Eco. Env. & Cons. 28 (2) : 2022; pp. (615-620)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i02.006

Feasibility and synergistic effect of glucoamylase hydrolysis and microbial fuel cell on electricity generation from potato-waste

Md. Nurul Islam Siddique[1]*, B.K. Zaied[2] and Mohd. Zamri Bin Ibrahim[1]

[1]***Faculty of Ocean Engineering Technology & Informatics, Universiti Malaysia Terengganu (UMT), 21030 Kuala Nerus, Terengganu, Malaysia***
[2]***Faculty of Civil Engineering Technology, Universiti Malaysia Pahang (UMP), 26300 Gambang, Kuantan, Pahang, Malaysia***

(Received 25 March, 2021; Accepted 29 September, 2021)

ABSTRACT

The present study established a new dual-phase biological system for electricity production from potato waste (PW). During the initial phase, commercially available glucoamylase was used to make hydrolysis of PW to generate PW hydrolysate. Results revealed that a hundred g PW could generate 30 g hydrolysis solid and 750 ml PW hydrolysate. During the second phase, the soluble PW hydrolysate was used to feed for electricity production from microbial fuel cell (MFC). The highest voltage of 1.1 V was achieved. The power density attained the highest amount of 93 mW/m^3 at the external resistance was 1091 Ω. Coulombic efficiency of 20% was obtained to evaluate MFC performance. This might be possibly used to convert high-starch compounds into biofuel generation that might cut the cost of commercial biofuel generation.

Key words : *Glucoamylase, Electricity production, Enzymatic hydrolysis, Microbial fuel cell, Potato waste.*

Introduction

Lately, environmental issues, like the contamination of municipal wastes, have attained huge focus by the growth of population (Islam Siddique *et al*., 2020). It has been studied that four times of municipal wastes produced in the last 3 decades (Jing *et al.*, 2020). In particular, potato waste (PW) management attained great attention from scientists (Indren *et al*., 2020). Conventional treatments of municipal wastes such as ignition and landfilling have not become popular because of huge energy demand and pollutant emission (Md. Nurul Islam Siddique, 2012). Therefore, it has become mandatory to find out an efficient option for PW management. In Malaysia, PW is taken as an abundant resource for biofuel generation due to the huge bio-degradable materials (Nasrullah and Zularisam, 2014). Several works have been done to utilize PW for biofuel generation. For instance, anaerobic degradation of PW was used to generate methane that can be used as electro-thermal energy (Nasrullah and Zularisam, 2014).

Energy need in Malaysia has driven focus to the necessity of research for alternate resources of power to counter part the remnant gasoline (Siddique, 2016). This need was significantly enhanced for the increasing rate of mechanization, populace, and urbanization (Md Nurul Islam Siddique, 2019). Accessibility of continuous power supply for farming and manufacturing is a key need for infrastructural growth (Md Siddique, 2018). Intake of power is anindicator of the rate of improvement of any country as it subsidizes enormously to the financial development (Md. Nurul Islam Siddique and Sakinah, 2014a). Recently, power intake in Malaysia has been increased. Nevertheless, it has been studied that approximately 39.99% of energy loss occurs in the process (Md. Nurul Islam Siddique and Sakinah, 2014b). Therefore, it might be a handy process toutilize PW for electricity generation. Microbial fuel cell (MFC) is an effective option that can transform different organics into electricity (Md. Nurul Islam Siddique, M.S., A.W. Zularisam, 2014). Nevertheless, the direct PW application for electricity production by the MFC is difficult due to the low nutrient exchange capacity compared to utilizing soluble organics (Md. Nurul Islam Siddique, 2012). Moreover, the nutrients carried by the PW must be broken into tiny fragments before being utilized by the exoelectrogens. Hence, hydrolysis is considered the controlling phase of the electricity production process (Md. Nurul Islam Siddique, 2012). This is the reason why limited data regarding electricity production from PW might be reported. There is a huge research gap in evaluating MFC performance by coulombic efficiency. In the present study, a new double-phase system of electricity production from PW is highlighted. During the firstphase, commercially available glucoamylase was applied to perform hydrolysis of PW to generate PW hydrolysate. During the subsequent phase, the soluble PW hydrolysate was applied to feed for electric power production from microbial fuel cell (MFC). The present study was anticipated to establish the viability of electric power production from PW with more nutrient conversion productivity.

Materials and Methods

PW was taken from a restaurant located in Kuala Nerus, Malaysia, and transferred to the laboratory for further processing. The PW sample was broken into tiny pieces by a food blender. Subsequently, the PW sample was sieved to maintain a size of less than 1 cm. The larger PW particles were transferred to the food blender. A 100 g of pretreated PW was kept in the beaker for subsequent processing. The properties of PW were determined according to Standard procedure APHA 2015 (MNI Siddique, 2018) and listed in Table 1. Commercially available glucoamylase was bought from CJ Bio Malaysia Sdn. Bhd. This was preserved in the cold room at 4 °C before enzymatic hydrolysis. Anaerobically digested sludge, which was taken from a waste processing plant, was utilized as seed sludge for the present study. The sludge was sieved with a diameter of 0.5 mm to free the unwanted wastes. Enzymatic hydrolysis of PW was done using a reactor having a volume of 1 L. Before performing enzymatic hydrolysis, the reactor was cleaned and placed at 90 °C using a heater. Nitrogen gas was sprayed in the reactor for 5 minutes to ensure an anaerobic environment. A 100 g of PW was taken in a reactor to attain a loading rate of 10% (w/v). The deionized water was fed into the reactor to obtain a total volume of 1 L. A 1 g of glucoamylase was measured and then incubated into the reactor. The mix was then blended with a speed of 200 rpm at 47 °C. The pH of the mix was not essential to be maintained. A 5 ml waste sample was collected in every 15 mins. The obtained samples were centrifuged at the states of 4 °C and 8000 rpm and filtered by (0.2 μm) filter for getting the supernatant. It was utilized for analyzing the glucose generation in the enzymatic hydrolysis of PW (Han *et al.,* 2019). The glucose level stopped enhancing within 5 hours that ensured the enzymatic hydrolysis of PW. The final substrate was centrifuged for 30 min maintaining an agitation speed of 10,000 rpm at 4 °C. Subsequently, it was filtered by Whatman No. 1 filter paper for obtaining the PW hydrolysate. A tiny level of oil wasdetached in this phase. The resultant PW hydrolysate was kept at –20 °C until used as feed-substrate for electricity production in the microbial fuel cell.

Table 1. Properties of PW

Parameters	Quantity
Protein (g/kg)	91 ± 2
Starch (g/kg)	487 ± 13
Total organic nitrogen (g/kg)	16 ± 2
Phosphorous (mg/kg)	802 ± 101
Moisture (g/ kg)	244 ± 9
Ash (g/kg)	24 ± 3

A double-chamber microbial fuel cell made of glasswas utilized in the present work for electric power production (Figure 1). The capacity of both chambers was approximately 1 L having a length of 13 cm and a diameter of 11 cm. Carbon paper having a surface area of 25 cm^2 was utilized as electrodes. Copper wires were used to make a connection between electrodes and the interaction area was wrapped by epoxy adhesive. Both chambers were detached using a proton exchange membrane (42180Nafion N-117 membrane, 0.180 mm thick) that was supplied by Thermo Fisher Scientific, Malaysia. Interestingly, the anode was airtight by a rubber stopper, whereas the cathode was kept open. A 1000 Ω resistance was maintained externally. The resultant PW hydrolysate was added to demineralized water to make dilution (desired acetate level 1 g/l). Subsequently, it was used as a substrate for evaluating the viability of electric power production.

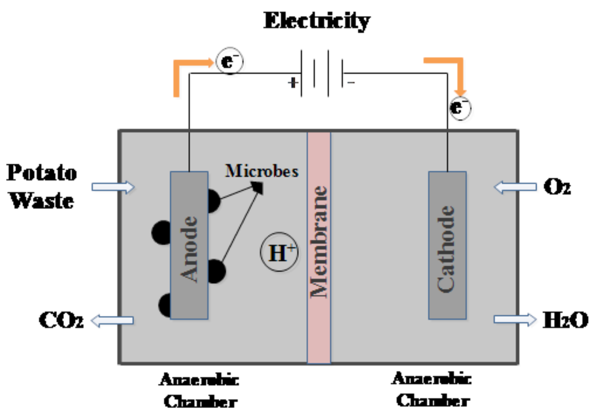

Fig. 1. Schematic diagram of microbial fuel cell configuration

In the present study, the microbial fuel cell was run in the fed-batch approach. The produced voltage (V) against an external resistance (1000 Ω) was notedevery 5 minutes with the help of a multimeter. Produced electricity can be determined by using Ohm's law (I = V/R). The power density (P) can be determined by using P = (IV)/A. The resistance was varied from 10 to 9999 Ω to achieve the polarization and the power density curvewas taken as a function of current density. In the beginning, acetate (1 g/l) was used as feedstock for 2 weeks to enhance exoelectrogens and to establish biofilm over the anode. As the voltage reduced to 51 mV, the acetate was substituted by the diluted PW hydrolysate. In the present work, Ag+ (silver chloride) was utilized as a cathodic electron acceptor. As Ag+ changed to Ag, the hypothetical redox potential was 0.15 V with acetate, whereas the anode and the electromotive forces were –0.43 V and 0.57 V, respectively.

Analysis

Before the anaerobic process, wastewater should be sufficiently characterized (Gupta *et al*., 2021; Mimi *et al.,* 2012). Therefore, substrates were analyzed to identify their characteristics. The characteristics of the substrates were determined at the wastewater processing Lab of University Malaysia Terengganu following the standards of APHA, 2015(MNI Siddique, 2013; Parkhey and Sahu, 2020).

MFC Performance Assessment

One of the key features to assess the performance of the microbial fuel cell is coulombic as well as efficiency (MNI SIddique, 2014; Rabaey *et al*., 2009). The energy efficiency of themicrobial fuel cell may be calculated by the energy recovered from the organic matter to the total energy content of the organic materials. The coulombic efficiency ranges from 2% to more than 10% based on the nature of substrates (Logan, 2008). Coulombic efficiency, CE may be assessed using Equation below:

$$CE = M \int_0^t Idt / Fb\Delta COD \quad .. (1)$$

where v is the volume of the anode chamber of MFC, M is 32 (MW of O2), Faraday's constant (F) is 96485 C/mol, and b is 4; ΩCOD is the subtraction of the initial to final anolyte concentration in terms of COD (g/l).

Results and Discussion

The present workdescribed the viability of electric power production from PW in a new double-phase system using a combination of enzymatic hydrolysis and microbial fuel cell. The commercially available glucoamylase was used to hydrolyze the PW. Glucose might be obtained from PW through enzymatic hydrolysis and enhanced by time. The maximum glucose generation of 23 g/l might be attained within 6 hours. A 100 g PW might be transformed to 30 g hydrolysis solid and 750 ml PW hydrolysate. The rest of the PW might be further hydrolyzed by the subsequent phase together with the raw PW and no solid residue might be freed via the projected technique. The substrates might be processed by 6 hours that might efficiently cut the substrate processing expenses for commercial application (NI Siddique, 2012; Siddique *et al*., 2017; Suresh *et al*., 2020).

Afterward, the resultant PW hydrolysate was subjected to dilution using deionized water to the desired acetate level (1 g/l) and applied as feed waste for electric power production in the microbial fuel cell. Figure 2 exhibited the glucose usage obtained from PW hydrolysate and voltage generation from MFC process. The glucose of PW hydrolysate was utilized extensively and electric power was generated simultaneously. The highest voltage of 1.1 V was attained from the present work. Figure 3 showed the relationship between current, voltage, and power density produced by PW hydrolysate. To assess the nature of microbial fuel cell, a polarization curve can be obtained by changing the resistance from 10 to 9999 Ω). The maximum power density of 33mW/m^3 was attained with a resistance of 1080 Ω. Results showed that the PW hydrolysate might be utilized as feed-waste in a microbial fuel cell for electric power generation. Several works on electric power production using microbial fuel cell were selected organic soluble wastes (NI Siddique, 2012;

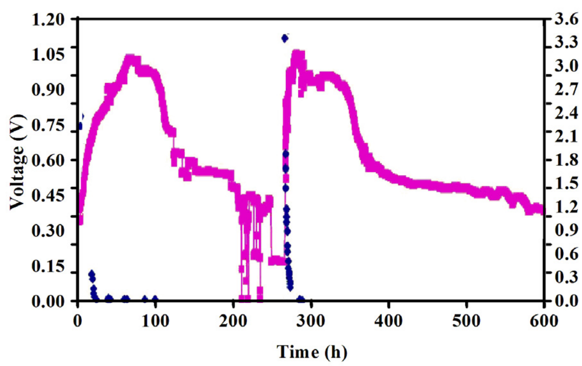

Fig. 2. Glucose usage and voltage generation from PW hydrolysate in the subsequent phase of microbial fuel cell.

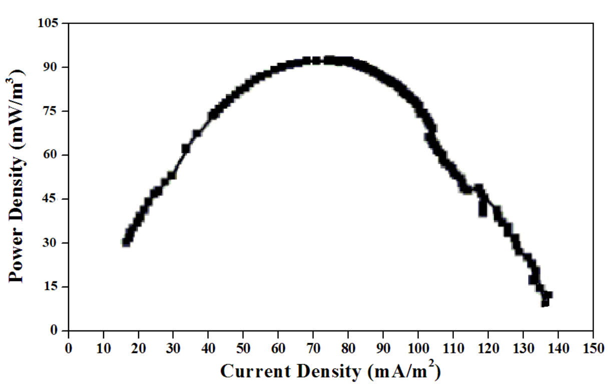

Fig. 3. The power density (b) as a function of current density from PW hydrolysate in the second phase of microbial fuel cell.

Toczylowska-Mamiñska *et al.,* 2020). Electricity production using solid wastes is harder than that of soluble wastes because of its prolonged hydrolysis period, less nutrient conversion efficiency (Casula *et al.*, 2020; Siddique *et al.*, 2015). Therefore, hydrolysis was the key phase for electricity production from organic materials (Gustave *et al.*, 2020; Siddique *et al.*, 2016). In the present study, a new double-phase framework of electricity production from PW is created. During the first phase, a maximum of 23 g/l glucose might be produced bythe enzymatic hydrolysis (EH) process. The exchange rate of nutrients might be enhanced during this phase. During the subsequent phase, the tiny molecules might be converted by EH of PW in 6 hours. The PW hydrolysis activity was effectively augmented and the treatment expenses might be reduced. This result indicated that the double-phase bio-technique may not only increase the liquification rate of PW but also accelerate nutrient conversion rate and electric power production. This might be significantly applied to convert higher starch compounds into biofuels that may decrease the total costing efficiency. It is noticeable that the maximum voltage of 1.1 V and a power density of 93mW/m^3 was achieved from the present study, respectively.

MFC feasibility Assessment

The feasibility of the suggested double-phase bio-technique of EH and MFC was carried out using equation no 1. After putting all the values in equation 1 we obtained the Coulombic efficiency, CE value for the present study 20%. Therefore, the outcomes revealed that the suggested double-phase bio-technique of EH and MFC might be possibly utilized to produce electric power from PW for commercial use.

Conclusion

A new double-phase bio-technique was proposed in the present study for electric power production from PW. Results revealed that the PWhydrolysate was a potential substrate for electric power production using a microbial fuel cell.The maximum glucose production of 20 g/l might be attained within 6 hours and the maximum COD removal was 85%. Themaximum voltage of 1.1 V and a power density of 93mW/m^3 were achieved from the present study, respectively. It was derived from this work that the widely available high-starch containing raw materials could have the potential for direct electricity generation with the proposed bioprocesses. This might be significantly applied to convert higher starch compounds into electric power using the proposed bio-technique.

Acknowledgments

The authors are thankful to the Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu (UMT) for allowing lab facilities. This work was made possible by FRGS-59625.

References

Casula, E., Kim, B., Chesson, H., Lorenzo, M.D. and Mascia, M. 2020. Modelling the influence of soil properties on performance and bioremediation ability of a pile of soil microbial fuel cells. *Electrochimica Acta.* 137568.

Gupta, S., Srivastava, P., Patil, S.A. and Yadav, A.K. 2021. A comprehensive review on emerging constructed wetland coupled microbial fuel cell technology: Potential applications and challenges. *Bioresource Technology.* 320 : 124376.

Gustave, W., Yuan, Z., Liu, F. and Chen, Z. 2020. Mechanisms and challenges of microbial fuel cells for soil heavy metal (loid)s remediation. *Science of The Total Environment*. 143865.

Indren, M., Birzer, C.H., Kidd, S.P., Hall, T. and Medwell, P.R. 2020. Effects of biochar parent material and microbial pre-loading in biochar-amended high-solids anaerobic digestion. *Bioresource Technology.* 298: 122457.

Islam Siddique, M.N., Khalid, Z.B. and Ibrahim, M.Z.B. 2020. Effect of additional nutrients on bio-methane production from anaerobic digestion of farming waste: Feasibility & Fertilizer recovery. *Journal of Environmental Chemical Engineering.* 8(1): 103569.

Jing, H., Wang, R., Jiang, Q., Zhang, Y. and Peng, X. 2020. Anaerobic methane oxidation coupled to denitrification is an important potential methane sink in deep-sea cold seeps. *Science of The Total Environment.* 748 : 142459.

Logan, B.E. 2008. Microbial fuel cells.

M Nasrullah, M.S. and Zularisam, A.W. 2014. Effect of high current density in electrocoagulation process for sewage treatment. *Asian Journal of Chemistry.* 26(14) : 4281.

M.N.I.Siddique, M.F.I.A.A.W.Z. 2016. Enriched Renewable Methane from the Anaerobic Digestion of Petrochemical Wastewater: A Bio-Remediation Structure. *International Journal of Engineering Technology and Sciences.* 7 : 1-8.

Md Nurul Islam Siddique, Z.B.K. and Muhammad Nomani Kabir, 2019. Progressive Two-Stage Efficient Co-Digestion of Food Waste and Petrochemical Wastewater for Higher Methane and Hydrogen Production. *Asian Journal of Chemistry.* 31(11) : 2575-2578.

Md Siddique, N.I. and Zularisam Bin Abdul Wahid, 2018. Enhanced Methane Yield by Codigestion of Sewage Sludge with Microalgae and Catering Waste Leachate. *Water Environment Research.* 90(9) : 835-839.

Md. Nurul Islam Siddique, A. and Sakinah, M. 2014a. Biomethane generation potential of petrochemical wastewater by anaerobic digestion using CSTR. *4th Johor Biotechnology Conference and Exhibition, malaysia.*

Md. Nurul Islam Siddique, A. and Sakinah, M. 2014b. Intensified CSTR for bio-methane generation from petrochemical wastewater. *International Conference on Chemical, Environmental and Biological Sciences. IICBE-2014, Malaysia*.

Md. Nurul Islam Siddique, M.S. and Zularisam, A.W. 2014. Sustainable bio-methane generation from petrochemical wastewater using CSTR. *International Journal of Engineering Technology and Science*. 1(1): 1-4.

Md. Nurul Islam Siddique, Z. 2012. Temperature and organic loading rate influence on biomethanation of Petrochemical wastewater using CSTR. *International Journal of Civil Engineering and Geo-Environment.* 2: 59-64.

Md. Nurul Islam Siddique, Z.A. 2012. Continuous stirred tank reactor application for renewable methane from anaerobic biodegradation of Petrochemical wastewater. *Engineering E-Transaction.* 7 : 23-27.

Mimi Sakinah Lakhveer Singh, M.N.I.S., Zularisam A.W. and Mohd. Hasbi Ab. Rahim, 2012. Optimization of sustained hydrogen production from palm oil mill effluent using immobilized mixed culture. I*nternational Journal of Civil Engineering and Geo-Environment*. 1(1) : 5-9.

MNI Siddique, A.Z. 2013. Role of ammonium bicarbonates in methenogenesis while co-digesting petrochemical wastewater with activated manure sludge. *Ener. Edu. Sci. Technol.* 31(1): 80-90.

MNI Siddique, A.Z. 2018. Application of natural seaweed modified mortar for sustainable concrete production. *IOP Conference Series: Materials Science and Engineering.* 342 : 012008.

MNI SIddique, M.M. and Zularisam, A.W. 2014. Role of Bio-filtration in Petrochemical Wastewater treatment using CSTR. *Int. J. Eng. Tech. Sci*. 2 : 9-12.

NI Siddique, A.Z. 2012. Renewable Methane from Ammonium Bicarbonate Supplemented Petrochemical Wastewater Treatment During Anaerobic Co-Digestion in CSTR. *Procedia Engineering.* 50 : 134-141.

NI Siddique, Z.A.W. 2012. Application of chemical and biological coupled treatment technology in POME and petroleum waste water as biodegradation alternative. *Journal of Environmental Science and Technology.* 5(3) : 155-167.

Parkhey, P. and Sahu, R. 2020. Microfluidic microbial fuel cells: Recent advancements and future prospects. *International Journal of Hydrogen Energy.*

Rabaey, K., Angenent, L., Schröder, U. and Keller, J. 2009. *Bioelectrochemical Systems: From Extracellular Electron Transfer to Biotechnological Application*. IWA Publishing.

Siddique, M.N.I., Abdul Munaim, M.S. and Zularisam, A.W. 2015. Feasibility analysis of anaerobic co-digestion of activated manure and petrochemical wastewater in Kuantan (Malaysia). *Journal of Cleaner Production.* 106 : 380-388.

Siddique, M.N.I., Munaim, M.S.A. and Ab. Wahid, Z., 2016. Role of hydraulic retention time in enhancing bioenergy generation from petrochemical wastewater. *Journal of Cleaner Production.* 133: 504-510.

Siddique, M.N.I., Munaim, M.S.A. and Wahid, Z.B.A. 2017. The combined effect of ultrasonic and microwave pre-treatment on bio-methane generation from co-digestion of petrochemical wastewater. *Journal of Cleaner Production.* 145 : 303-309.

Suresh, T., Sivarajasekar, N., Balasubramani, K., Ahamad, T., Alam, M. and Naushad, M. 2020. Process intensification and comparison of bioethanol production from food industry waste (potatoes) by ultrasonic assisted acid hydrolysis and enzymatic hydrolysis: Statistical modelling and optimization. *Biomass and Bioenergy.* 142 : 105752.

Toczy³owska-Mamiñska, R., Pielech-Przybylska, K., Sekrecka-Belniak, A. and Dziekoñska-Kubczak, U. 2020. Stimulation of electricity production in microbial fuel cells via regulation of syntrophic consortium development. *Applied Energy.* 271 : 115184.