Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 23, No. (1) : 2021 : 72-76

ISSN-0972-3005

OPTIMIZATION OF SALT BRIDGE AND ELECTRODE SIZE FOR ENHANCED BIOELECTRICITY PRODUCTION IN MICROBIAL FUEL CELL DEVELOPED USING SLAUGHTER HOUSE WASTE RUMEN FLUID

S. MEIGNANALAKSHMI[1*], B. HARITHA[2], S. RATHNAPRABHA[3] AND M. PARTHIBAN[4]

[1,2,4] Department of Animal Biotechnology, Madras Veterinary College, TANUVAS, Chennai, T.N., India
[3]Viral Vaccine Research and Control Centre, TANUVAS, Chennai, T.N., India

(Received 21 September, 2020; Accepted 24 December, 2020)

Key words: *Bioelectricity, Slaughter house waste, Microbial fuel cell.*

Abstract–In the present study, production of bioelectricity in microbial fuel cell developed with slaughter house waste rumen fluid was enhanced by optimization of agarose salt bridge and electrode size. Agarose salt bridge was optimized by different percentage of agarose from 1%-3% with different sodium chloride concentration from 1%-3%. Graphite plates of different sizes (LXBXH) 4x4x0.3cm, 5x5x0.3cm, 6x6x.0.3cm, 7x7x0.3cm and 6x6x3cm were used. 1% agarose salt bridge with 3% sodium chloride produced maximum voltage and current, 560mV and 2.60mA respectively. Graphite plate of 6x6x3cm gave the maximum voltage of 620mV and 4.8mA after 7 days, when compared to other sizes of graphite plates.

INTRODUCTION

In recent years Microbial fuel cells have emerged as an alternate promising and challenging technology to meet the increasing energy needs. MFC is considered as a sustainable technology as they can generate electricity and treat waste simultaneously (Rabey *et al*., 2007; Lu *et al*., 2009). Though there are several reports on MFC the maximum voltage obtained from a single MFC is found to be less. The electricity production in MFC depends on many important factors including temperature, pH, designs of MFC and construction, Electrodes, material of electrode, size of the electrodes, Microorganisms, Salt Bridge concentration, Agarose Concentration, carbon concentration and the External resistance. (Kevser Cirik, 2014; Mostafa *et al*., 2015). The Electricity generation rate also depends on the substrate conversion rate (Akshay *et al*., 2016). Decreasing the distance between the anode and cathode will decrease the internal resistance in the microbial fuel cell (Hailiang *et al*., 2017). Hence there is a need to optimize the parameters to improve the bioelectricity production in MFC. Among the various parameters salt bridge and electrode are found to be critical. Hence the present study has been undertaken to optimize the maximum bioelectricity production by optimizing the percentage of agarose in salt bridge and different sizes of graphite electrodes.

MATERIALS AND METHODS

Collection of rumen fluid

Rumen fluid was collected from the Slaughter house located at Perambur in Chennai. Collected rumen fluid was filtered and filtrate was used for electricity generation.

Microbial fuel cell (MFC) configuration

Dual chamber MFC was designed and fabricated with polyacrylic material. Size of each chamber is 6.5 cmx 6.5 cm (LxB) x 9.5 cm (height) and 0.5 cm thickness. The dual chambers were connected by a acrylic bridge with opening on anode and cathode chambers with a dimension of 4x4 cm.

Optimization of agarose percentage and salt concentration in salt bridge

Salt bridge optimization was carried out with different percentage of agarose ranging from 1-3% and salt concentration from 1-3%. Salt bridge was prepared with 1% sodium azide. The anodic chamber was filled with 250 mL freshly collected and filtered rumen fluid. In the cathode chamber water was used as a catholyte. Graphite plate (4x4cm) was used as an electrode in both anode and cathode chambers. The anodic chamber was sealed tightly. Current and Voltage produced were monitored for every 24 hrs for 7 days. On 7th day cyclic voltammetry of MFC were taken using potentiostat (Gamry instruments).

Optimization of Agar-Agar% in salt bridge

Normally agarose will be used for salt bridge. A trial has been conducted with Agar-agar instead of agarose. Agar agar in different concentration from 1-3% was used for the present study. Salt bridge was prepared with 1-3 % agar agar with 3% NaCl and 1% sodium azide. Current and Voltage produced were monitored for every 24 hrs for 7 days. On 7th day cyclic voltammetry of MFC were taken using potentiostat (Gamry instruments).

Optimization of Graphite plate size

MFC was constructed with different sizes of graphite plates (4x4x0.3cm, 5x5x0.3cm, 6x6x0.3cm and 7x7x0.3cm) with optimized salt bridge. Current and Voltage produced were monitored for every 24 hrs for 7 days. On 7th day cyclic voltammetry of MFC was taken using potentiostat (Gamry instruments). Size of the graphite plate 6x6x0.3cm was found to be producing maximum current and voltage. Hence the graphite plate 6x6x0.3cm was compared with 6x6x3cm graphite plate.

RESULTS

The voltage and current produced in dual chamber MFC developed with different percentage of agarose salt bridge is given in Table 1. The cyclic voltammetry taken on 7th day for different percentage of agarose is given in Figure 1, 2, 3. The voltage and current produced was found to be maximum with 1% agarose and 3% sodium

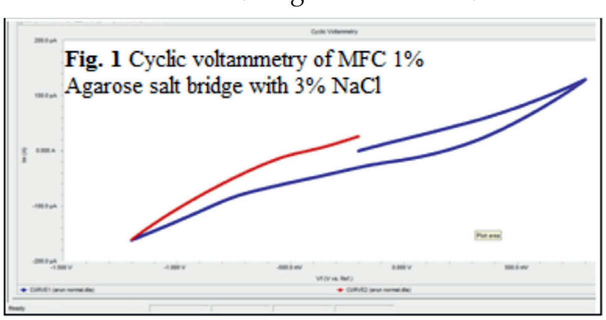

Fig. 1 Cyclic voltammetry of MFC 1% Agarose salt bridge with 3% NaCl

Table 1. Voltage and current production in MFC with salt bridge of different percentage of agarose and different percentage of NaCl

Days	1% agarose						2% agarose						3% agarose					
	1% NaCl		2% NaCl		3% NaCl		1%NaCl		2% NaCl		3% NaCl		1%NaCl		2% NaCl		3% NaCl	
	mV	mA	mV	mA	mV	mA	mV	mA	mV	mA	mV	mA	mV	mA	mV	mA	mV	mA
0	48	0.046	76	0.76	72	080	52	0.64	80	0.78	80	0.82	64	0.72	78	0.84	82	0.86
1	148	0.089	152	0.83	150	098	124	0.86	142	0.84	150	0.96	120	0.96	110	0.96	108	0.92
2	248	.099	140	0.96	260	1.2	148	0.92	220	0.92	180	1.2	160	1.20	180	.120	210	.102
3	325	.108	310	1.12	330	1.4	192	1.1	280	1.2	210	1.32	220	.240	220	.146	240	.240
4	368	.156	370	2.42	370	1.6	220	1.2	320	1.36	240	1.5	270	.320	280	.212	280	.46
5	402	.280	410	.312	420	1.7	360	1.6	336	1.56	280	1.7	320	.460	316	.420	360	0.92
6	428	.360	440	.460	480	1.9	392	1.8	386	1.78	320	1.9	380	.520	390	.680	420	1.2
7	456	.460	487	.500	560	2.6	412	2.0	496	1.82	380	2.1	460	.670	480	.960	502	2.2

chloride. The maximum voltage obtained on 7[th] day was found to be 560mV with 2.6mA when compared to 2% and 3% agarose.

In MFC developed with salt bridge containing agar-agar, the maximum voltage and current produced on 7[th] day were 696 mV, 2.96mA with 1% agar-agar, 646 mV, 2.63mA with 2% agar-agar and 547mV, 2.19mA with 3% agar-agar (Table 2). The cyclic voltammetry taken on 7th day for different % of agar-agar is given in Figure 4, 5, 6.

When agar-agar was used as salt bridge though the current and voltage produced was good, but the current and voltage tend to decline after 5[th] day

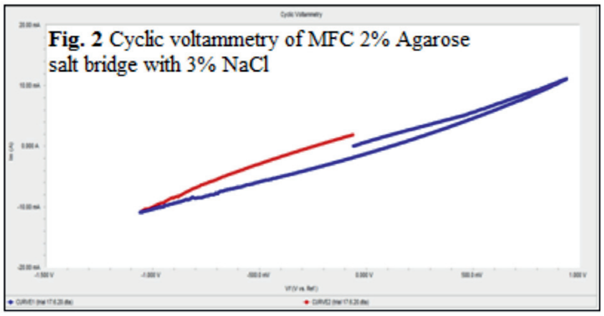

Fig. 2 Cyclic voltammetry of MFC 2% Agarose salt bridge with 3% NaCl

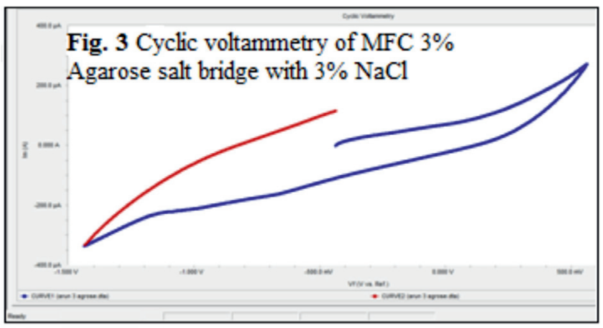

Fig. 3 Cyclic voltammetry of MFC 3% Agarose salt bridge with 3% NaCl

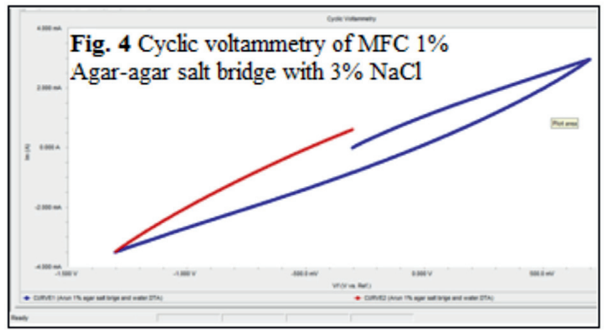

Fig. 4 Cyclic voltammetry of MFC 1% Agar-agar salt bridge with 3% NaCl

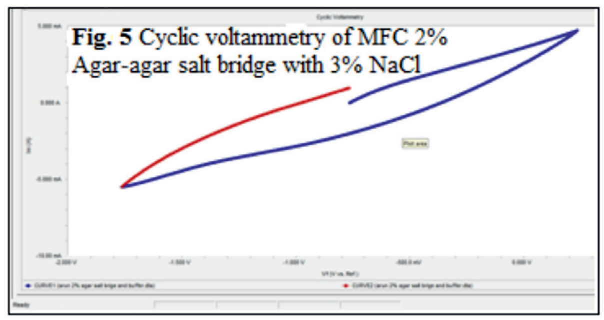

Fig. 5 Cyclic voltammetry of MFC 2% Agar-agar salt bridge with 3% NaCl

Table 2. Voltage and current production in MFC with different % Agar-agar salt bridge

Days	1% Agar-agar		2% Agar-agar		3% Agar-agar	
	mV	mA	mV	mA	mV	mA
1	36	0.025	121	0.163	83	0.124
2	71	0.319	419	1.57	362	1.22
3	145	0.810	555	1.40	361	0.614
4	134	0.205	579	3.21	582	0.620
5	311	1.20	631	1.84	531	1.96
6	696	2.965	223	1.966	567	1.306
7	6 96	2. 96	646	2.63	547	2.19

Table 3. Voltage and current production on MFC with different sizes of graphite electrode

Days	Graphite plate size and Bioelectricity production							
	4x4x0.3cm		5x5x0.3cm		6x6x0.3cm		7x7x0.3cm	
	mV	mA	mV	mA	mV	mA	mV	mA
0	52	0.192	64	0.352	68	0.42	76	0.44
1	124	0.64	136	0.82	140	0.9	132	o.86
2	260	1.2	262	1.26	256	1.2	270	1.2
3	320	1.46	346	1.48	352	1.5	296	1.4
4	430	1.62	440	1.72	460	1.8	380	1.6
5	480	1.8	490	1.86	492	1.96	440	1.72
6	492	1.9	510	1.92	520	2.2	496	2.1
7	502	1.96	540	2.1	560	2.6	540	2.3

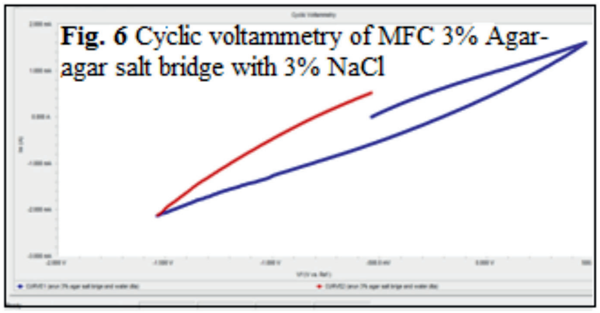

Fig. 6 Cyclic voltammetry of MFC 3% Agar-agar salt bridge with 3% NaCl

which is found to be a major disadvantage in using agar-agar.

When graphite plates of different sizes were used as electrode, the voltage and current produced are given in Table 3, the graphite plate size of 6x6x3cm found to produce 620mV 4.8mA on 7th day when compared to 6x6x0.3cm which produced 560mV and 2.73 mA (Table 4).

DISCUSSION

Voltage produced using different total surface areas of electrodes were compared by Sanguine *et al.*, 2004. Voltage for ferricyanide cathode 22.5cm^2 was 39% higher than that obtained with Platinum coated carbon electrode. When the surface area was reduced from 22.5 unit to 5.8 unit the voltage was reduced from 300V to 200V (Deepika *et al.*, 2015).

Electrode materials play a key role in enhancing the electricity generation in MFC (Bestamin *et al.*, 2012). Bestamin also reported that Ti-TiO$_2$ electrode is a promising electrode in MFC. They reported maximum power and current density with Ti-TiO2 electrode when compared to graphite electrode. In the present study though only graphite electrode was used the power density produced was more than the reported power density by Bestamin *et al.*, 2012. The reason for achieving more current and voltage may be because of the waste used in the present study was rumen fluid collected from slaughter house but Bestamin *et al.*, 2012 used synthetic waste water with inoculums enrichment. Rumen fluid has rich source of bacteria with diverse substrate affinity.

Table 4. Voltage and current production by electrodes of different width

Days	Electrode Size 6x6x0.3cm		Electrode Sixe 6x6x3 cm	
	mV	mA	mV	mA
0	146	0.6	156	1.2
1	355	0.96	342	2.14
2	425	1.61	408	2.84
3	496	1.82	424	2.86
4	459	2.21	443	2.89
5	460	2.37	460	2.91
6	462	2.61	520	3.2
7	560	2.73	620	4.8

Anandprakash., (2015) reported that salt bridge for MFC with KCL produced 2 volts which is higher than salt bridge with NaCl. In the present study the voltage obtained was less with salt bridge with NaCl.

Ramyanair *et al.*, (2013) used agarose concentration ranging from 7 to 12% and found that optimum concentration was 10% with maximum current production of 0.97 mA and 0.95 V after 22 days

Surajbhan Sevda and Sreekrishnan, 2012 studied MFC with varied concentrations of agarose salt bridge from 1-10% and reported that maximum power density was observed with 10% agarose with 5% salt concentration. In the present study, the current production with 1% agarose was more when compared to current produced with 10% Agarose as reported by Ramyanair *et al.,* 2013. The difference in current production may be difference in wastage used in microbial fuel cell. Less current production may be because of their usage of hostel sewage waste water but the higher current production in the present study may be because of rumen fluid which is a rich source of bacteria.

CONCLUSION

In the present study, 1% agarose salt bridge with 3% sodium chloride produced current and voltage which is more than the current and voltage obtained with other percentage of agarose. From the present study it is clearly understood that electrode, salt concentration and agarose used in MFC play a role to achieve more voltage and current. The type of waste used in the anode also plays a major role in determining the maximum voltage and current obtained.

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