Experimental Investigation of the Bio-conversion of Human Faeces to Energy

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Abstract: *The use of human excretes for power generation has been considered beneficial and environmentally friendly against conventional sources causing series of unmanaged hazards to the society. Therefore, the conversion of human faeces to usable energy is receiving tremendous attention. This investigative study is concern with the suitability of human faeces as a feedstock for power generation. It quantified the recoverable energy potential from human faeces and explored the optimal parameters such as voltage and current for power and power density evaluation. Experimental results established from research indicates increase in power and power density by 0.589 – 1.056μW and 0.0074 – 0.0132μW/m^2 with respect to time duration in days. Meanwhile, an average of 0.859μW and 0.0107μW/m^2 deviation of the parameters was recorded after the last day of the experiment. Furthermore, the deduced values of voltage and current measurement across the system yielded an optimum value of 0.878V and 0.016μA respectively. It is therefore, concluded that the human faeces is an effective and valuable source of renewable energy.*

Key Words: *Aerobic, Anaerobic, Bacteria, Electrode, Energy, Human Faeces, Microbial Fuel Cell, Power, Power density, Sustainability*

1. INTRODUCTION:

The idea of waste to energy is the current research focus of scholars. Over the years energy has been a developmental key to human society used by man in controlling and adapting to the environment, though majorly cultivated from the conventional sources. This practically have a wide range of negative impacts on the environment and on public health of the habitations. These ubiquitous and long-standing challenges could undoubtedly become huge global threats to human existence if not addressed urgently.Therefore, in contemporary society, the need to move out of the conventional source of energy to a more innovative and environmentally friendly energy generating means is receiving serious attention. The importance of clean sources of energy cannot be over emphasized. Hence the study of evaluating energy generated from human faeces is in line with the current research frame-work.

It is established in a reviewed literature that human faeces is a potential renewable energy source and the potential energy value from this process needs much attention and its benefits will contribute to energy demand of the society (Lambok, 2015). A supportive research unveils the production of biogas from human excreta and other sources such as animal dung, agricultural waste, etc. The energy conversion from this source is capable of controlling the unmanaged human excreta disposal system which is beneficial in environmental management (Dain et al., 2015). The generation of energy through this technology reduces drastically environmental pollution and most importantly decreases greenhouse gas effect caused by the waste. Conversely, the utilization of human excreta as energy source is advantageous because it does not require additional starter like microorganisms, thus the supply of microorganisms occurs continuously during the feeding of raw materials in the process. This directly supports the sustainability of the production of biogas (Dain et al., 2015). Biogas is generated through anaerobic digestion resulting from bacteria breakdown of faecal matter and any other organic material. It is approximately 60% methane by volume and has an average thermal value of 25MJ per m^3(Cao and Shengdao, 2011).

Report from scholars indicates that out of the world's population of 7-billion, 14-million tonnes of faeces are produced by people every day where 25% of this production is capable of generating roughly 40000MW of power(Onojo et al., 2013). Perhaps the enhancement of this production is as a result of large concentration of pathogenic viruses, bacteria, cysts of protozoa and eggs of helminths as contained in the human faeces (Richard et al., 1983).Through scientific research it is revealed that the composition of bacteria in human faeces is liable to generate electric current using microbial fuel cells (MFC) technology(Liu, et al., 2004, Min and Logan, 2004). This new technology can also be used for wastewater treatment. Study reveals that bacteria in some conventional sewage treatment systems use enzymes to oxidise the organic matter. In this process, electrons - carriers of electricity are released. Normally, the electrons power the respiratory reactions of the bacteria's cells, and eventually combine with oxygen molecules (Lau et al., 2017).

However, the MFC technology allows microorganisms from human faeces to serve as biocatalyst to convert the chemical energy stored in organic compounds directly to an electrical energy (Deepak et al., 2010). Meanwhile, it hasanaerobic and aerobic chambers that are separated by a membrane. According to study, feasted bacteria from human faeces in anaerobic anodic chamber oxidize substrate and cluster around the anodes and break down the organic waste as it is pumped in, releasing electrons and protons (Duduyemi et al., 2015). Thus, with no oxygen to help wash up the electrons, the bacteria's enzymes transfer them to the anodes, while the protons migrate to the central cathode. Consequently, molecules on the proton exchange membrane (PEM) encourage the protons to permeate through the cathode. Hence, their combination with oxygen from the air and electrons from the anodes will eventually produce water. Obviously, the migration of electrons will create potential difference between the two chambers.

Therefore, in this current study of waste to wealth, evaluation of energy from human faeces is carried out aimed at harnessing all possible sourcesof energy devoid of any component capable of deteriorating the environment. Thus, the study of cultivating or harnessing energy from septic tanks could substitute the continuous dependence on fossil fuels and create energy sustainability.

2. SETUP OF EXPERIMENTATION:

Wastewater sample of human faeces which is the key focus of the study is collected from hostels A – H septic tanks of the main campus of Niger Delta University, Wilberforce Island of Bayelsa State in Nigeria. Collected sample of waste water is stored at 4°C as shown in figure 1, to maintain bacteria growth temperature. Experiment is conducted using bacteria isolates from sewage water which is in form of broth culture. Hence, sample is allowed to sediment after 24 hours and residuals were serially diluted with saline water of 0.9% w/v NaCl up to 5 – 10 dilutions.

Figure 1: Sewage Sludge from hostel septic tank

At each dilution of 0.1mlwere spread 10g of tryptone, 10g ofNaCl, 20g of Agarand 5g of yeast extraction into 250 ml distilled water on lysogeny broth (LB) and they were incubated for 24-hours at 30˚C.Morphologically distinct bacterial colonies were purified and further inoculated in LB and kept at different temperatures and pH in an orbital shaker to study the growth pattern of these micro-organisms by measuring absorption at 660-nanometre against the blank sterile LB.Thus, the bacteria isolation was further inoculated in waste water samples in an incubator as shown in figure 2 and then their growth parameters were recorded. The best surviving bacterial strains were used further in constructed fuel cells as shown in figure 3 to test the electrical potential across the circuit.

Bacterial growth optimization at different temperatures and pH were carried out and thus isolations were considered for seven (7) days with temperatures 27, 30, 37, 55°C and pH 4, 5, 9 and 11. It was observed that most isolates were able to grow at 27°C and pH 5 but absolutely well at 37°C with pH 9 though with weak or poor growth at temperature of 55°C and pH of 11. The basic design of figure 3 is of two distinguished or distinct compartments, the aerobic and anaerobic chambers. The anaerobic chamber is of a glass conical flask sealed with a punch rubber cork which carries the substrates of growth.

Figure 2: Isolations and growth of bacteria in an incubator

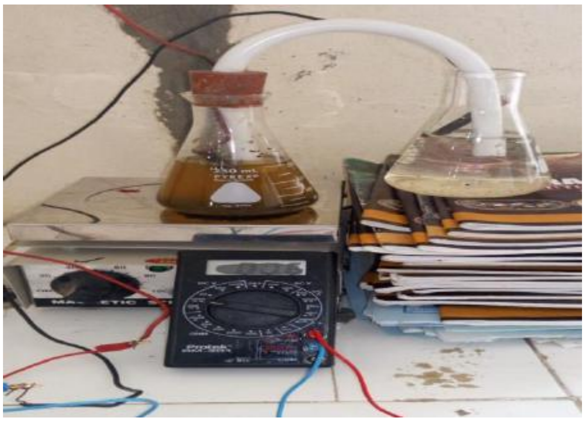

Figure 3: ConstructedMicrobial Fuel Setup

In it is placed a magnetic stirrer to maintain agitation in the sample to assure homogeneity and proper mixing of reactor feed andalso to prevent settling of the medium in the bottle.The magnetic stirrer is used to facilitate optimum agitation in the substrate.Extreme care is necessary while setting the speed for the magnetic stirrer to avoid upsetting the electrode setup in the chamber. This setup is left undisturbed but with continuous monitoring for over 24 hours. Meanwhile the aerobic chamber is kept uncovered to allow some technical operations. This operates as the salt-bridge supplied with the necessary entities in optimum concentrations of about 2-5% of agar heated with 1M KCl. Carbon electrodes shown in figure 4 is inserted in the aerobic chamber and it is used as the cathode with a similar carbon electrode fitted via the punched cork into the anaerobic chamber which functions as the anode. However, a multimeter is connected to check and measure the electrical potentials generated across the circuit after noticing slight deflection on the setup of the cells.

Figure 4: Carbon Electrodes

3. RESULTS PRESENTATION:

The identification and classification of bacteria isolates with the aid of 16S ribosomal RNA sequences has been used and widely reported in other works(Khadija et al., 2016, Michael and Sharon, 2007, Woo et-al., 2008)and its effectiveness is proven beyond doubt. The current study is established on this procedure and identification of isolates by 16S rRNA was performed. The obtained sequence was trimmed, chimera removed and was blasted. The bacteria species were identified on the basis of maximum similarity with known genera and then the sequences were submitted to Genbank and accession numbers were obtained. Table 1 is a presentation of results based on the physiological characteristics and 16S rRNA gene sequencing identification of bacterial isolates obtained from waste water samples.

Table 1: Identification of Isolates and Classification

Sequences	Strain ID	Identification	Gram staining	Respiration	Accession numbers
seq1	Z1	*Chromobacterium*sp. 1	Gram negative	Facultative anaerobic	KT347176
seq2	Z2	*Amantichitinumursilacus*	Gram negative	Facultative anaerobic	KT347177
seq3	Z3	*Chromobacterium*sp	Gram negative	Facultative anaerobic	KT347178
seq4	Z4	*Bacillus licheniformis*	Gram positive	Facultative anaerobic	KT347179
seq5	Z5	*Enterobacter*sp	Gram negative	Facultative anaerobic	KT347180
seq6	Z6	Unidentified bacteria	Gram	Facultative	NOT

			negative	anaerobic	identified
seq7	Z7	*Escherichia coli*	Gram negative	Facultative anaerobic	KT347181
seq8	Z8	*Citrobacter*sp.	Gram negative	Facultative anaerobic	KT347182

The collation of data was based on the MFC operation for 6-days at an interval of 2-hrs between 8.00hrs – 18.00hrs per day using human faeces wastewater mixed with amino acetate (food for bacteria) to grow the substrate in anode compartment and distilled water in the cathode compartment as explained earlier. The measurement of DC voltage and current was conducted with the appropriate instrumentation and the following results were obtained as depicted in tables 2 and 3 respectively, while table 4 is the presentation of results showing power and power density deduced from the research study.

Table 2: Voltage Generation for 6-days

Days	Voltage (v)					
	Day - 1	Day – 2	Day - 3	Day - 4	Day - 5	Day – 6
8.00hrs	0.468	0.520	0.620	0.685	0.850	0.870
10.00hrs	0.475	0.525	0.632	0.793	0.856	0.745
12.00hrs	0.488	0.560	0.650	0.815	0.860	0.710
14.00hrs	0.494	0.575	0.665	0.820	0.868	0.650
16.00hrs	0.498	0.600	0.672	0.835	0.872	0.620
18.00hrs	0.505	0.607	0.680	0.842	0.878	0.612
Average	**0.586**	**0.677**	**0.784**	**0.958**	**1.037**	**0.841**

Table 3: Experimentation of Current for 6-days

Days	Current (μA)					
	Day - 1	Day – 2	Day - 3	Day - 4	Day - 5	Day – 6
8.00hrs	0.0052	0.0092	0.0115	0.0137	0.0150	0.0160
10.00hrs	0.0061	0.0097	0.0118	0.0139	0.0152	0.0153
12.00hrs	0.0074	0.0099	0.0120	0.0141	0.0155	0.0150
14.00hrs	0.0078	0.0100	0.0122	0.0144	0.0157	0.0147
16.00hrs	0.0083	0.0105	0.0129	0.0146	0.0158	0.0145
18.00hrs	0.0090	0.0110	0.0132	0.0149	0.0160	0.0140
Average	**0.009**	**0.012**	**0.015**	**0.017**	**0.019**	**0.018**

Table 4: Results for Power and Power Density for 6-days

Days	Average Voltage (V)	Average Current (μA)	Power (μW)	Power Density (μW/m^2)
1	0.586	0.009	0.5890	0.0074
2	0.677	0.012	0.6890	0.0086
3	0.784	0.015	0.7990	0.0100
4	0.958	0.017	0.9750	0.0122
5	1.037	0.019	1.0560	0.0132
6	0.841	0.018	0.8590	0.0107

4. DISCUSSION OF RESULTS:

The graphical results presented in figures 5 – 8 show the trend of voltage and current generation which yields power from human faeces as conducted in the research experimentation.It is evident that, the voltage generated from day-1 to day-5 in figure 5 precisely indicates a rapid increase of voltage from 0.468V to 0.878Vexcept the sudden negative change experienced at day-6 which declined to 0.612V. The voltage measured was open circuit voltage since the external resistance is not used. Hence the voltage generated was due to internal impedance which appeared to be very high in the range of mega ohms.Similarly in figure 6, the total current observed at the first five days is between 0.0052 – 0.016μA. However, a setback is witnessed at day-6 of the experimental test with significant reduction of 0.014μA. Current was determined by measuring the voltage (V) across thesalt-bridge as illustrated in figure 3 between the two carbon electrodes using a multimeter. The determination of power ($P = VI$) and power density ($P_{Den} = VI/A$)was calculated from the measured voltage (V), current (I) (V/R), and the surface area of the anode electrode (A)as presented on table 4 is used to plot figures 7 and 8 respectively.

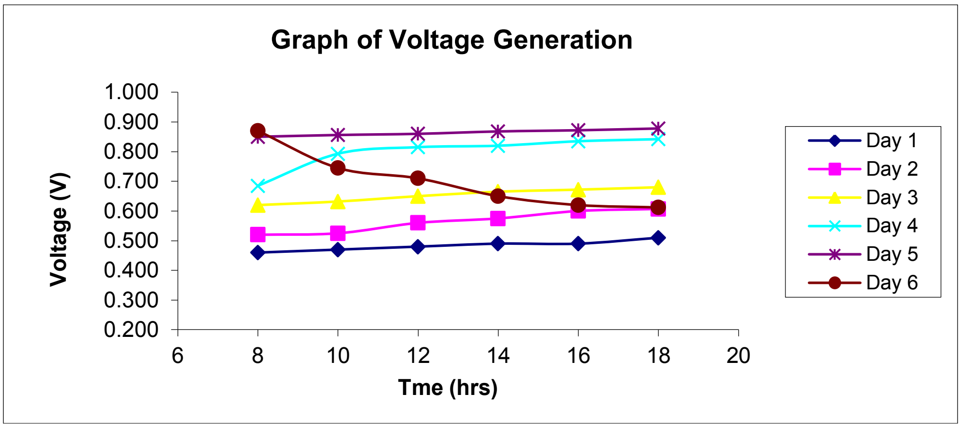

Figure 5: A graph plot for voltage against time

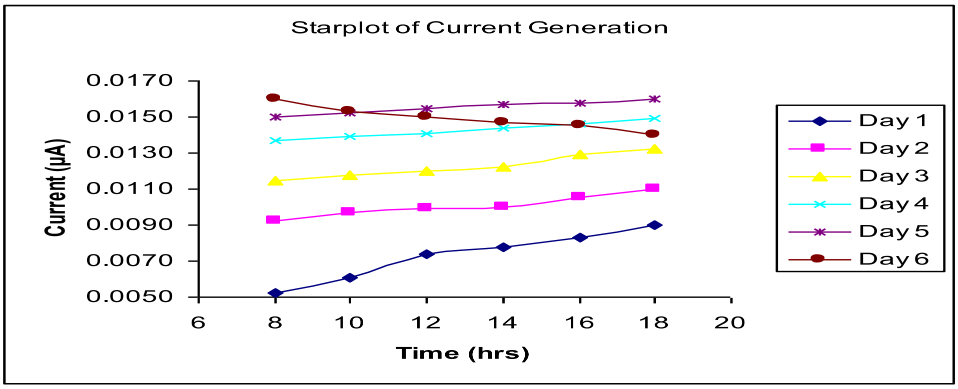

Figure 6: Plot of current versus time frame generation

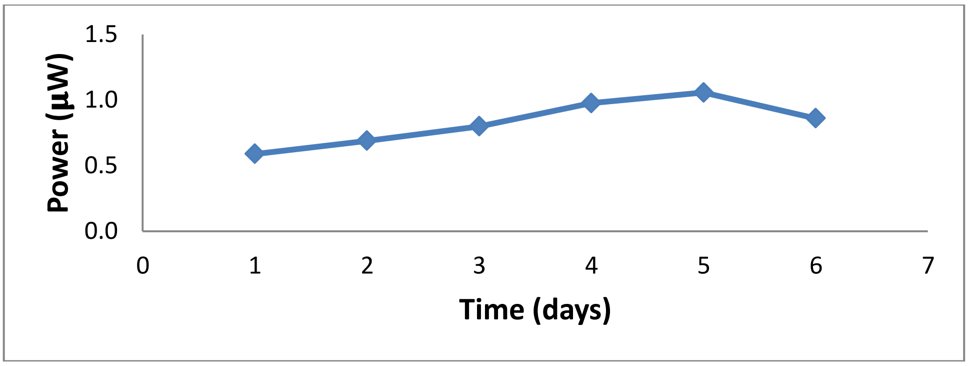

Figure 7: Graph plot for average voltage and power generation

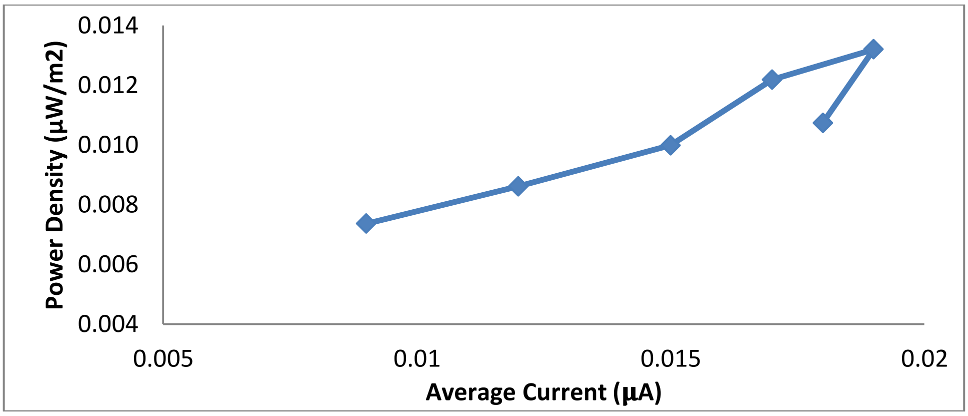

Figure 8: Graph plot for current and power density

Results show that both power and power density increases with time of the experiment by 0.589 – 1.056μW and 0.0074 – 0.0132μW/m^2 respectively. However, the sharp deviation on both figures is as a result of decrease in the generated power and power density from its climax to 0.859μW and 0.0107μW/m^2. Meanwhile, the possibility for the production of electric energy under the condition of microbial fuel setup construction as revealed in reviewed literatures could only be understood with an extensive knowledge of the characteristics of the bacteria that generate electricity inMFCs.

Conversely, that perception might not all be true because in the experimental setup oxygen is diffused into the anodal chamber even though there is a cork on it. This movement is made possible via the aerobic chamber of the constructed salt-bridge as seen in figure 3. According to (Ajoko and Kilakime, 2014), an electrochemical hydrogen-oxygen fuel cell which uses fuel value of hydrogen has the capability of converting the chemical energy involved in the process into electrical energy. This was ascertain as they successfully built and conducted a laboratory based hydrogen-oxygen fuel cell test rig and generated electric power of 13.44W.It is worthy of note therefore, that the production of electricity by bacteria attached directly on the electrode may have no concern with the presence of oxygen concentration in the setup.

5. CONCLUSION:

The conducted experimentation for the conversion of human faeces to usable energy was successful and justifiable due to the following reasons:-

- Test results confirmed that human excreta waste suchas faeces and urine feasted by bacteria is capable of generating voltage and current.
- Experimental data validates and confirmed that human faeces waste could be considered as alternative source of renewable energy.
- Results for power and power density were extremely low by observation but could be increased by setting bigger test rig and also the close spacing of the carbon electrodes in the experiment would help increase the generation of energy.

Therefore, the study of the experimental procedure of converting human faeces to energywas feasible. Improving on the methodology used for the research study could enhance energy sustainability and reduce the continuous dependence on fossil fuel and hence the environmental hazards caused by these conventional systems.

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