ISSN: 0974-5823 Vol. 7 (Special Issue, Jan.-Mar. 2022)

International Journal of Mechanical Engineering

Impact of Low and Moderate pH on the Effectiveness of the Microbial Fuel Cell using Slaughterhouse Wastewater

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ABSTRACT

Aim: The main aim of this study is to compare the power generation of moderate and low pH conditions operated by double chamber microbial fuel cells (DMFC) using slaughterhouse wastewater. **Materials and Methods:** The wastewater samples collected from MFC with Moderate pH conditions (N=33) and Low pH conditions (N=33) operated for 11 days (G Power 80%). Voltage was measured using a multimeter and current, power, power density was calculated from it for both groups. **Results:** The power generation was found to be high in Moderate PH (248mW/m^2) operated MFC compared to Low pH conditions (96mW/m^2). The independent sample t test was done which showed that the MFC operated Moderate pH power generation ($P < 0.001$) found to be significantly higher compared to Low pH conditions. **Conclusion:** The study shows that MFC operated Moderate pH is able to achieve higher power generation compared to Low pH conditions

Keywords: Microbial fuel cell, slaughterhouse wastewater, Moderate pH, Low pH conditions power generation, Novel power source, Green energy.

INTRODUCTION

Over the past century, increase in the population leads to environmental problems such as pollution of water, air and land resources. Moreover, the major challenges for the wastewater technologies are increase in costs and higher power consumption (Saba et al. 2017). Bioelectricity production using microbial fuel cells (MFCs) is one of the regions of green energy productions that make use of renewable resources through sustainable means, which has been gaining significance because of its clean, efficient and renewable nature. (Tremouli, Martinos, and Lyberatos 2017). Microbial fuel cells (MFCs) are novel power sources which convert chemical energy into electrochemical power instantly and have potential usage for an equal time wastewater treatment and energy restoration through electro-active microorganisms. It can be used to simultaneously treat the wastewater such as Industry wastewater, Agricultural wastewater, slaughterhouse wastewater and produce electricity (Cetinkaya et al. 2017; Abbasi et al. 2016; Tharali, Sain, and Jabez Osborne 2016). A Microbial fuel cell (MFC) is controlled by two major types of parameters such as Temperature and PH.(Cui, Lai, and Tang 2019) Among these two

operating parameters pH is considered as a key factor that affects both electrochemical and biochemical processes.

The pH imbalance among the anode and cathode chamber, that's due to the restricted proton transfer throughout the PEM, results in the anode chamber acidification, which results in the inhibition of microbial activity and, thus, a deteriorated performance (Obileke et al. 2021; Yang et al. 2016). However, extremely low pH shows a negative effect on the performance and stability of microorganisms,decreasing bacterial activity, and consequently, the electron and proton generation (Ivars-Barceló et al. 2018). Inorder to protect the microorganisms and to favour the biological treatment processes pH level of the wastewater is to be maintained neutral (Obileke et al. 2021). Moderate pH conditions are the most favourable conditions for the growth of microorganisms. Moderate pH avoids both acidification and alkalinization (Singh et al. 2019; Ali et al. 2019). The bacterial growth performance was improved due to the Moderate pH conditions. Our team has extensive knowledge and research experience that has translate into high quality publications(M. S. Kumar et al. 2006; Ramesh et al. 2016; Viveka et al. 2016; Gupta, Dhanraj, and Sivagami 2010; Swathy, Gheena, and Varsha 2015; A. Kumar et al. 2015; Abitha and Santhanam 2019; Malli Sureshbabu et al. 2019; Gopalakannan, Senthilvelan, and Ranganathan 2012; Siddique and Nivedhitha 2019)Previously our team has a rich experience in working on various research projects across multiple disciplines(Ezhilarasan et al. 2021; Balachandar et al. 2020; Muthukrishnan et al. 2020; Kavarthapu and Gurumoorthy 2021; Sarode et al. 2021; Hannah R et al. 2021; Sekar, Nallaswamy, and Lakshmanan 2020; Appavu et al. 2021; Menon et al. 2020; Gopalakrishnan et al. 2020; Arun Prakash et al. 2020)

The major limitation of Low pH conditions was it inhibits the growth of the microorganisms and decreases the power efficiency. So, in this study the Moderate and Low pH conditions in MFC were compared to identify best pH operating conditions which helps to improve the growth of microorganisms and to increase the power generation.

MATERIALS AND METHODS

The study was conducted at a biochemistry laboratory in Saveetha School of Engineering , Chennai, India. Two different groups were taken for analysis: Group A, Moderate pH (N=33); Group B, Low pH (N=33). Sample size was calculated using previous study results in Clincalc by keeping threshold 0.05, and G power 80%, confidence interval 95% and enrollment ratio as 1 (Saba et al. 2017).

The wastewater was collected from Saidapet slaughterhouse, Chennai and used as substrate for all the experiments. Anaerobic sludge was collected from the municipal wastewater plant, Chennai and used as inoculums for all the experiments. To delay the microbial turn of events, the collected anaerobic sludge, wastewater were stored at 4°C in the refrigerator. The wastewater was taken out from the refrigerator and stirred with a mechanical stirrer for 20 minutes to make the substrates uniformly distributed in the wastewater before placing into MFC whereas anaerobic sludge was taken out and used as such for inoculum before use.

The collected wastewater was taken in a DMFC vessel. In anode compartment of MFC_1 and MFC_2, 100m1 of slaughterhouse wastewater, 5ml of anaerobic sludge was added in the anode chamber of DMFC. In the cathode compartment, potassium permanganate was used as a catholyte.In the cathode compartment, potassium permanganate was used as catholyte. In MFC_1, Moderate pH conditions was maintained keeping all other parameters the same whereas In MFC_2, Low pH conditions was maintained keeping all other parameters same. Both the anode and cathode compartments in MFC_1 and MFC_2 were separated using a NAFION 117 membrane.

Connected the wires from the anode and cathode to the resistor box. Adjusted the resistance and measured the voltage using the multimeter. Calculated the current and power (green energy) from the generated voltage as reported by (Baranitharan et al. 2013).

Statistical Analysis

The statistical comparison of power generation from Low pH conditions and Moderate pH conditions operated MFC was done through SPSS version 21. There are no dependent variables and the independent variable is power density. The statistical analysis was done using an Independent sample T- test.

RESULTS

From Fig. 1, it was observed that the maximum Power density of MFC operated with Moderate PH conditions (248mW/m^2) is higher compared to Low pH conditions (96 mW/m^2). From Fig. 2, it was observed that MFC operated with Moderate pH conditions attained a higher COD removal efficiency of about 88% compared to Low pH conditions (71%). The COD removal efficiency of DMFC operated with Moderate pH conditions was found to increase slowly in the initial time and then gradually reached 88% on the 11thday. Similarly, DMFC operated with Low pH conditions was also gradually increased with time and reached 71% on the 11thday.

The statistical analysis between Moderate pH conditions and Low pH conditions were performed, in that, Moderate pH conditions obtained 73.15577 standard deviation with standard error of 12.73479 while Low pH conditions obtained 30.29692 standard deviation with standard error of 5.27402 as shown in Table 1. Since the deviation is more for Moderate pH conditions compared to Low pH conditions, the former has better potential to enhance its conditions if optimized suitably. Independent t-test was used to compare the power density of Moderate pH conditions and Low pH conditions as shown in Table 2 and a statistically significant difference was noticed ($P< 0.001$). The significance value smaller than 0.001 showed that our hypothesis holds good. The mean power density of Moderate pH and Low pH conditions was compared in Fig 3, which clearly reveals that Moderate pH conditions generate higher power compared to Low PH conditions.

DISCUSSION

In this study, it was found that MFC operated with Moderate pH conditions is able to achieve higher power generation compared to MFC operated with Low pH conditions. It was also observed that there is a significant ($p<0.05$) difference between MFC operated with Moderate pH and Low pH conditions done by using SPSS version 21.

MFC operated with Moderate pH conditions attained a higher power density of about 248mW/m^2 than the Low pH conditions (96 mW/m^2) which indicates that the Moderate pH conditions are more stable and able to generate higher power density. Similar kinds of results obtained by (Jannelli et al. 2017) in the case of MFC operated with slaughterhouse wastewater for power generation. Moreover, MFC operated with Moderate pH conditions attained a higher COD removal efficiency of about 88% compared to Low pH conditions (71%). The highest COD removal efficiency obtained in this type of DMFC configuration is consistent with the other findings reported elsewhere (Al-saned et al. 2021).

pH of the electrolyte is controlled near neutral to maintain optimal conditions for bacterial growth and power generation (Linke, Lijuan, and Li 2017). Low pH allows oxygen reduction as well as achieves higher power from the MFCs (Obileke et al. 2021). The benefits of operating MFC at low pH are the accessibility of protons at the cathode and the proton transfer across the cation-interchange layer isolating the anode and cathode (Li et al. 2021). MFCs worked at low anodic pH may have higher proton move rates and higher action of intracellular electron transporters (Hou et al. 2017). The Moderate pH conditions enhances the growth of electrogenic microorganisms (Munoz-Cupa et al. 2021). The benefits of maintaining Moderate pH conditions was increase in the power generation and substrate degradation .

However, very low pH would cause permanent harm to power-generating microbes.So,the pH conditions need to be maintained at optimum conditions in order to increase the power efficiency and to improve the performance of DMFCs. MFCs need to handle the wastewater treatment and power efficiency with a broader range of pH in future.

CONCLUSION

Microbial fuel cells operated with Moderate pH conditions are able to achieve higher power generation compared to Low pH conditions.

DECLARATIONS

Conflict of Interest

No conflict of interest in this manuscript

Authors Contribution

Author PY was involved in data collection, data analysis and manuscript writing. Author BT was involved in conceptualization, data validation and critical review of manuscript.

Acknowledgements

The authors would like to express their gratitude towards Saveetha School of Engineering. Saveetha Institute of Medical and Technical sciences (Formerly known as Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Funding: We thank the following organizations for providing financial support that enabled us to complete the study

1. Sri Ragavendra Biofertilizers, Tiruvannamalai
2. Saveetha University
3. Saveetha Institute of Medical and Technical sciences
4. Saveetha School of Engineering

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TABLES AND FIGURES

Table 1: Comparison of mean power density of DMFC operated Moderate and Low pH conditions.

	Group	N	Mean	Std.Deviation	Std.Error Mean
PD	MODERATE pH	33	148.2727	73.15577	12.73479
	LOW pH	33	53.8182	30.29692	5.27402

Table 2: Independent sample T test between DMFC operated with Moderate pH and Low pH has a p value of <0.001 (P<0.05)

		Levene's Test of equality of variance		T- Test of equality of means						
		F	Sig	t	df	sig(2-tailed)	Mean difference	Std. Error difference	95% Confidence interval of the Difference	
									Lower	Upper
PD	Equal variances assumed	23.235	<.001	6.853	64	<.001	94.45455	13.78369	66.91847	121.99062
	Equal variances not assumed		<.001	6.853	42.663	<.001	94.45455	13.78369	66.65075	122.25835

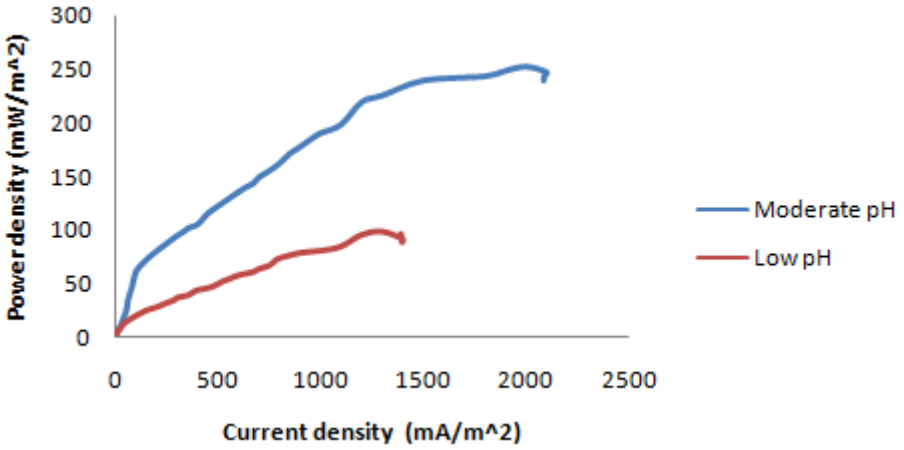

Fig. 1. Power density curves of DMFC operated with Moderate pH and Low pH where blue represents moderate pH and red represents low pH.

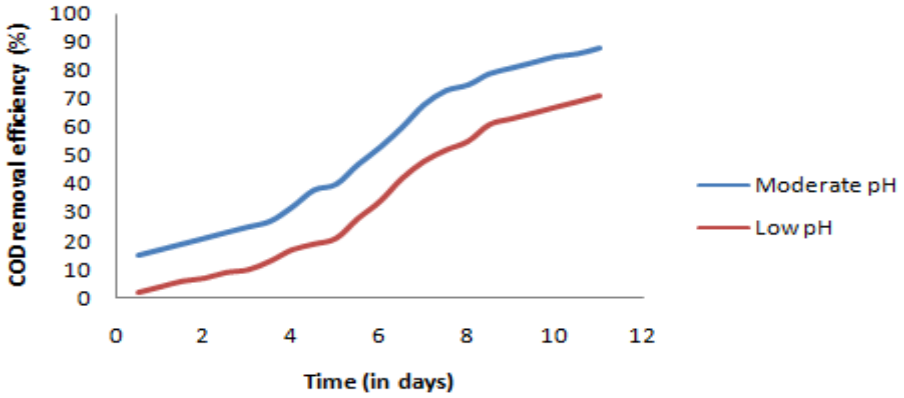

Fig. 2. COD vs Time graph of DMFC operated with moderate pH and low pH where blue represents moderate pH and red represents low pH.

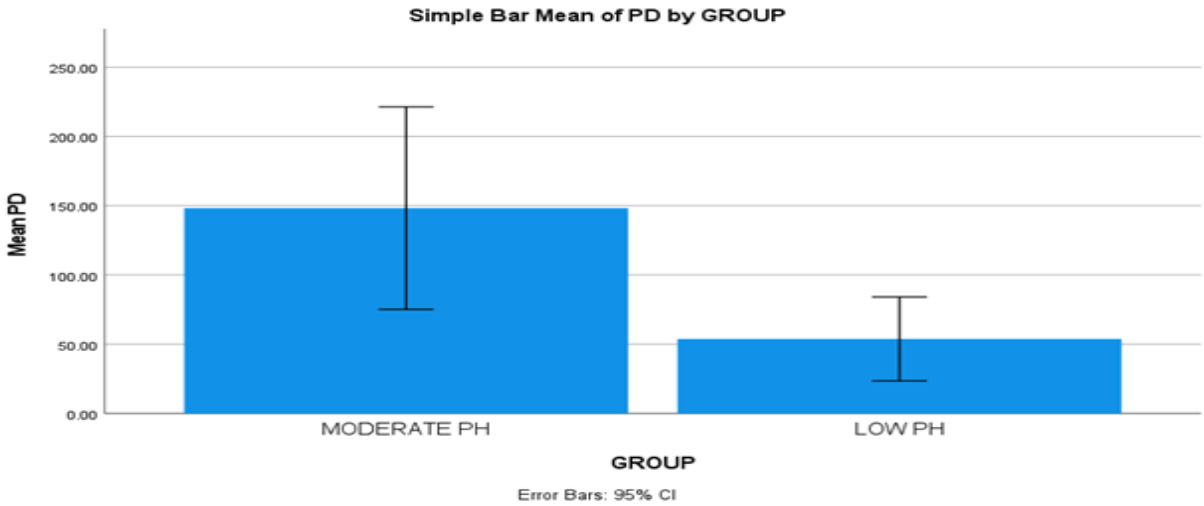

Fig. 3. Comparison of Moderate pH conditions and Low pH conditions in terms of mean power generation. The mean power generation of Moderate pH conditions is significantly higher than Low pH conditions whereas the standard deviation of Low pH conditions is lower than Moderate PH conditions. X Axis: Moderate pH conditions vs Low pH conditions Y Axis: Mean power generation ± 1 SD