezo crystals has the ability to generate voltage by absorbing the pressure energy and converting to electrical energy. It is called as Piezo-electric phenomenon. The main advantage is that the areas which are needed to generate energy is not isolated or divided from the surroundings, it uses the active surroundings to generate electricity, saving the cost for land and any other premises.

The Prototype can be installed in any place especially crowded region, from road pavements, schools and other educational institutions, offices etc. The practical implementation is such a prototype will inculcate feelings of using cleaner energy, conserving the planet and efficiently utilizing all resources god has gifted us with.

The microbial fuel cell can be used for waste treatment as well as for biological power generation. Microbial Fuel Cell (MFC) uses bacterial metabolism to producing electrical current from organic substrates. Here the byproduct obtained from Paneer making process in a dairy is the fuel to the Microbial Fuel Cell and the analysis of the MFC with different varieties of bacteria has been carried out.

We are using the action of Klebsiella Pneumonae bacteria for the whole process as it yields comparatively high amount of output from other micro-organisms. The Whey paneer used for power generation is treated with different microorganisms in a two compartment cell without any mediators in the microbial fuel cell.

The microorganisms utilized carbonate especially the lactose present in the Whey for generation of bioelectricity. The microbial fuel cell has no intermediary process and hence efficient bioelectricity is produced by this process.

Significant amount of MFC s can be stacked together for increasing the output level. So basically, the said idea can contribute to the energy demand crisis by adopting cleaner method and at the same time it can also help to achieve proper waste management industrially and can use the byproducts of the process for various other applications.

The characteristics of Paneer Whey is shown in below table

TABLE 1: Paneer Whey characteristics

Characteristics	Value
pH	5.5
Total amount of carbohydrate(g/ml)	32.9
Total amount of Protein (g/ml)	6.9
COD (mg/l)	52000

Paneer whey is rich in organic contents and it suits as a fuel for the MFC. Due to its high COD value, we can't directly discharge into the nature. The microorganisms make use of the organic contents in the whey substrate and breaks it down to liberate electrons as well as lower the COD value considerably to a safe limit that's fine to be used for agricultural purposes

The chemical reaction is

Reaction in anode

$$C_6H_{12}O_6 + H_2O \rightarrow 12CO_2 + 24e^- + 24\ H^+$$

Reaction in Cathode

$$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$$

For construction of MFC, In the experiment two glass bottle of 500ml capacity is used for two chamber MFC. Instead of Proton exchange membrane, agar salt bridge is used here. When two electrodes are immersed in MFC, the salt bridge provides electronic contact between solutions in two bottles. [3] Carbon is used as electrode. The electrode has dimension 12cm x 1.5cm. Single stranded 0.8mm copper wire is used for connecting cell to external circuit.

The agar solution is prepared by heating 2 to 5% agar with 1M KCl. The solution is poured to a glass tube of internal diameter 12mm. The glass tube has to be kept in 1M KCl solution. Distilled water is used for filling cathode compartment and 500ml whey in inoculum is used for filling anode compartment. It is continuously aerated using aquarium aerator. [1]. The MFC was run using Klebsiella pneumonae.

Klebsiella pneumonae colony was inoculated into conical flask of 100ml. which contains nutrient broth. Under aerobic condition incubated the flask for 24hours at 370C. Then 50ml of above was added to 450ml of treated whey. It is then charged in anodic chamber of cell. Distilled water of 500ml is filled in cathode chamber. Immersed the salt bridge and electrode. The cell is kept for 24 hours to stabilize. [2].

We also used saccharomyces (yeast) as our lacto actor in the MFC instead of Klebsiella pneumonae. The process involved where similar to that when we used Klebsiella pneumonae but for yeast, the output was much lower than the other.

For bucket design, bucket Design, the process is same and the only difference is in the design structure. Here the cell is designed with a capacity to process for 5 litres total. Incidentally, we have developed a new design with 4 cylindrical chambers and the microbial fuel cells were planned to be charged with the required quantity of paneer whey. We took 3.6 litres of paneer whey and distributed it in 4 chambers and added 400 ml of klebsiella inoculum (100ml in each chamber).

Our earlier study provided data that klebseilla organism is better suited to this study as it comes under coliform group of organisms. Other strains like E-coli, Geobacter, saccharomyces, shewanella are also suitable for power

generation. [3, 4] Data available on power generation of these organisms were also closely monitored and the current organism was selected based on the ease of availability under the pilot study process.

Materials and Methods

The cathode chamber is filled with 5 litres of distilled water and the 4 anode chambers are placed inside the cathode chamber connected through 4 agar salt bridges serially. Four carbon electrodes each were connected with 0.6 mm copper wire was placed inside anode and cathode chambers.

Aeration was done cathode chamber with the help of two aerator pumps in the experiment. The one side of agar salt bridge was immersed in the whey in the anode chamber and the other end in distilled water solution in the cathode chamber. The 4 anode chambers were filled with 900ml of whey inoculated with 100 ml of the Klebsiella culture, thus 3.6 litres of whey and 400 litres of inoculum were evenly distributed in the 4 chambers. [6]

Figure 1. Bucket model

Figure 2. Single PVC anode chamber

Materials Used are 15 litrebucket, 3.6 Litre whey, 0.4 Litre inoculum, 4 Litre distilled water, 4 PVC pipe, 8 PVC Cap, 4 Agar salt bridge, 8 carbon electrodes, Aerator.

In Box Design, four individual cells are connected in series which is occupied in the box which provide the mechanical protection to the cells.

This design we further modified as a box type model. The anode chambers in this study was poly propylene bottles filled with the same quantity of whey and inoculum as done above and fitted with lids provided with openings to introduce agar salt bridge and copper wire fitted to the carbon electrode.

All the precautions of making the chamber air tight and the salt bridge end immersed in whey were taken care of. The cathode chambers were also made up of poly propylene and filled with distilled water frequently aerated using two aerator pumps as before. The bottles were placed serially inside a box to make the design compact.

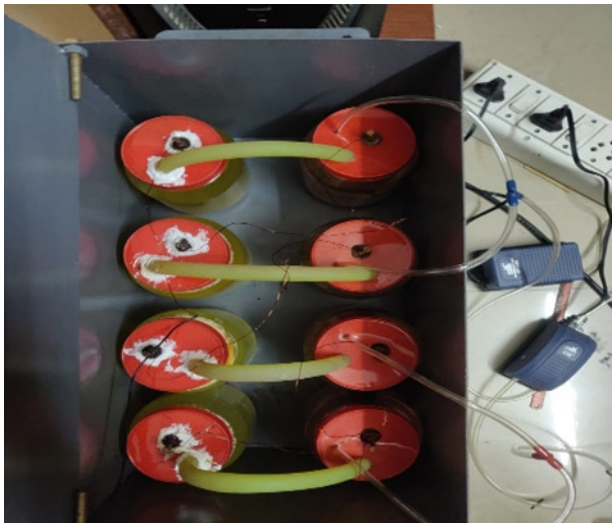

Figure 4. Box model

Materials used are 3.6 Litre whey, Litre inoculum, Eight 1Litre glass bottle, Four Agar salt bridge, Eight carbon electrodes, Aerator

In Piezoelectric Tile, when a mechanical stress is applied across a piezoelectric crystal an emf is obtained and the electricity so produced is termed as Piezo Electricity. As walking is a daily activity of human, the footsteps can be used for power generation. In normal case the footstep taken by human per day is 3000 to 5000. While walking energy is lost or converted in the form of vibration, sound etc. This transfer of energy depends on weight of the person and the force with which he walks. The energy from footstep can be utilized for producing electricity with the help of Piezo-electric crystal. [7, 8].

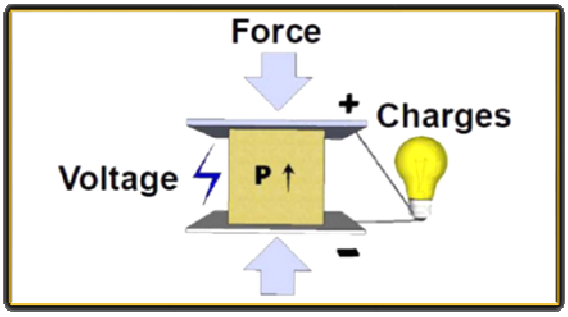

Figure 6. Energy generation from piezoelectric crystal

The prototype tile consists of 20 Piezo sensors

Area of single tile = 1 Square feet

Diameter of the Piezo sensor = 27 mm

Piezo sensors that can be

installed in a single tile = 5*4 = 20 units

Length of rubber mat = 90 cm

Breadth of rubber mat = 30 cm

Number of tiles per step = 3 tiles

Total units of sensors required = 3*20 = 60 units

About 800 steps are required to get 1volt from the battery. [13]

We need a 12V battery

Total number of steps = 12*800 = 9600 steps (minimum)

If the mat is placed in a busy area, assuming 1 footstep per second,

Time taken for 9600 steps = 9600/60 = 160 minutes (approx.)

TABLE 4: Components used for the prototype

Sl. No	Components	Specification	Quantity (no.)
1	Piezo sensors	5V/με, 1A p-p	20
2	Diodes	IN4007	20
3	Bridge rectifiers	3NIX W10G	20
4	Capacitor	25V, 22μF	1

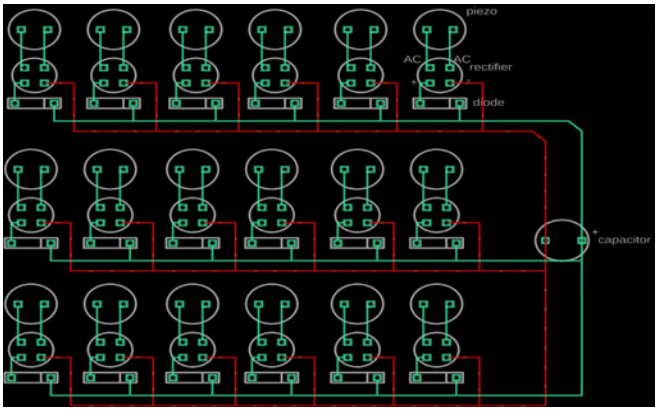

Figure 7. Piezo tile circuit

Piezoelectric tile makes use of piezoelectric sensors/ transducers. The piezoelectric sensors convert vibrational energy i.e. the mechanical energy from the footsteps into electricity. Here a top plate is provided, which has springs that help to concentrate the pressure on the Piezo module surface. The output of Piezo module is unregulated dc. To make it regulated, rectification circuit using diodes and bridge rectifier is provided. The bridge rectifier will convert variable dc to fixed dc. The blocking diode will prevent reverse charging of capacitor. The energy is stored and maintained steady using a capacitor.

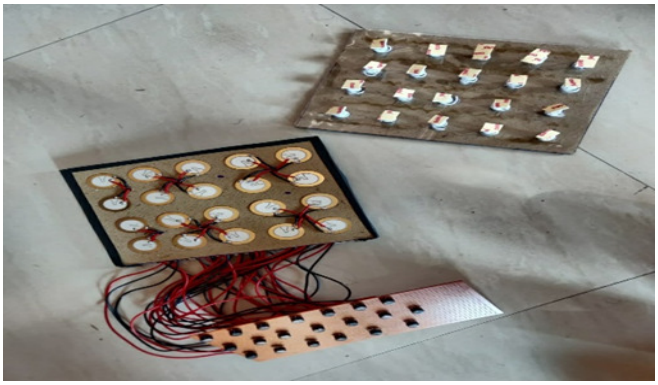

Figure 8. Hardware setup

Results and Discussions

It is observed that series connection provided maximum open circuit potential. Readings from 0 hour to 24 hours for 4 days were taken and the output data is mentioned here under. The voltage V at the start of the experiment was found to be 0.34 volts & at the end after 4th day it was 0.69 volt.

TABLE 2: Readings obtained at the end of the day

Day	After 24 Hours		
	Voltage (V)	Current (μA)	Power (μW)
1	0.61	354	251.94
2	0.71	504	357.84
3	0.7	323	226.1
4	0.69	87	60.03

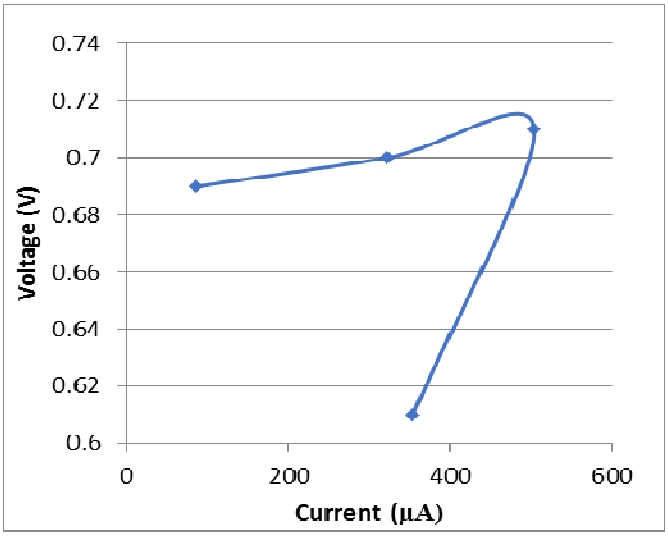

Figure 3. Voltage versus current graph

The result obtained from box type model is shown in table 3 and figure 3.

TABLE 3: Readings at the end of each day

Day	After 24 Hours		
	Voltage (V)	Current (µA)	Power (µW)
1	0.67	317	212.39
2	0.79	627	495.33
3	0.8	657	525.6
4	0.71	213	151.23

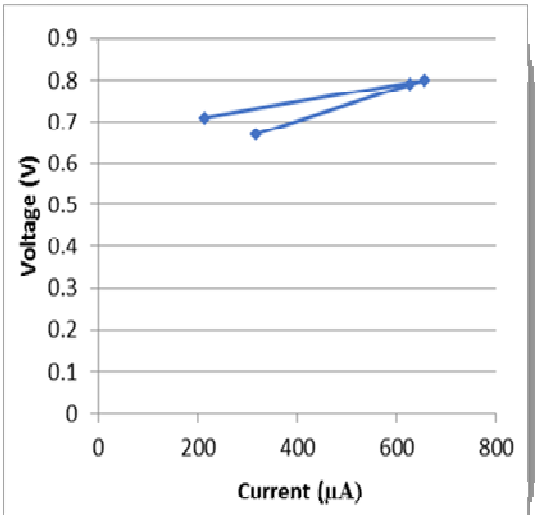

Figure 5. Voltage verses current

The maximum voltage we obtained with the prototype tile was 12.42V and minimum around 2V, considering the fact that average weight of persons to be 50kg.

Figure 9. Display value

The energy is generated from the organic substrates by the help of bacterial action. The conversion was done using the fuel cell and the whey acts as the fuel for generating bio-electricity. The concept can be used industrially for the large-scale conversion of bio-waste to useful power

The pressure energy is harvested using the piezoelectric transducers. Using this technique, a significant amount of energy is being converted. The technique can be actively used for harnessing energy from the road by installing a new version of the prototype so that the pressure energy created by the vehicles can be actively be converted to electricity.

Conclusion

It is evident that electrical energy can be tapped from the industrial effluents based on the experiment conducted in this study. More power can be generated by modifying the design so that surface area increases and also electrodes in the fuel cell.

The output can be improved by selection of suitable microbes and electrodes. The adhesion capacity of microbe should be more for maximum output from cell. Environmental aspects have to be considered while selecting microbes and electrodes. The system has to be scaled up using latest technology. Agitation effect, pH value, conductivity, surface area of electrodes are the significant factors considered for efficient power generation.

This method of power generation is suitable for rural and remote area also. Electricity can be generated until anode gets corroded. Maximum power is obtained during the first half of reaction as anode is more active to donate electron in due course the anode losses its ability and gets corroded. At the end of the operating hours the production of electricity is reduced slightly. Development in better bio electrode can solve this issue. More study is required in this case

Developing countries are nowadays depending more and more onto renewable sources. One of the most popular method is using piezoelectric material to harvest energy from vibration source.

The test conducted or the experimental setup is economical and technically feasible. This process can be used for low power generation. A better energy management scheme helps to utilize energy produced from Whey for the illumination and working of equipment which requires less power. By using battery, the energy from Piezo can be stored for future use.

Small or mini low power charging stations can be installed by using the power generated from Whey and Piezo crystal in the form of tile as we can utilize the power of footsteps continuously. This method is highly suitable for densely populated areas as people keeps on moving. The generated energy can be utilized for street lights, mini power charging booths etc. In future the concept of Piezo electricity generation can be applied to thread mill, commercial buildings, railways and all walk ways.

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