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# Bioelectricity Generation of Coconut Waste -based Double Chamber Microbial Fuel Cell with Various Substrate Compositions

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**ABSTRACT**

*The aim of this study was to investigate the generation of electricity in a microbial fuel cell (MFC) using coconut waste as substrate with various compositions. Different types of substrate with different pH values were tested in dual-chamber MFC. The maximum voltage level reached 699mV under alkaline condition after day 7th, which was considerably higher than those previously reported in literature using solid waste substrates. The series connection of the coconut waste MFC with boost converter module showed the ability to light up the bulb. Our results showed that implementation of local organic waste was promising in fabricating MFC for home appliances.*

**Keywords:** Microbial Fuel Cell, Coconut waste, nutrient, pH, grahite, copper, zinc

## 1. INTRODUCTION

Renewable energy production has resumed in an effort to lessen the negative effects of fossil fuel consumption on the environment. One of the potential renewable energies is microbial fuel cell (MFC). MFCs utilize the bio catalytic capabilities of viable microorganism and are capable of using a range of organic fuel source by converting the energy stored in the chemical bonds, to generate an electrical current instead of relying for example, on the use of metal catalysts [1]. Microorganism such as bacteria, can generate electricity by utilizing organic matter and biodegradable substrates such as wastewater, whilst also accomplishing biodegradation product such as municipal wastewater [2]. Significant attention has been given to substrate of MFCs due to its biological factors that can affect the overall performance of MFCs, including its bioelectricity generation and operational cost [3]. The development of a bio-potential, due to the bacterial metabolic activity in the anodic compartment, an electron acceptor conditions in the cathode, leads to generation of bioelectricity in MFCs. In anodic compartment, the electrochemically active microorganism can donate electrons to an anode, which are liberated by oxidizing organic or inorganic waste, thus producing a source of energy. In review, there are few sources of organic waste that have been studied for the generation of bioelectricity, including potato waste [4], wheat straw [5], rice waste [6] and sago waste [7]. It was reported that the maximum current

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density obtained was 278 mA/m$^2$/d (10 fold increment) from a mixture of cooked and uncooked potato [4]. The columbic efficiency (CE) in the range of 15.5%–37.1% was obtained for wheat straw hydrolysate [5] while about 26% improvement of total production of electricity has been observed from rice bran MFC [6]. Recently, the maximum power density obtained from 20g/L of sago hampas was 73.8mW/cm$^2$ with stable cell voltage output of 211.7mV [7]. These findings shows the potential of bioelectricity generation of MFCs from organics waste.

The performance of MFCs depends on several factors including microbial activity, substrate types, and electrode types [8]. Many of the studies focus on liquid food waste than solid food waste [9-10]. Solid food wastes are promising substrates for electrical generation in MFC because they have higher energy density than soluble organic compounds [11]. One of potential organic waste is coconut kernel grated waste. To date, no research has been investigated using coconut grated waste as a substrate. In Malaysia, coconut is the fourth largest crop industries. Accorgding to Ministry of Agriculture and Agro-based Industry (MOA), Malaysia is one of the top 10 producers of coconuts in the world and the market value of coconut-based products increased to approximately US$ 11.8 billion in 2018 and this value is projected to reach more than US$ 31.5 billion by 2025 [12]. It should be noted that the increased number of products will significantly increase the amount of waste produce by coconut industry, which subsequently is associated with environment pollution problems if it is poor handled. Coconut kernel grated waste is biomass produced during the extraction of coconut milk which contains dietary fibers, sugar, mineral and other micro minerals [13]. It is a potential source of material for MFC because of it contained the highest sucrose, sorbitol, fructose, glucose that has potential to increase the power output and current generation [14]. Furthermore, according to the Journal of Food Science, the coconut grated waste contains Acinetobacter, Enferobacteriaceae, Flavobacterium, Microbacterium, Micrococcus species, yeast, and moulds can accelerate the breakdown of the organic and nutritional components inside the waste [15]. The breakdown that took place may have resulted in electron collisions, which produce modest values of volts current.

In this study, we investigated the voltage generation of a coconut grated waste-based or coconut waste double chamber MFC (CW-DCMFC) with diverse anode compartment substrate compositions. The parameter such as substrate concentration, pH, and temperature dependence were taken into account. The output voltage was increased by using the boost converter module.

## 2. EXPERIMENTAL SETUP

### 2.1 Construction of Coconut Waste Based-Double Chamber Microbial Fuel Cell (CW-CMFC)

In this study, a DCMFC was utilised to extract an electron from bacteria while simultaneously generating power. The 2 containers with capacity of 745ml were used as cathodic and anodic chamber. The anoidic chamber was filled with solid coconut grated waste or coconut waste and nutrients that are listed in Table 1. Coconut waste was collected from Pasar Satok, Petra Jaya Kuching. The pH of substrates was measured and the performance of CW-DCMFC was evaluated in terms of voltage level. The chambers of MFC were joined with a salt bridge. The salt or sodium chloride (NaCl) was dissolved in water and heated for approximately three minutes to ensure its solubility in water.

**Table 1** Composition of substrates

| Substrate and Nutrient | pH |
|---|---|
| Pure coconut waste | 6 |
| Coconut waste+ Soda bicarbonate | 9 |
| Coconut waste+Soil | 8 |
| Coconut waste+ Lemon | 4 |
| Coconut waste+Chicken manure | 8 |

The cloth was then submerged in the solution for a few minutes until they were completely saturated. According to Al Moinee et al., a liquid phase saturated with sodium chloride (NaCl) can improve ion exchange efficiency and conductivity [16]. This experiment utilised two sets of electrodes. The zinc was used as the anode, while copper was chosen as the anode electrode. The setup of CW-DCMFC is shown in Figure 1.

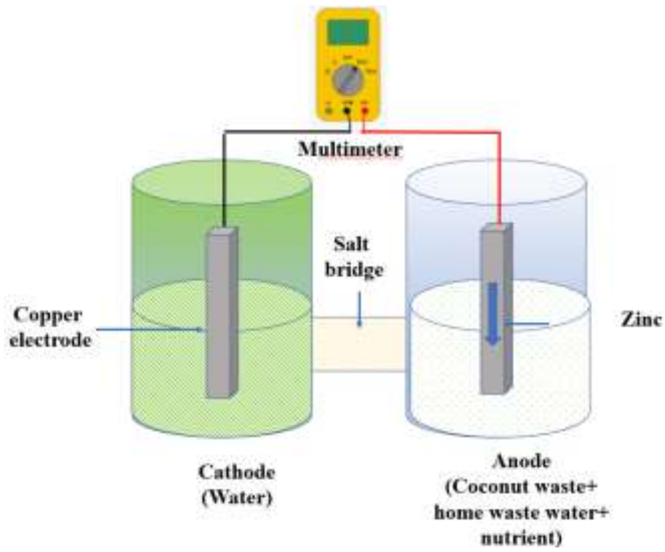


**Figure 1**. Schematic representation of CW-DCMFC.

## 2.2 Measurement of Voltage from CW-DCMFC

### *2.2.1 Open Circuit Voltage (OCV) Measurement*

In this work, the OCV was performed on a single unit of CW-DCMFC to observe the performance of CW-DCMFC with various substrate composition. Due to the limited voltage that a single CW-DCMFC can generate, four of them were connected in series as illustrated in Figure 2. The cathode chamber was connected to the multimeter's negative pole, and the anode chamber to its positive pole. According to Zhao et al. [17], the accumulation of the voltages from each separate source causes the series combination of MFC to produce a greater voltage.

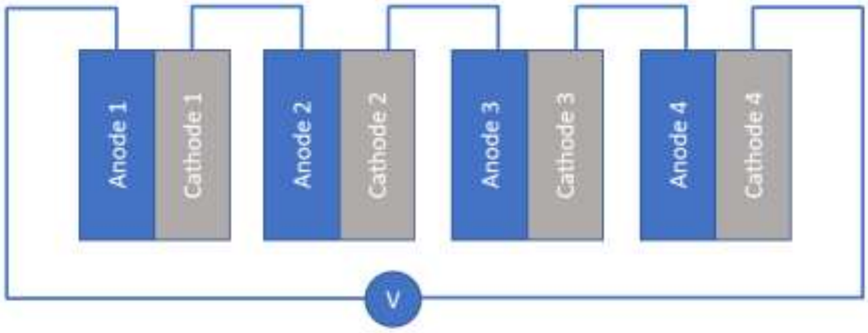


**Figure 2**. A series connection of four unit of Coconut waste based CW-DCMFC.

## 3. RESULTS AND DISCUSSION

### 3.1 Comparison of Substrates Concentration

Initially, all CW-DCMFCs were operated on an open circuit condition to evaluate their performance in the absence of a load. The open circuit voltage (OCV) was measured at 24-hour intervals. Figure 3 illustrates the relationship of CW-DCMFC voltage generation on substrate concentrations. This experiment's substrate consisted of pure coconut waste. The chosen substrate was investigated at 2 different substrate concentrations: 125g/L and 62.5g/L. The results indicate that there is little difference between two substrate concentrations in the voltage level during the first two days of observation, but a significant difference can be observed after two days. For substrate concentrations of 62.5g/L and 125g/L, an increase in voltage was detected on the second and fifth day of observation respectively, indicating the establishment of a microbial community with bacteria in the log phase where the rate of bacterial reproduction is proportional to the current population size. At this stage, it was predicted that the bacteria obtained sufficient food, and their activity increased. Following this phase is stationary phase in which microbial growth in the system saturates due to the limiting factor which implies that the amount of food was decreasing that limit the activity of bacteria and maximal OCVs are reached, a somewhat stable period ensues. These results are consistent with the bacterial growth curve described by Wang et al [18]. Based on these findings, it can be concluded that the concentration of the substrate affected the bacterial activity which is similar with the previous report [19]. Clearly, voltage production can be enhanced by increasing the substrate concentration. On the seventh day, the MFC containing 125g/liter of coconut waste demonstrated the maximum voltage level of 35mV.

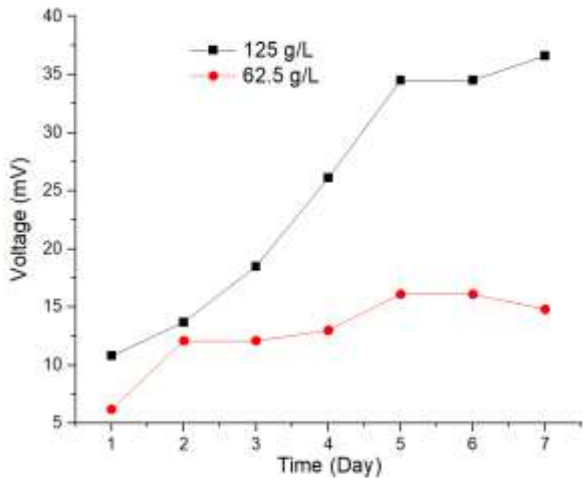


**Figure 3.** Influence of substrate's concentration on the voltage production of CW-DCMFC.

### 3.2 Substrates Composition Dependence

To determine the effect of different substrates on the performance of the CW-DCMFC, five types of substate composition were used as illustrated in Table 1. The pH of each substrates was measured at the beginning of experiment. The amount of coconut waste in each chamber was identical, as was the weight of the nutrients such as sodium bicarbonate, lemon, soil, and chicken manure. The voltage level produced by an MFC with different substrate compositions was shown in Figure 4. At the first 7 days of observation, the subsrate composition of coconut waste and soda bicarbonate resulted higher voltage level while after 7 days of observation, the composition of coconut-waste and soil that has pH 8 resulted highest voltage level. Maximum observed voltage level was 980mV. The trend of voltage level at different pH levels suggests that an alkaline environment is ideal for the growth of electrogenic bacteria. This finding is in good agreement with the previous work, which revealed that the highest voltage was produced on day 4 at a pH of 8, where the electrochemical interaction of the bacteria greatly increases, resulting in more power under alkaline conditions [20]. In addition, the highest voltage in soil composition may be due to complex syntrophic relationship between the mixed culture of bacteria in the soil [21]. After 10 days of monitoring, the inconsistency of voltage levels produced by all substrate compositions was observed. The discrepancy of voltage level can be related to the fluctuating metabolic activity rate of the electrogenic bacteria during the experiment's fluctuating temperature [22-23]. To determine the optimal temperature for bacterial activity, we will examine the relationship between temperature and voltage in the next section.

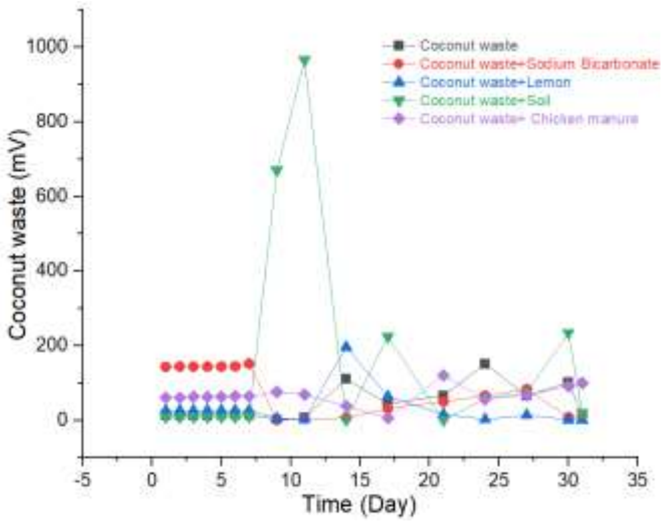


**Figure 4.** Generation of voltage from various substrate compositions.

## 3.3 Influence of Temperature on Voltage Generation of CW-CW-DCMFC

In this section, we investigated the effect of temperature on the voltage level of CW-DCMFC. The temperature was ranging between 293 and 303K (between 20°C and 30°C). As shown in Figure 5, no abrupt changes of the voltage level was observed as the temperature increased from 293 K to 297K. It was hypothesised that the lower temperature causes the bacteria less active, thereby maintaining the voltage level. Nonetheless, the voltage increased abruptly by around 228 percent when the temperature reached 298K. This voltage level was dropped by approximately 50 percent as the temperature continued to rise to 303K. These findings indicate that the optimal temperature for microbial activity was between 298 and 303K [24].

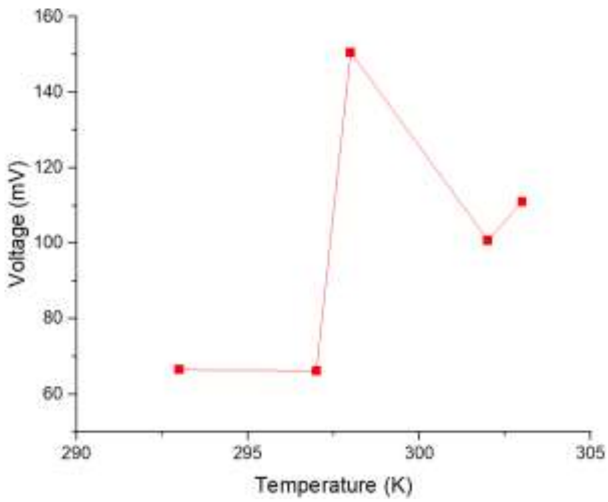


**Figure 5.** Generation of voltage at different temperatures.

### 3.4 Series connection of CW-CW-DCMFC with DC-DC boost converter

All substrate compositions were fermented for four months to provide the greatest possible voltage level. Four sets of CW-DCMFC were linked in series with our designed DC-DC Boost Converter that published in previous work [25], and the resulting voltage was measured and recorded in Table 2. According to Table 2, connecting four CW-DCMFC in series with a DC-DC boost converter can increase the voltage by 600% where it was enough to light a bulb as shown in Figure 6. These findings give great hope to companies and society that this technology will soon be implemented in a broader scale for household appliances.

**Table 2** Summary of output voltage with various substrate composition

| Substrates composition | Voltage of Single CW-DCMFC (V) | Voltage of 4 CW-DCMFC connected with DC-DC Boost Converter (V) |
|---|---|---|
| Pure coconut waste | 0.78 | 4.66 |
| Coconut waste+ Sodium Bicarbonate | 0.98 | 4.88 |
| Coconut waste+Soil | 1.12 | 4.91 |
| Coconut waste+ Lemon | 1.10 | 3.43 |
| Coconut waste+Chicken manure | 0.80 | 4.54 |

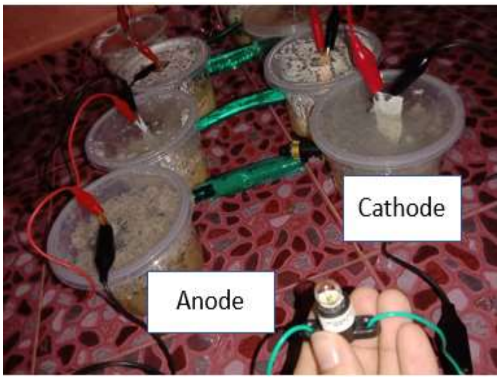


**Figure 6.** The connection of 4 CW-DCMFC by series with DC-DC boost converter illuminate the bulb.

### 3.5 Comparison of Previous Studies

Very few studies have been conducted on solid waste substrates for MFC applications. Recent research on the effect of various solid wastes on the voltage output of MFCs are presented in Table 3.

**Table 3** Recent literature of MFC with respect to solid waste substrate

| Substrates composition | Configuration | Voltage | Reference |
|---|---|---|---|
| Sago hampas | DCMFC | 0.211 V | [7] |
| Plant waste | Plant MFC | 0.85V | [26] |
| Potato Waste | Single Chamber MFC | 1.12V | [27] |
| Sewage sludge | DCMFC | 0.499V | [28] |
| Rice bran waste | Single Chamber MFC | 0.325V | [6] |
| Fermented vegetable waste | Single Chamber MFC | 3.43V | [29] |
| Coffee waste | DCMFC | 0.75V | [30] |
| Winery sludge | DCMFC | 0.63V | [31] |
| Coconut waste | DCMFC | 4.91V | *This study |

It is evident that our outcome represents the greatest voltage level among the others. From these study, the upscaling of MFC to large systems can be regarded a new area of industry interest. In order to realize the MFC technology, the focus must be boosting up the voltage level of MFC through the design of a power management system (PMS).

## 4. CONCLUSION

This study demonstrates that the usage of coconut-waste and various nutrients has the potential to generate bioelectricity. The substrate with alkaline characteristics produced the greatest voltage. In addition, the study illustrates how temperature and substrate concentration affect MFC voltage generation. By connecting 4 units of CW-DCMFC in series with a DC-DC boost converter, this work also demonstrates the highest voltage generation reported in the literature. In conclusion, the present study reveals that the MFC may produce energy from inexpensive materials by combining agriculture waste with various nutrients. In addition, the publication of this study will inspire other researchers to develop power management systems for energy enhanced energy output.

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