

Generation of Electricity Using Food Processing Industry Wastewater by Microbial Fuel Cell

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ABSTRACT: Food processing industry wastewater poses pollution problems due to its high COD (Chemical Oxygen Demand) and BOD (Biochemical Oxygen Demand). Moreover the characteristics of wastewater depict wide variation due to the variation in the type of products manufactured and also the different fruits, vegetables and raw materials used. Many preservatives, colour, salts, oil, sugar, gelatin etc are added as per the requirement of production of various products, this adds to the pollution load. The application of Single chamber Microbial Fuel Cell (MFC) for electricity generation has been developing recently. In recent years, researchers have shown that MFC can be used to produce electricity from water containing glucose, acetate or lactate. This research explores the application of MFC in generating electricity food industry waste water. In order to obtain the aim of this research, a system of MFC with microbes has been used. Based on the results of different waste water samples, it can be reported that the maximum voltage can be generated . The potential difference generated by the MFC was measured using multimeter.

KEYWORDS: Microbial Fuel Cell, Maiz Industry Wastewater, Energy Recovery, Organic waste, COD, Electricity

I. INTRODUCTION

India's food processing sector ranks 5th in the world in exports, production and consumption. Wastewater generated from these industries depicts wide variation in strength and characteristics. Variation due to the amount of water usage, type of vegetable and fruits used, type of product and different additives like salt, sugar, gelatin, colour, oil and preservatives added also leads to the pollution load in the wastewater but this wastewater is non toxic in nature because it comprises less hazardous compounds. Almost 50% of the water utilized in food processing industry is for washing and rinsing purposes. Water being the primary ingredient is widely used as a cleaning agent in food processing industry. Energy calamity in India is rising each year, as there is a constant activity in the price of fuels and also due to depletion of fossil fuels to a larger level. The demand for an alternating fuel has erupted extensive research in discovering a potential, economical and reusable source for energy manufacture. Rapid urbanization and industrialization in the developing countries like India pose severe problems in collection, treatment and disposal of effluents. This situation leads to serious public health problems. For constructing a sustainable world we require to minimize the expenditure of fossil fuels as well as the pollution generated. These two aims can be accomplished all together by treating the wastewater (From disposing waste to using it. Industrial waste, agricultural waste and household waste are ideal substrates for energy productions as they are rich in organic contents.

II. LITERATURE REVIEW

[1] **AmitPremKhare&Dr.HemLataBundela**, treated wastewater obtaining from biscuit and potato processing factory and the application of Single chamber Microbial Fuel Cell (MFC) for electricity generation has been developed. In recent years, researchers have shown that MFC can be used to produce electricity from water containing glucose, acetate or lactate. This research explores the application of MFC in generating electricity using different waste water samples from Jabalpur. In order to obtain the aim of this research, a system of MFC with microbes has been used. Based on the results of different waste water samples, it can be reported that the maximum voltage generated for all four substrate is 357mV at day five by vermin compost. The potential difference generated by the MFC was measured using multimeter.[2] **Dr. M. O. Aremu, Dr. S. E. Agarry**, Reported Microbial Fuel Cell (MFC) is a biochemical-catalyzed system which generates electricity by oxidizing biodegradable organic matter in the presence of either fermentative bacteria or enzymes. Microbial fuel cell technology is a new type of renewable and sustainable technology

for electricity generation since it recovers energy from renewable materials that can constitute environmental pollution if disposed of without proper treatment, such as organic wastes and wastewaters.[3] **H. Vignesh and HemaKalai Rani**, reported Microbial fuel cells (MFCs) are devices that can use bacterial metabolism to produce an electrical current from a wide range of organic substrates. Microbial fuel cells (MFCs) represent a completely new long term, affordable, accessible and eco-friendly approach to waste water treatment with production of sustainable energy.[4] **Mohanakrishnaet G, Venkata Mohan S and Sarma P.N**, evaluated Microbial fuel cell (MFC; open-air cathode) as bio-electrochemical treatment system for distillery wastewater during bioelectricity generation. MFC was operated at three substrate loading conditions (OL: 3.6, 7.85 and 16.2 kg COD/m³) in fed-batch mode under acidophilic (pH 6) condition using anaerobic consortia as anodic biocatalyst. Current visualized marked improvement with increase in substrate load without any process inhibition (2.12-2.48 mA). Apart from electricity generation, MFC documented efficient treatment of distillery wastewater.[5] **Behera M, Jana P.S, More T.T and Ghangrekar M.M**, reported maximum power production capacity of these MFCs was evaluated using permanganate as cathodic electron acceptor instead of aerated tap water after achieving steady state in the MFCs.

III. METHODOLOGY

The study was carried out in Environmental Engineering Laboratory, Department of Civil Engineering, PDA College of Engineering, and Kalaburagi. The materials used for the Study and methodology adopted are shown in the following sections.

Wastewater collection

Maize processing industry wastewater was collected from nearby Industry. Which is very famous for the food industries.

Microbial fuel cell(mfc)

Single (MFC-1) and Double chambered (MFC-2), Microbial fuel cells have been fabricated for the treatment of food processing industry wastewater.

Materials collection for the fabrication of MFC:

Various materials are used for the construction of MFCs were as follows:

- Three Non-Reactive plastic boxes of Ten liters capacity
- Agar agarBacto (for bacteriology), SDFCL
- Potassium chloride(1M), AR Grade, SDFCL(s d fine-chem limited)
- Carbon rods of 4mm diameter & 47mm length extracted from Eveready battery cells.
- Copper wire
- PVC pipe of 3.2 cm diameter and length of 22cm.
- Sealants: M-seal, pidilite industries ltd.
- Digital Multimeter (DT-830D)

Functions of the materials used for fabrication of MFC:

- **Plastic boxes:** used to prepare anode & cathode chambers. The anode chamber is having 10 liters capacity with a working volume of 7.5 liters and holds the wastewater and the cathode chamber holds a conductive salt solution.
- **Agar agarbacto :** is used to prepare agar salt bridge, proton exchange membrane for keeping the anode & cathode liquid separate.
- **Carbon rods:** are used as anode & cathode materials.
- **Copper wire:** is used to connect the electrodes to the millimeter which form external circuit.
- **Pvc pipe:** holds the agar salt mixture, which is called as agar salt bridge.
- **Sealant:** PVC pipe was connected to the sides of the plastic boxes and sealed with epoxy to prevent the leakages.
- **Digital multimeter:** is used to measure the current and voltage.

OPERATING CONDITIONS

The whole study was conducted under ambient environmental conditions. The microorganisms present in food processing industrial wastewater acted as the substrate for MFCs. The food processing industrial wastewater samples were kept in refrigerator at 4⁰C before use. The wastewaters are used as substrates for all MFC tests without any modifications such as pH adjustments or addition of nutrients etc. The study was conducted by feeding food processing



industrial wastewater separately to MFC-1 and MFC-2 with different wastewater strengths (concentrations).

ANALYSIS OF WASTEWATER, CURRENT AND VOLTAGE GENERATION

All the parameters are determined soon after sampling. The physico-chemical and biological parameters are analyzed as per the method described in Standard Methods for the examination of water and wastewater. pH is determined by pH meter LI 120, biochemical oxygen demand (BOD) is determined at 20⁰c for 5 days by Winkler’s method, chemical oxygen demand (COD) by closed refluxed method, total solids & dissolved solids is determined by gravimetric method, sulphate is determined by turbid metric method, chloride is determined by argent metric method, phosphate by stannous chloride method and nitrate is determined by Phenoldisulphonic acid (PDA) method.

IV. RESULT

The characteristics of Maize wastewater and the experimental data relating to single chambered and double chambered microbial fuel cell are shown in the below table .

CHARACTERISTICS OF MAIZE FOOD PROCESSING INDUSTRY WASTEWATER

The characteristics of Maize wastewater are as shown in table 1.

Table 1: Characteristics of Maize wastewater

Sl.no.	Characteristics	Unit	Maize Wastewater
1.	pH	-	4.0
2.	Color	By eye observation	Cremish yellow
3.	Total solids	mg/L	12490
4.	Dissolved solids	mg/L	9850
5.	Suspended solids	mg/L	2960
6	COD	mg/l	8000
7	BOD ₅ @20 ⁰ C	mg/l	5630
8	Chloride	mg/l	480
9	Phosphate	mg/l	3750
10	Sulfate	mg/l	3930
11	Nitrate	mg/l	243
12	Iron	mg/l	864

TREATMENT AND ELECTRICITY GENERATION USING VARIOUS CONCENTRATIONS MAIZE INDUSTRY WASTEWATER IN MFC-1 AND MFC-2

Maize wastewater were diluted to get desired feed concentrations. The varied feed concentrations of wastewater were given as the substrate for MFC-1 and MFC-2, as shown in table 2 and table 3.

Table.2. Treatment efficiency of Maize wastewater and electricity generation for various feed concentration in MFC-1

Time in days	Chemical Oxygen Demand (mg/L)			Biochemical Oxygen Demand (mg/L)			Total Solids (mg/L)			Dissolved Solids (mg/L)			Chlorides (mg/L)		
	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction
1-5	1000	530	47	700	340	51.42	1550	710	54.19	1230	620	49.59	60	20	66.66
6-10	2000	850	57.5	1400	600	57.14	3100	1380	55.48	2460	980	60.16	120	35	70.83
11-15	3000	930	69	2100	750	64.30	4650	1860	60	3690	1400	62.05	180	46	74.89
16-20	4000	1024	74.4	3000	930	66.78	6200	2300	62.29	4920	1580	67.88	240	52	78.33
21-25	5000	1130	77.4	3500	1120	68	7750	2660	65.67	6150	1760	71.38	300	60	80
26-30	6000	1225	79.58	4200	1170	72.14	9300	2700	70.96	7380	2080	71.82	360	64	82.22
31-35	7000	1670	76.14	4900	1500	69.38	10850	3150	70.96	8610	2530	70.61	420	75	82.14
36-40	8000	1980	75.25	5600	1800	67.85	12400	3800	69.35	9840	3010	69.41	480	93	80.62



Time in days	Phosphate (mg/L)			Sulfate (mg/L)			Iron (mg/L)			Nitrate (mg/L)			pH		Current (mA)	Voltage (volts)
	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent		
1-5	470	310	34.04	490	210	57.14	30	23	23.33	108	52	51.85	4.0	5.1	0.85	0.68
6-10	940	380	59.57	980	305	70.91	60	32	46.66	216	72	66.66	5.1	5.3	1.11	0.95
11-15	1410	425	69.85	1470	315	78.57	90	46	48.88	324	97	70.06	5.1	5.2	1.94	1.38
16-20	1880	485	74.20	1960	398	79.69	120	52	54.16	432	123	71.52	5.1	5.4	2.87	1.94
21-25	2350	515	78.08	2450	455	81.42	150	63	58	540	150	72.22	5.3	5.6	3.73	2.32
26-30	3020	575	79.60	2940	510	82.65	180	72	60	648	172	73.45	5.4	5.6	5.58	4.92
31-35	3290	675	79.48	3430	605	82.36	210	85	59.52	756	202	73.30	5.5	5.76	4.59	3.55
36-40	3760	775	79.38	3920	695	82.27	240	99	58.75	864	253	70.71	5.6	5.8	4.30	3.20

Table.3. Treatment efficiency of Maize wastewater and electricity generation for various feed concentration in MFC-2

Time in days	Chemical Oxygen Demand (mg/L)			Biochemical Oxygen Demand (mg/L)			Total Solids (mg/L)			Dissolved Solids (mg/L)			Chlorides (mg/L)		
	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction
1-5	1000	630	37	700	368	47.42	1550	842	44.67	1230	853	30.65	60	22	63.33
6-10	2000	1039	48.05	1400	592	57.71	3100	1420	54.19	2460	1203	51.09	120	37	69.16
11-15	3000	1068	64.4	2100	823	60.80	4650	1947	58.12	3690	1521	58.78	180	48	73.33
16-20	4000	1136	71.60	3000	953	65.96	6200	2437	60.69	4920	1618	67.11	240	54	77.5
21-25	5000	1252	74.96	3500	968	72.34	7750	2639	65.94	6150	1785	70.97	300	62	79.33
26-30	6000	1418	76.36	4200	972	76.88	9300	3050	69.38	7380	1983	73.13	360	66	81.66
31-35	7000	1738	75.17	4900	1150	76.53	10850	3580	67.00	8610	2332	72.91	420	77	81.66
36-40	8000	2081	73.98	5600	1380	75.35	12400	4099	66.94	9840	2752	72.03	480	95	80.20

Time in days	Phosphate (mg/L)			Sulfate (mg/L)			Iron (mg/L)			Nitrate (mg/L)			pH		Current (mA)	Voltage (volts)
	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent	Percent Reduction	Influent	Effluent		
1-5	470	313	33.40	490	212	56.73	30	25	16.66	108	54	50	5.1	5.3	0.83	0.64
6-10	940	383	59.25	980	307	70.71	60	34	43.33	216	74	65.74	5.1	5.5	1.00	0.93
11-15	1410	430	69.64	1470	317	78.43	90	48	46.66	324	99	69.44	5.2	5.6	1.90	1.23
16-20	1880	488	74.04	1960	400	79.59	120	54	55	432	125	71.06	5.3	5.6	2.73	1.83
21-25	2350	518	77.95	2450	457	81.34	150	65	56.66	540	152	71.85	5.4	5.5	3.63	2.23
26-30	3020	578	79.50	2940	512	82.58	180	74	58.88	648	174	73.14	5.4	5.6	5.21	4.72
31-35	3290	678	79.39	3430	607	82.30	210	87	58.57	756	204	73.01	5.5	5.79	3.42	3.23
36-40	3760	778	79.30	3920	697	82.21	240	101	57.91	864	255	70.48	5.6	5.8	3.97	3.12

COD removal efficiency And Percentage Reduction of Maize wastewater for various feed concentrations in MFC-1 and MFC-2

Maize wastewater showed its potential for COD removal indicating the functions of microbes present in wastewater in metabolizing the carbon source as electron donor. It is evident from experimental data that current generation and COD removal showed relative compatibility. Continuous COD removal was observed in MFC-1 and MFC-2. In MFC-1, the COD removal efficiency from day 1 to day 30th increased from 47% to 79.58% as the feed concentration increased from 1000 mg COD/L to 6000 mg COD/L respectively as shown in Fig 1. In MFC-1 the highest COD removal efficiency is 79.58% on 30th day. In case of MFC-2, COD removal efficiency from day 1 to day 30th increased from 37% to 76.36% as the feed concentration increased from 1000mg COD/L to 6000 mg COD/L respectively as shown in Fig 2. In MFC-2 the highest COD removal efficiency is 76.36% on 30th day. After 30th day onwards the COD removal efficiency decreased as the feed concentration increased from 6000 mg COD/L to 8000mg COD/L from 76.14% to 75.25% in MFC-1 and 75.17% to 73.98% in MFC-2.

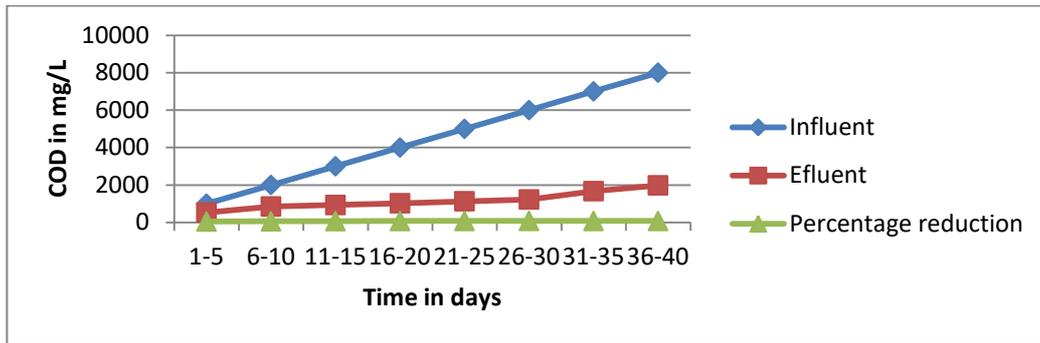


Fig 1.COD Removal efficiency and percentage reduction of Maize wastewater at various feed concentrations in MFC-1

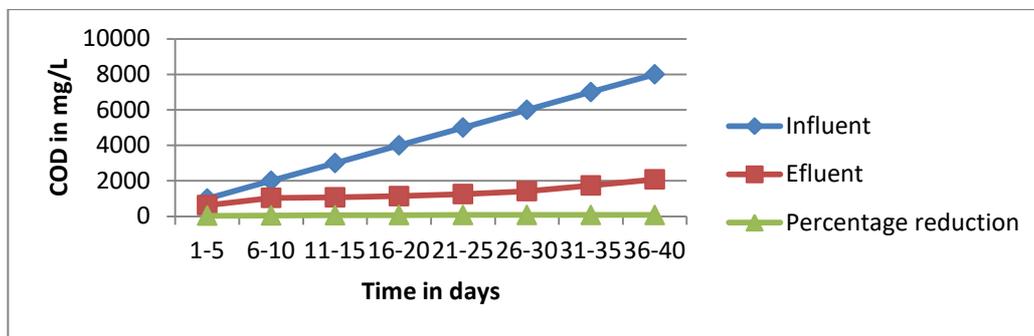


Fig 2.COD Removal efficiency and percentage reduction of Maize wastewater at various feed concentrations in MFC-2

Current and voltage Generation of Maize wastewater for various feed Concentrations in MFC-1 and MFC-2

The average value of current and voltage for each feed concentration in MFC-1 and MFC-2 are as given in the fig 3. and fig 4. The current and voltage showed a gradual increase with respect to increase in feed concentration. The highest average values of current and voltage obtained 5.58mA and 5.21mA in MFC-1 and MFC-2 respectively from 1000mg COD/L to 6000 mg COD/L respectively. Similarly the voltage values obtained were 4.92V and 4.72 V in MFC-1 and MFC-2 respectively.

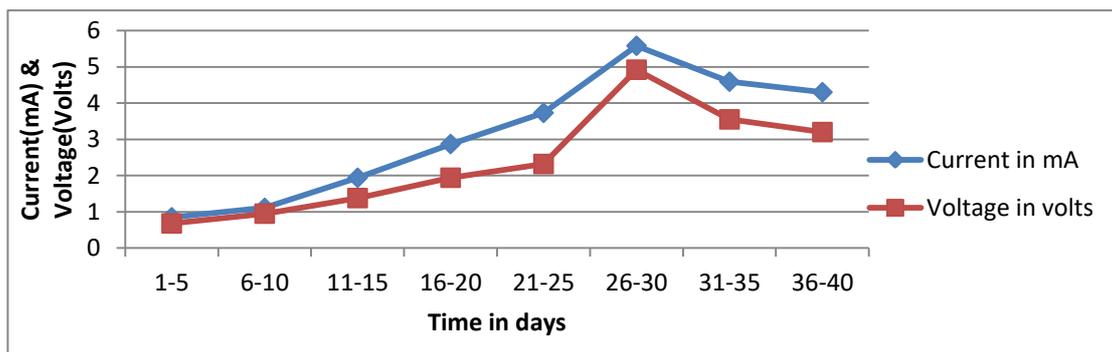


Fig 3. Current generation of Maize wastewater at various feed concentrations in MFC-1

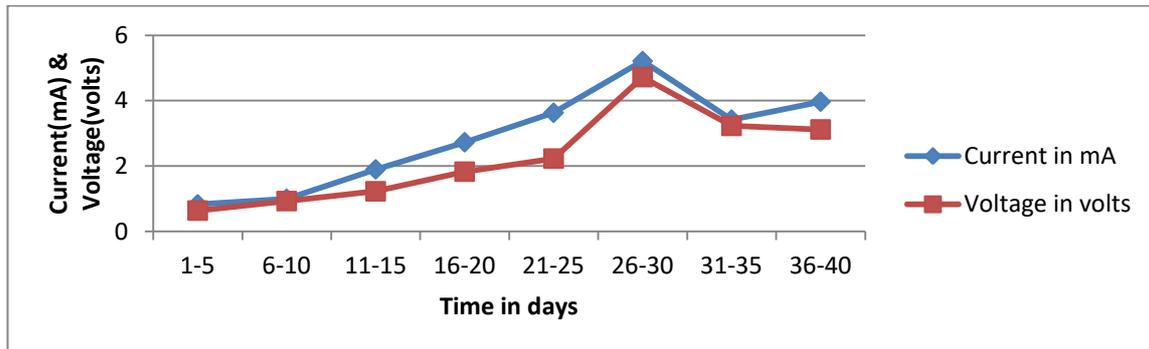


Fig 4. Current generation of Maize wastewater at various feed concentrations in MFC-2

V. CONCLUSION

On analyzing the results based on the laboratory experiments conducted, the following conclusions are drawn.

1. MFC-1 for Maize wastewater showed 79.58% COD, 72.14% BOD, 70.96% TS and 71.82% DS, 82.22% Chlorides, 82.65% Suspended solids, 79.60% Phosphate 82.65% Sulfate, 60% Iron, 73.45% Nitrate removal with different feed concentrations. The current, voltage and power generation in the reactor is 5.58 mA, 4.92 V and 1.65 W/m² respectively.
2. MFC-2 for Maize wastewater showed 76.36% COD, 76.85% BOD, 69.35% TS and 73.13% DS, 82.56% Suspended solids, 81.66% Chlorides, 79.50% Phosphate, 82.58% Sulfate, 58.88% Iron, 73.14% Nitrate removal with different feed concentrations. The current, voltage and power generation in the reactor is 5.21 mA, 4.72 V and 1.48 W/m² respectively.
3. MFC-1 proves to be better for current generation when compared with MFC-2 due to the fact that cathode in single chamber MFC (MFC-1) is exposed to air, because the presence of abundant oxygen which accepts the generated electrons.
4. The single chamber air cathode MFC (MFC-1) proves to be more reasonable because of the reduced cost of construction, low maintenance and higher electricity generation when compared with double chambered MFC (MFC-2).

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