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Application of Glucoamylase Hydrolysis with Anaerobically Driven Microbial Fuel Cells: Effect on Energy Generation from Potato Wastes

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A unique dual-phase biological system for producing power from the potato wastes was developed. In the beginning, commercially available glucoamylase was used to hydrolyze potato wastes resulting the production of potato waste hydrolyzate. A 100 g of potato waste produced 30 g of hydrolysis solid and 750 mL of potato waste hydrolyzate. Within 6 h, the maximum glucose generation was 20 g/L while the maximum COD elimination was 85%. During the second phase, the soluble potato waste hydrolyzate was utilized to feed microbial fuel cells (MFC), which produced electricity. The maximum voltage measured was 1.1 V. When the external resistance was 1091 Ω, the power density reached its greatest point of 93 mW/m^3. To evaluate MFC performance, a Coulombic efficiency of 20% was obtained, thus exploring a new field by converting the high-starch molecules into biofuels, thereby lowering the cost of commercial biofuel production.

Keywords: Glucoamylase, Electricity production, Enzymatic hydrolysis, Microbial fuel cell, Potato wastes.

INTRODUCTION

Environmental issues, such as the contamination of urban trash, have recently received attention as a result of population expansion [1]. In last three decades, four times of municipal wastes has been produced [2]. Scientists have paid particular emphasis to the management of potato wastes [3]. Because of the high energy consumption and pollutant emis-sions, traditional municipal garbage treatments such as igniting and landfilling have fallen out of favour [4]. As a result, finding an effective potato wastes management solution has become essential. Due to a large number of biodegradable materials, potato wastes is considered an abundant resource for biofuel generation in Malaysia [5]. Potato wastes have been used to generate biodiesel, *e.g.* the anaerobic breakdown of potato wastes produced methane, which can be used as electro-thermal energy [6].

Energy needs have prompted the researchers to look into alternative power sources to replace the gasoline [7]. Because of the increasing pace of automation, population and urbaniza-tion, this need has grown dramatically [8]. Continuous electri-city supply for farming and manufacturing is a critical require-ment for infrastructure development [9]. Power consumption is a good indication of a country's progress because it contri-butes significantly to financial development [10]. Malaysia has recently raised its power intake (Fig. 1). Nonetheless, around 39.99% of energy is lost in the process [11]. As a result, using potato wastes to generate power could be a useful procedure.

Microbial fuel cells (MFCs) are a viable solution for conv-erting various organics into electricity [12]. However, due to the limited nutritional exchange capacity of potato wastes compared to soluble organics, direct potato wastes application for electricity production by the MFC is challenging [13]. Furthermore, before the exoelectrogens can use the nutrients carried by the potato wastes, they must be broken down into minute bits. As a result, hydrolysis is regarded as the controlling stage of the electricity generation process [14]. As a result, only limited information about potato wastes electricity output may be supplied. When it comes to measure MFC performance

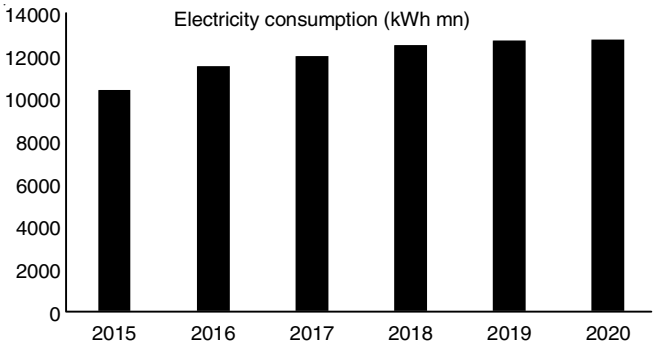

Fig. 1. Electricity consumption trend in Malaysia (2005-2020)

using coulombic efficiency, there is a significant research gap. A unique double-phase system for producing power from potato wastes is emphasized in this study. The first phase involved using commercially available glucoamylase to hydrolyze potato wastes and produce potato wastes hydrolyzate. The soluble potato wastes hydrolyzate was then used as a feed for microbial fuel cell electric power generation in the following step (MFC). The goal of this study was to determine the feasibility of producing electric power from the potato wastes with higher nutrient conversion productivity.

EXPERIMENTAL

Potato wastes was collected from a restaurant in Kuala Nerus, Malaysia and transported to the lab for further analysis. A food blender was used to break down the potato wastes sample into tiny pieces. The potato wastes was then sieved to reduce its size to less than 1 cm. In beaker, 100 g of pretreated potato wastes was saved for further processing. The characteristics parameters of the potato wastes were determined using the standard method APHA 2015 [15] and are presented in Table-1.

TABLE-1
PROPERTIES OF POTATO WASTE

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

Procedure: Before enzymatic hydrolysis, glucoamylase (procured from CJ Bio Malaysia Sdn. Bhd.) was kept in a cold chamber at 4 ºC. For this investigation, anaerobically digested sludge from a waste processing factory was used as seed sludge. To remove the undesired wastes, the sludge was sieved with a diameter of 0.5 mm. The enzyme hydrolysis of potato wastes was carried out in a 1 L reactor. The reactor was cleaned and heated to 90 ºC before commencing enzymatic hydrolysis. For anaerobic condition, nitrogen gas was injected into the reactor for 5 min. To achieve a loading rate of 10% (w/v), 100 g of potato wastes was placed in a reactor. A total volume of 1 L was obtained by feeding deionized water into the reactor. Glucoamylase (1.0 g) was measured and then added to the reactor for incubation. The mixture was then mixed at 47 ºC at 200 rpm [16]. After the interval of every 15 min, 5 mL waste sample was taken out. For supernatant, the acquired samples were centrifuged at 4 ºC at 8000 rpm and filtered (0.2 µm filter). It was used to investigate the production of glucose during the enzymatic hydrolysis of potato wastes [17]. Within 5 h, the glucose level had stopped rising, indicating that potato wastes had been hydrolyzed by enzymes. At 4 ºC, the finished substrate was centrifuged for 30 min at 10,000 rpm with constant agitation. The potato wastes hydrolyzate was then obtained by filtering it through Whatman No. 1 filter paper. During this phase, a small amount of oil was released. The resulting potato wastes hydrolyzate was stored at 20 ºC until it was employed as a feed-substrate in the microbial fuel cell to generate energy.

In this study, a glass-based double-chamber microbial fuel cell was used to generate electricity (Fig. 2). Both chambers were approximately 1 L in size, with a length of 13 cm and a diameter of 11 cm. Electrodes were made from carbon paper with a surface area of 25 cm^2. Copper wires were used to connect the electrodes and epoxy adhesive was employed to surround the interaction region. A proton exchange membrane (42180 Nafion N-117 membrane, 0.180 mm thick) supplied by Thermo-Fisher Scientific, USA, was used to separate the two chambers. The anode was airtight thanks to a rubber stopper, while the cathode was left uncovered. Externally, a 1000 resistance was maintained. To make a dilution, the potato wastes hydrolyzate was mixed with demineralized water (desired acetate level 1 g/L). It was then used as a testbed for determining the viability of electric power generation.

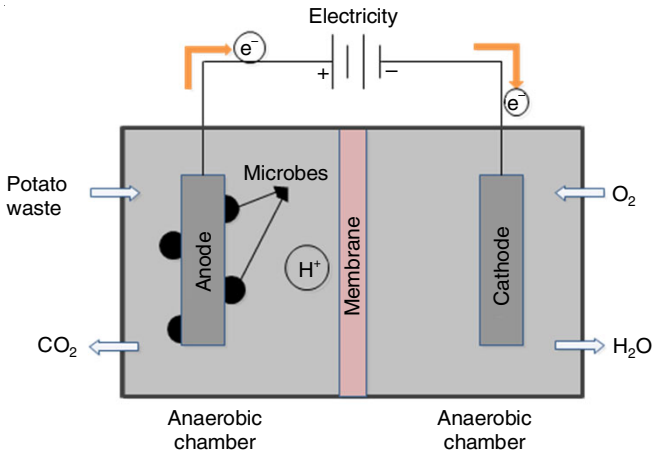

Fig. 2. Schematic diagram of microbial fuel cell configuration

Electricity generation: The fed-batch method was used to run the microbial fuel cell in this investigation. A multimeter was used to record the produced voltage (V) against an external resistance (1000) every 5 min. The Ohm's law (I = V/R) can be used to calculate the amount of electricity produced, whereas P = (IV)/A can be used to calculate the power density (P). To accomplish polarization, the resistance was changed from 10 to 9999 and the power density curve was shown as a function of current density. For the first two weeks, acetate (1 g/L) was employed as a feedstock to boost exoelectrogens and build a biofilm over the anode. The acetate was replaced by diluted potato wastes hydrolyzate when the voltage dropped

to 51 mV. The Ag^+ (AgCl) was used as a cathodic electron acceptor in this study. The hypothetical redox potential with acetate was 0.15 V as Ag^+ converted to Ag, but the anode and electromotive forces were 0.43 V and 0.57 V, respectively.

Analysis: Water should be sufficiently used before the anaerobic procedure [18]. As a result, substrates were investigated to determine their features. The properties of the substrates were determined at the University Malaysia Terengganu's wastewater processing lab using standard APHA 2015 [15] method.

MFC performance assessment: Coulombic, as well as efficiency, are two important characteristics to consider when evaluating the performance of a microbial fuel cell [19]. The energy recovered from organic matter to the overall energy content of the organic materials can be used to calculate the microbial fuel cell's energy efficiency. Depending on the composition of the substrate, coulombic efficiency might range from 2% to more than 10% [20]. The coulombic efficiency (CE) can be calculated using eqn. 1:

$$CE = M\int_0^t \frac{Idt}{FbV\Delta COD} \quad (1)$$

where v is the capacity of the MFC's anode chamber, M is 32 (MW of O_2), F is 96485 C/mol and b is 4; COD is the difference between the initial and final anolyte concentration in terms of COD (g/L).

RESULTS AND DISCUSSION

The current study looked at the possibility of producing electric power from potato wastes in an innovative double-phase system, which included the enzymatic hydrolysis with microbial fuel cells. The potato wastes was hydrolyzed using commercially available glucoamylase. Fig. 3 shows the glucose generation from the enzymatic hydrolysis of potato wastes. Enzymatic hydrolysis of potato wastes could yield glucose, which could be improved with time. Within 6 h, a maximum glucose production of 23 g/L could be achieved. A 100 g potato wastes may be converted into 30 g hydrolysis solid and 750 mL potato wastes hydrolyzate using this method. The remaining potato wastes, together with the raw potato wastes, maybe further hydrolyzed by the succeeding phase and no solid residue may be released using the proposed technique. The substrates might be processed in 6 h, which could significantly reduce the cost of substrate processing for commercial applications [21].

The COD of the potato wastes sample was initially 6800 mg/L. The COD of potato wastes was reduced by a microbial fuel cell in 5 cycles lasting up to 3 days. During this experiment, the initial cycle achieved a minimum of 25% COD removal while the fifth cycle achieved a high of 85% COD removal. As shown in Fig. 4, the potato wastes treatment efficiency was remarkable, having R^2 value of 0.97. Then, the potato wastes hydrolyzate was diluted with deionized water to the appropriate acetate concentration (1 g/L) and used as feed waste in the microbial fuel cell to generate electricity.

Fig. 5 shows that potato wastes hydrolyzate glucose was widely utilized and the electricity was generated at the same time. The current work achieved the highest voltage of 1.1 V.

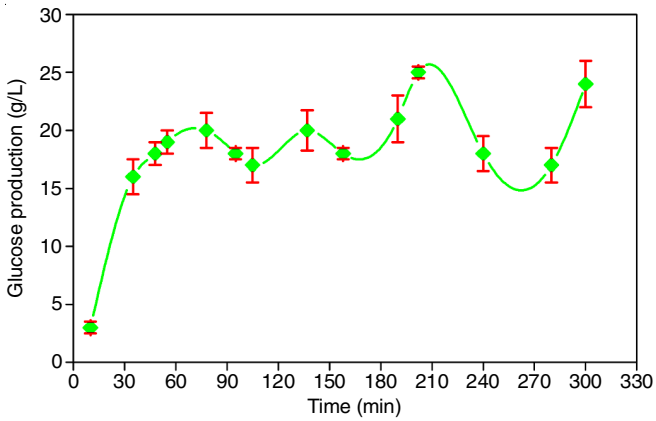

Fig. 3. Soluble glucose discharge during the initial phase of enzymatic hydrolysis from potato waste

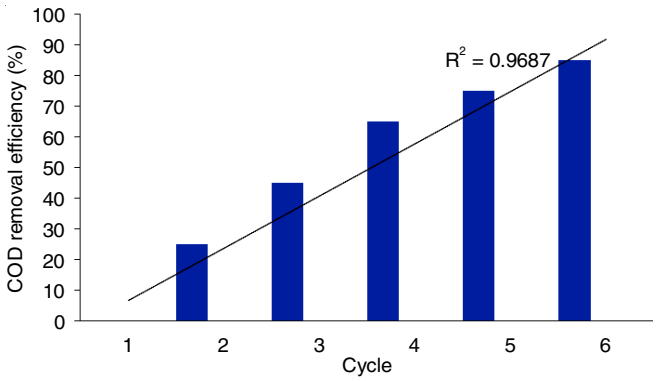

Fig. 4. Removal efficiency of COD during the five cycles from potato wastes

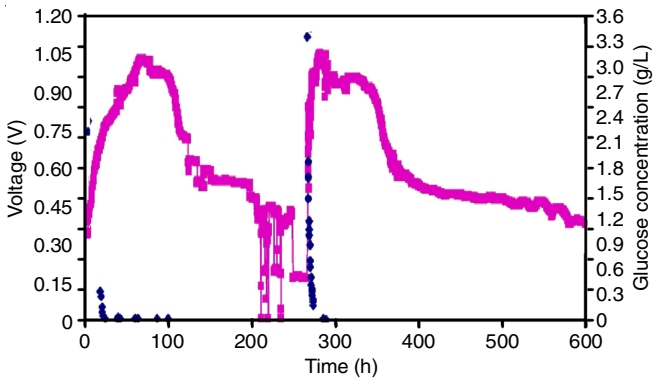

Fig. 5. Glucose usage and voltage generation from potato waste hydrolyzate in the subsequent phase of microbial fuel cell

The relationship between current, voltage and power density produced by potato wastes hydrolyzate is shown in Figs. 6 and 7. A polarization curve may be created by varying the resistance from 10 to 9999 to analyze the nature of microbial fuel cell. With a resistance of 1080, a maximum power density of 33 mW/m^3 was achieved. The potato wastes hydrolyzate might be used as feed-waste in a microbial fuel cell to generate electricity, according to the findings.

Comparative studies: Organic soluble wastes were also applied as sources for the electric power generation utilizing microbial fuel cells [22]. However, solid waste electricity generation is more difficult than soluble waste electricity generation due to the longer hydrolysis duration and lower nutrient conver-

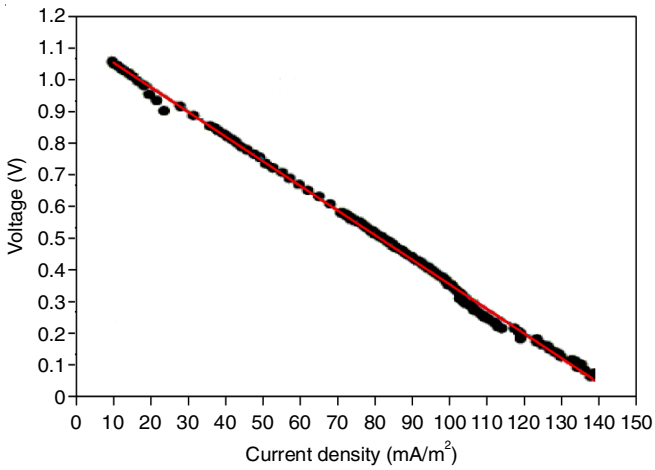

Fig. 6. Voltage as a function of current density from potato waste hydrolyzate in the second stage of microbial fuel cell

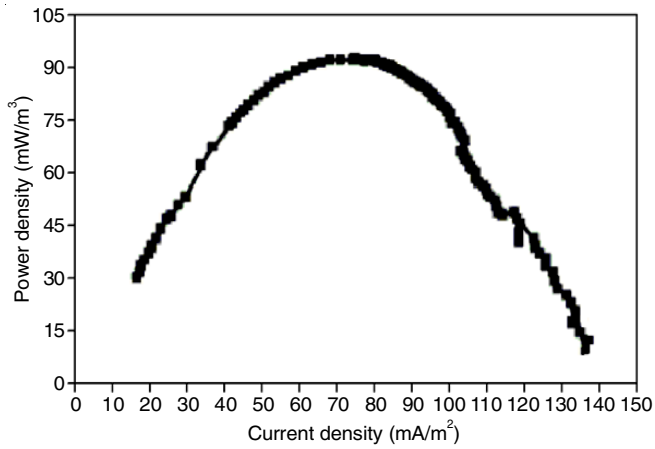

Fig. 7. Power density (b) as a function of current density from potato waste hydrolyzate in the second phase of microbial fuel cell

sion efficiency [23]. As a result, hydrolysis was a critical step in the creation of energy from the organic materials [24].

Using potato wastes, a new double-phase framework was used for the electricity production in this study. The enzymatic hydrolysis technique could produce up to 23 g/L of glucose during the first phase. The rate of nutrient exchange may be increased during this phase. The small molecules might be transformed by enzymatic hydrolysis of potato wastes in 6 h during the following phase. The activity of potato wastes hydrolysis was effectively increased and treatment costs may be lowered. This study suggested that the double-phase biotechnique could improve not only potato wastes liquefaction but also the nutrition conversion and electric power production. This could be used to convert higher starch molecules into biofuels, perhaps lowering total costing efficiency. Present study attained a maximum voltage of 1.1 V and a power density of 93 mW/m^3, respectively.

MFC feasibility assessment: After plugging all of the numbers into eqn. 1, the Coulombic efficiency was found to be 20% in this case. Thus, the proposed double-phase biotechnique of enzymatic hydrolysis and MFC could be used to generate the electric power from potato wastes for commercial purposes.

Conclusion

In this study, a new double-phase bio-technique was proposed for producing the electric power from potato wastes. The potato wastes hydrolyzate was shown to be a viable substrate for generating electricity utilizing a microbial fuel cell. Within 6 h, the maximum glucose production was 20 g/L and the maximum COD elimination was 85%. The current investigation produced a maximum voltage of 1.1 V and a power density of 93 mW/m^3, respectively. This study suggests that the commonly available high-starch-containing raw materials could be used in the proposed bioprocesses to generate direct electricity. Using the proposed biotechnique, might be used to convert higher starch molecules into electric power.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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