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Production potential of cow dung for the generation of electric current using microbial fuel cell

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Abstract

Production potential of cow dung for the generation of electricity was investigated using microbial fuel cell (MFC). Cow dung was collected from FUTA farm and Ilesha Garage farm in Akure. Voltage and current was measured per day for 21 days and the electrode used for the set up are carbon-carbon and carbon-aluminium electrode. Proximate, physico-chemical and mineral composition were determined using standard methods. Isolation and identification of microorganisms present in the cow dung were determined before and after generation of voltage and current using microbiological techniques. The microorganisms isolated were *Providencia alcalifaciens, P. rettgeri, P. stuartti, Escherichia coli, E. fergusonii, Morganella morganii, Staphylococcus haemolyticus, S. aureus, Micrococcus luteus, Fusarium solani, Saccharomyces cerevisiae* and *Mucor mucedo*. The highest voltage 0.737±0 mV and electric current 1.265±0 mA were generated from FUTA cow dung. The pH ranged between 7.3 to 9.9 and the temperature ranged between 25 ˚C to 33 ˚C during generation of voltage and current. This study has shown that cow dung is a potential substrate for generation of electric current using fabricated double chamber MFC.

Keywords: Microbial fuel cell; Voltage; Current; Cow dung; Electrode

1. Introduction

The increase in human population and tendencies towards urbanization in the last few decades has increased the demand of energy and the continuous use of fossil fuel to meet the demand of energy has led to its depletion, posed a threat to life with the secondary effect of global warming and environmental pollution [1,2]. In order to curb the depletion of fossil fuel and problems associated with it, alternative sources have been employed which involves the use of renewable materials such as waste products. This renewable source involves the conversion of waste to energy. Microbial fuel cell (MFC) has been emerging as one of the popular waste water treatment-based technology for provision of clean water and green energy [3]. The microbial fuel cell is a system which converts chemical energy into electrical energy and basically comprises of the anode, cathode and membrane. In an MFC system, the microorganisms present in the anode oxidize the substrate and electrons are released to the cathode [4] through an external load. The proton diffuses to the cathode which gets reduced by the incoming electrons, thus completing the circuit. The flow of electrons through the external load generates electric current [5]. The use of cow dung in microbial fuel cell will serve as an alternative for generation of energy which will drastically reduce the environmental effect and global warming caused by fossil fuel.

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2. Material and methods

2.1. Study area

The study was undertaken in Akure metropolis, Ondo state, Nigeria.

2.2. Collection of sample from study area

Fresh cow dung samples were collected in the morning by 8A.M. into a clean polyethene bag from two respective locations which are FUTA farm house and Ilesha garage farm house.

2.3. Proximate, physicochemical and mineral analysis

The proximate composition was determined according to standard method [6]. Physicochemical parameters such as conductivity, dissolved oxygen, organic matter, phosphate, total solids, total volatile solids, Biological oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were determined according to stan0dard laboratory methods [7]. Mineral composition was determined using the Atomic Absorption Spectrophotometer (AAS) Buck Scientific 210 VGP [8].

2.4. Isolation of microorganisms

One gram of pig dung was measured using a weighing balance. Ten test folds serial dilution of the sample was carried out using sterile distilled water. 0.5ml aliquot of the diluted sample 10^4 and 10^6 was measured and aseptically introduced into a clean sterile petri dish and the prepared media was aseptically introduced into the petri dish using pour plate technique. The dish was swirled gently for homogenous mixture and allowed to solidify. The media used are Nutrient agar, Eosine methylene blue agar, *Salmonella-shigella* agar and Potatoes dextrose agar. The petri dish were inverted and incubated at 37 °C for 24hours for bacterial growth and at 28 °C for 48 – 72 hours for fungi growth in duplicates. After examination of microbial growth, the bacterial isolates were subcultured and purified by streaking on fresh sterile nutrient agar plates. Fungi isolates were also subcultured to obtain pure isolates. The pure isolates were aseptically transferred to a slant and store at 4 °C for further use. Colony counts were carried out on plates in duplicates.

2.5. Identification of microorganism

The identification of pure bacteria and fungi isolates were determined using standard biological methods. Bacterial isolates were identified using biochemical tests according to and fungal isolates were identified microscopically [9].

2.6. Microbial Fuel Cell Construction

2.6.1. Making the salt bridge

Eight centimetre salt bridge was prepared using a half inch Polyvinyl Chloride (PVC) pipe, agar agar and sodium chloride (NaCl) in the ratio 2:1 [10]. 6 g of the agar agar and 3 g of NaCl were dissolved in 100 ml of deionized water in a conical flask and was dissolved by swirling it. It was autoclave at 121 °C for 15 minutes and allowed to cool to 55 °C. One end of the PVC was tightly sealed with a clean detachable nylon and was placed in a vertical position. The mixture was poured into the PVC tube of the open end and allowed to solidify after which the detachable nylon was removed.

2.6.2. MFC Fabrication

Two 1.2L plastic containers served as the anode and cathode chamber. A hole was drilled 4 cm from the base of the container for fitting of the $^1/_2$ inch PVC pipe with an electric soldering iron. A hole was also drilled on the lid of the container for passage of copper wire. The set up was coupled by joining the two chambers together using the salt bridge which serve as a membrane. An epoxy gum was use to seal the edges of contact between the hole and salt bridge and was allowed to dry. The set up was tested for leakage by pouring sterile water into the chambers and observed for 30 minutes. The anode and cathode chambers were cleaned with 95% ethyl alcohol to rule out any form of contaminant.

2.6.3. Preparation of electrodes

The electrodes used were carbon rod and aluminium mesh. The carbon rod was gotten from a dismantle battery cell, carefully cleaned with 95% ethyl alcohol and the naked end of copper wire was firmly wrapped round the carbon rods. The aluminium mesh with length 20 cm and width 5 cm was carefully folded into four and the naked end of the copper wire was tightly passed through the folded mesh.

2.6.4. Filling the anode chamber of the MFC

300g of cow dung was weighed and put into one of the chamber serving as the anode chamber.

2.6.5. Filling the cathode chamber of the MFC

In the cathode chamber, potassium ferricyanide was prepared by dissolving 20g in 1000 ml of deionized water and was poured into the chamber.

2.6.6. Testing the Microbial Fuel cell

The electrodes were carefully dipped into the chambers with the wires passing through the hole on the lid and a clean polyethene nylon was first use to cover the anode chamber before it was carefully covered with the lid to maintain anaerobic condition. The multimeter was connected to the anode and cathode copper wires and was set to 2 m for measurement of direct current and voltage. The initial reading was recorded and subsequent readings were taken six hours apart (7AM, 1PM, 7PM) as morning, afternoon and evening for 21 days.

Figure 1 Fabricated microbial fuel cell (MFC) with multimeter

2.6.7. Making and Testing of control MFC

For the control MFC, the cow dung was sun dried for six hours and was aseptically transferred into the anode chamber, sterile water served as the cathode and was poured into the cathode chamber.

2.7. pH and temperature of anode chamber during electricity generation

The pH was determined using a pocket pH meter and temperature was determined with the use of a standard thermometer.

2.8. Statistical analysis

All numerical data obtained were subjected to Analysis of Variance and Duncan’s New Multiple Range Test using Statistical Package for Social Science (SPSS) version 22.0 and the data are represented as mean ± standard error (SE). For all tests, the significance was determined at the level of at $P \leq 0.05$.

3. Results

3.1. Physical characteristics of cow dung from FUTA and Ilesha garage farm

The physical characteristics of cow dung gotten from FUTA and Ilesha Garage farm is presented in Table 1. The samples collected from FUTA appears in a semi solid state, dark green in colour with components of grass and corn while that of Ilesha Garage appears in components of only grass, semi solid and green in colour.

Table 1 Physical characteristics of cow dung from FUTA and Ilesha Garage farm

Content	FUTA farm	Ilesha Garage farm
Colour	Dark green	Dark green
Form	Semi solid	Semi solid
Component	Grass and corn	Mainly grass

3.2. Microbial load of cow dung obtained from FUTA and Ilesha Garage farm before voltage and current generation

The bacterial and fungal load of the cow dung before voltage and current generation is shown in table 2. Significant difference was observed among the cow dung sample from different location. FUTA has a microbial load of 1.08 x 10^6 cfu/g and fungal load 1.8 x 10^5 sfu/g of while Ilesha Garage has a microbial load 5.4 x 10^5 cfu/g of and fungal load of 1.4 x 10^5 sfu/g.

3.3. Microbial load of cow dung obtained from FUTA and Ilesha Garage farm after voltage and current generation

The bacterial and fungal load of the cow dung before voltage and current generation is shown in table 3. Significant difference was observed among the cow dung sample from different location. FUTA has a microbial load of 4.0 x 10^5 cfu/g and fungal load of 1 x 10^5 sfu/g while Ilesha Garage has a microbial load of 2.6 x 10^5 cfu/g and fungal load of 8 x 10^4 sfu/g.

Table 2 Microbial load of cow dung obtained from FUTA and Ilesha Garage farm before electricity generation

Sample	Bacterial (cfu/g)	Fungi (sfu/g)
FUTA farm	1.08 x 106	1.8 x 105
Ilesha Garage farm	5.4 x 105	1.4 x 105

KEY: cfu/g = colony forming unit per gram, sfu/g = spore forming unit per gram

Table 3 Microbial load of cow dung obtained from FUTA and Ilesha Garage farm after voltage and current generation

Sample	Bacterial (cfu/g)	Fungi (sfu/g)
FUTA farm	4.0 x 10^5	1 x 10^5
Ilesha garage farm	2.6 x 10^5	8 x 10^4

KEY: cfu/g = colony forming unit per gram, sfu/g = spore forming unit per gram

3.4. Biochemical test of bacterial isolates of cow dung from FUTA farm and Ilesha Garage farm

Biochemical characterization of bacterial isolates before voltage and current generation is shown in table 4. The result revealed 10 bacterial isolates were identified. The identified bacterial isolates from FUTA cow dung are *Providencia alcalifaciens, P. rettgeri, Escherichia coli, E. fergusonii, Morganella morganii* and *Staphylococcus haemolyticus* while that of Ilesha Garage bacterial isolates are *Staphylococcus aureus, Providencia alcalifaciens, P. stuartti and Micrococcus luteus.*

3.5. Morphological and cellular characteristics of fungal isolates of cow dung from FUTA farm and Ilesha Garage farm

The fungal isolates identified by morphological and cellular characteristics under the microscope are *Fusarium solani, Saccharomyces cerevisiae* and *Mucor mucedo* which is represented in Table 5.

Table 4 Biochemical characterization of bacterial isolates from cow dung

	Biochemical test																					
Isolate code	**TSIA**																	**Gram reaction**				**Tentative organism**
	Sucrose	**Glucose**	**Lactose**	**Gas**	**H_2S**	**Galactose**	**Ribose**	**Mannitol**	**Maltose**	**xylose**	**Fructose**	**Citrate**	**Motility**	**Indole**	**Mr**	**Vp**	**Starch**	**Shape**	**Gram**	**Catalase**	**Pigment**	
A1	-	+	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	Rod	-	+	-	*Providencia alcalifaciens*
B1	-	+	-	-	-	-	-	+	-	-	-	+	+	+	+	-	-	Rod	-	+	-	*Providencia rettgeri*
C1	+	+	+	+	-	+	+	+	+	+	+	-	+	+	+	-	-	Rod	-	+	-	*Escherichia coli*
D1	-	+	-	+	-	+	+	+	+	+	+	-	+	+	+	-	-	Rod	-	+	-	*Escherichia fergusonii*
E1	-	+	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	Rod	-	+	-	*Morgarella morganii*
F1	+	+	+	-	-	-	+	-	+	-	-	-	-	-	+	-	-	Cocci	+	+	-	*Staphylococcus haemolyticus*
A2	+	+	+	-	-	+	+	+	+	-	+	+	-	-	+	+	-	Cocci	+	+	+	*Staphylococcus aureus*
B2	-	+	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	Rod	-	+	-	*Providencia alcalifaciens*
C2	-	+	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	Rod	-	+	-	*Providencia stuartti*
D2	+	+	-	-	-	-	-	-	+	-	+	+	-	-	+	-	-	Cocci	+	+	+	*Micrococcus luteus*

Keys: Mr – methyl red, VP – Voges-Proskauer, (+)- positive, (-)- negative

Table 5 Morphological and cellular characteristics of fungal isolates of cow dung from FUTA farm and Ilesha Garage farm

Isolate	Morphological characteristics	Cellular characteristics	Tentative organism
1	Creamy round mycelium	Spherical collumella that bear the sporangiophores arranged in rows	*Saccharomyces cerevisiae*
2	White abundant cottony mycelium	Septate and branched hyphae at acute angle	*Fusarium solani*
3	White cottony mycelium	Unbranched sporangiophores	*Mucor mucedo*

3.6. Proximate composition of cow dung from FUTA farm and Ilesha Garage farm

The proximate composition of the cow dung from FUTA farm and Ilesha Garage farm is presented in table 6. The result showed a significant difference in the proximate composition of the cow dung from different location. Cow dung from FUTA farm had the highest value of moisture content, fat, crude fibre and carbohydrate with values of 5.271 ± 0^{b} %, 5.545 ± 0^{b} %, 1.275 ± 0^{a} % and 51.625 ± 0^{e} % while cow dung from Ilesha Garage farm had the highest values in ash content and crude protein which are 21.394 ± 0^{c} % and 27.822 ± 0^{c} %.

3.7. Physicochemical composition of cow dung from FUTA farm and Ilesha Garage farm

The physicochemical composition of the cow dung from FUTA farm and Ilesha Garage farm is presented in Table 7. A significant difference was observed between the samples from different location. Cow dung of FUTA farm had a physicochemical composition of 5.166 ± 0.06^{a} mg/L dissolved oxygen, $15{,}000\pm0^{h}$ Ns/cm electrical conductivity, 420.00 ± 1.15^{g} mg/L COD, 11.668 ± 0.001^{b} % organic matter, 30.666 ± 0.06^{d} mg/L BOD, 224.00 ± 1.15^{f} mg/L phosphate, 82.221 ± 0^{e} % total solids and 13.983 ± 0^{c} % total volatile solids while that of Ilesha Garage farm had 5.600 ± 0.11^{a} mg/L dissolved oxygen, $15{,}600\pm1.33^{h}$ Ns/cm conductivity, 840.66 ± 1.76^{g} mg/L COD, 12.832 ± 0^{b}% organic matter, 34.600 ± 0.11^{d} mg/L BOD, 272.00 ± 1.15^{f} mg/L phosphate, 77.154 ± 0^{e} % total solids and 14.213 ± 0^{c} % total volatile solids.

3.8. Mineral composition of cow dung from FUTA farm and Ilesha Garage farm

The mineral composition of the cow dung from FUTA farm and Ilesha Garage farm is shown in Table 8. The mineral composition includes potassium (K), sodium (Na), phosphorus (P), lead (Pb) and iron (Fe). The cow dung of FUTA farm had the mineral content of 59.680 ± 0^{e} mg/kg Potassium, 39.000 ± 1.15^{d} mg/kg Sodium, 0.460 ± 0.33^{c} mg/kg Phosphorus, 0.120 ± 0.01^{a} mg/kg lead and 0.150 ± 0^{ab} mg/kg Iron while Ilesha Garage farm had a mineral content of 42.500 ± 0.11^{e} mg/kg Potassium, 31.100 ± 0.11^{d} mg/kg Sodium, 2.100 ± 0.11^{c} mg/kg Phosphorus, 0.097 ± 0.01^{a} mg/kg lead and 0.172 ± 0^{ab} mg/kg Iron.

Table 6 Proximate composition of cow dung from FUTA farm and Ilesha Garage farm

Sample	Moisture (%)	Ash (%)	Fat (%)	Crude protein (%)	Crude fibre (%)	Carbohydrate (%)
FUTA farm	5.271 ± 0^{b}	15.608 ± 0^{c}	5.545 ± 0^{b}	20.676 ± 0^{d}	1.275 ± 0^{a}	51.625 ± 0^{e}
Ilesha Garage farm	4.981 ± 0^{b}	21.394 ± 0^{c}	4.040 ± 0.01^{b}	27.822 ± 0^{c}	0.583 ± 0^{a}	41.180 ± 0.01^{d}

Values are expressed in mean ± SEM. $P < 0.05$ was considered to be statistically significant

Table 7 Physicochemical composition of cow dung from FUTA farm and Ilesha Garage farm

Sample	DO (mg/L)	EC (Ns/cm)	COD (mg/L)	OM (%)	BOD (mg/L)	P (mg/L)	TS (%)	TVS (%)
FUTA farm	5.166±0.06[a]	15,000±0[h]	420.00±1.15[g]	11.668±0.001[b]	30.666±0.06[d]	224.00 ±1.15[f]	82.221±0[e]	13.983±0[c]
Ilesha Garage farm	5.600±0.11[a]	15,600±1.33[h]	840.66±1.76[g]	12.832±0[b]	34.600±0.11[d]	272.00±1.15[f]	77.154±0[e]	14.213±0[c]

Keys: DO= Dissolved solids, EC= Electrical conductivity, COD= Chemical oxygen demand, OM= Organic matter, BOD= Biological Oxygen Demand, P= Phosphate, TS= Total solids, TVS= Total volatile solids.

Values are expressed in mean ± SEM. $P < 0.05$ was considered to be statistically significant

Table 8 Mineral composition of cow dung from FUTA farm and Ilesha Garage farm

Sample	K (mg/kg)	Na (mg/kg)	P (mg/kg)	Pb (mg/kg)	Fe (mg/kg)
FUTA farm	59.680±0[e]	39.000±1.15[d]	0.460±0.33[c]	0.120±0.01[a]	0.150±0[ab]
Ilesha Garage farm	42.500±0.11[e]	31.100±0.11[d]	2.100±0.11[c]	0.097±0.01[a]	0.172±0[ab]

Keys: K= Potassium, Na= Sodium, P= Phosphorus, Pb= Lead, Fe= Iron

Values are expressed in mean ± SEM. $P < 0.05$ was considered to be statistically significant

3.9. Voltage generated from FUTA cow dung using carbon-carbon electrode

The voltage generated from FUTA cow dung using carbon-carbon electrode is presented in Figure 1. There were significant difference the voltage generated each day. The minimum and maximum voltage generated from the morning session was on day 1 with a voltage of 0.186±0 mV and day 8 with a voltage of 0.695±0.01 mV. In the afternoon session, the minimum and maximum voltage generated was on day 1 with a voltage of 0.221±0.11 mV and on day 8 with a voltage of 0.743±0 mV. In the evening session, day 1 had the minimum voltage of 0.239±0 mV and maximum voltage of 0.642±0.01 mV on day 11.

3.10. Current generated from FUTA cow dung using carbon-carbon electrode

The current generated from FUTA cow dung using carbon-carbon electrode is presented in Figure 2. There were significant difference in the current generated each day. The minimum and maximum current generated from the morning session was on day 1 with a current of 0.099±0.01 mA and day 8 with a current of 1.153±0.11 mA. In the afternoon session, the minimum and maximum current generated was on day 1 with a current of 0.115±0 mA and on day 8 with a current of 1.265±0 mA. In the evening session, day 18 had the minimum current of 0.180±0 mA and maximum current of 1.096±0.11 mA on day 8.

3.11. Voltage generated from FUTA cow dung using carbon-aluminium electrode

The voltage generated from FUTA cow dung using carbon-aluminium electrode is presented in Figure 3. There were significant difference the voltage generated each day. The minimum and maximum voltage generated from the morning session was on day 1 with a voltage of 0.215±0 mV and day 18 with a voltage of 0.354±0.01 mV. In the afternoon session, the minimum and maximum voltage generated was on day 1 with a voltage of 0.210±0.01 mV and on day 9 with a voltage of 0.480±0.01 mV. In the evening session, day 5 had the minimum voltage of 0.142±0 mV and maximum voltage of 0.521±0.01 mV on day 9.

3.12. Current generated from FUTA cow dung using carbon-aluminium electrode

The current generated from FUTA cow dung using carbon-aluminium electrode is presented in Figure 4. There were significant difference the current generated each day. The minimum and maximum current generated from the morning session was on day 6 with a current of 0.179±0 mA and day 19 with a current of 0.418±0.01 mA. In the afternoon session, the minimum and maximum current generated was on day 6 with a current of 0.216±0.01 mA and on day 9 with a current of 0.499±0.01 mA. In the evening session, day 5 had the minimum current of 0.145±0.01 mA and maximum current of 0.669±0.01 mA on day 9.

3.13. Voltage generated from Ilesha Garage cow dung using carbon-carbon electrode

The voltage generated from Ilesha Garage cow dung using carbon-carbon electrode is presented in Figure 5. There were significant difference the voltage generated each day. The minimum and maximum voltage generated from the morning session was on day 1 with a voltage of 0.202±0.11 mV and day 9 with a voltage of 0.709±0 mV. In the afternoon session, the minimum and maximum voltage generated was on day 1 with a voltage of 0.234±0 mV and on day 8 with a voltage of 0.698±0.01 mV. In the evening session, day 1 had the minimum voltage of 0.222±0 mV and maximum voltage of 0.737±0.01 mV on day 8.

3.14. Current generated from Ilesha Garage cow dung using carbon-carbon electrode

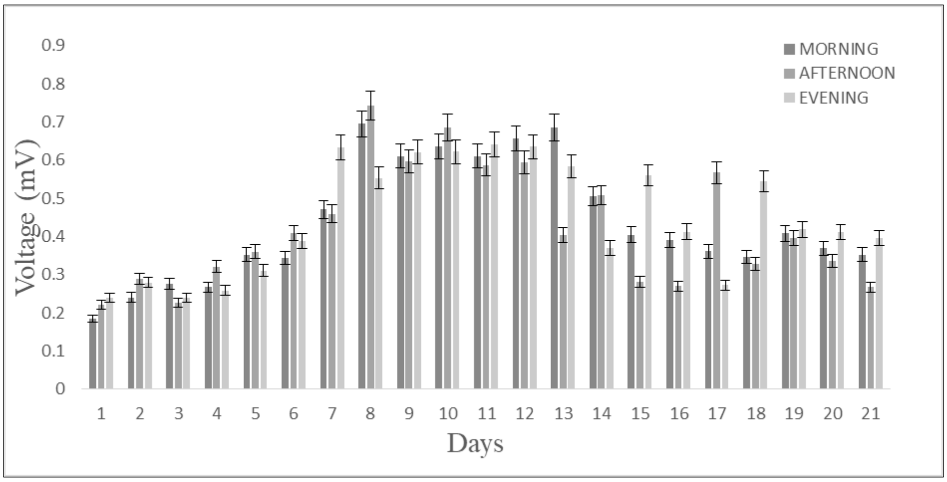
The current generated from Ilesha Garage cow dung using carbon-carbon electrode is presented in Figure 6. There were significant difference the current generated each day. The minimum and maximum current generated from the morning session was on day 17 with a current of 0.102±0.11 mA and day 8 with a current of 0.985±0.11 mA. In the afternoon session, the minimum and maximum current generated was on day 14 with a current of 0.170±0.11 mA and on day 8 with a current of 1.150±0.01 mA. In the evening session, day 16 had the minimum current of 0.176±0.01 mA and maximum current of 1.183±0.01 mA on day 8.

3.15. Voltage generated from Ilesha garage cow dung using carbon-aluminium electrode

The voltage generated from Ilesha Garage cow dung using carbon-aluminium electrode is presented in Figure 7. There were significant difference the voltage generated each day. The minimum and maximum voltage generated from the morning session was on day 4 with a voltage of -0.033±0 mV and day 14 with a voltage of 0.389±0 mV. In the afternoon session, the minimum and maximum voltage generated was on day 4 with a voltage of -0.018±0.01 mV and on day 12 with a voltage of 0.365±0.01 mV. In the evening session, day 3 had the minimum voltage of -0.104±0 mV and maximum voltage of 0.480±0 mV on day 9.

3.16. Current generated from Ilesha garage cow dung using carbon-aluminium electrode

The current generated from Ilesha Garage cow dung using carbon-aluminium electrode is presented in Figure 8. There were significant difference the current generated each day. The minimum and maximum current generated from the morning session was on day 4 with a current of -0.010±0 mA and day 9 with a current of 0.573±0.11 mA. In the afternoon session, the minimum and maximum current generated was on day 4 with a current of -0.024±0.1 mA and on day 9 with a current of 0.495±0.11 mA. In the evening session, day 3 had the minimum current of -0.074±0 mA and maximum current of 0.540±0 mA on day 12.



Error bar: +/- 2 SE

Figure 1 Voltage generation of cow dung obtained from FUTA farm using carbon-carbon electrode

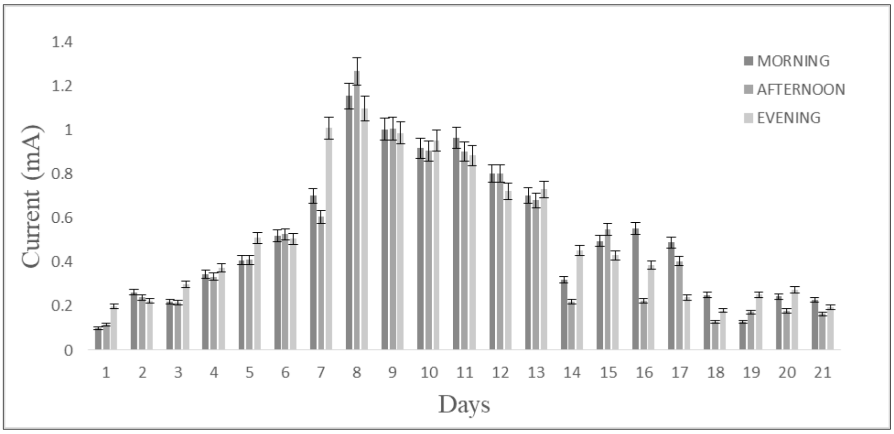


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Figure 2 Electric current generation of cow dung obtained from FUTA farm using carbon-carbon electrode

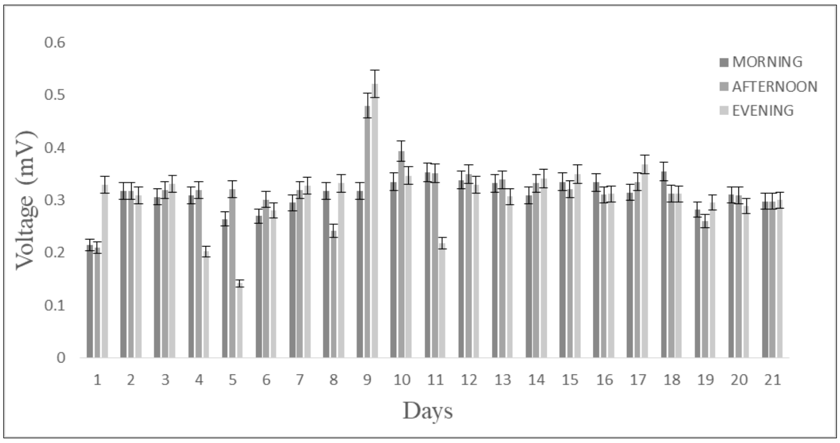

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Figure 3 Voltage generation of cow dung obtained from FUTA farm using carbon-aluminium electrode

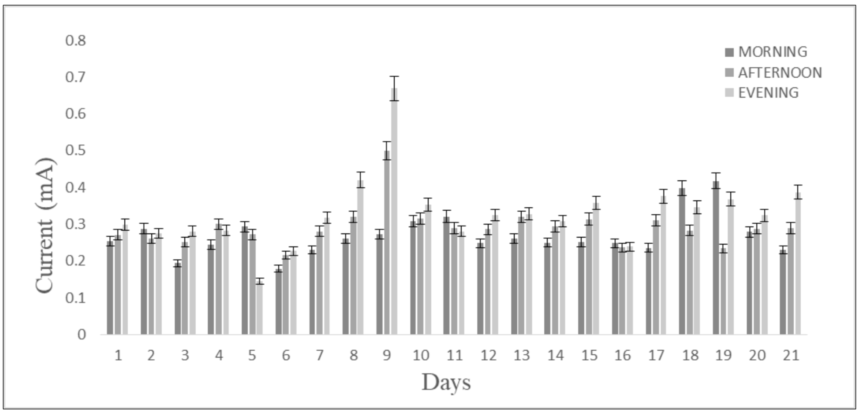

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Figure 4 Electric current generation of cow dung obtained from FUTA farm using carbon-aluminium electrode

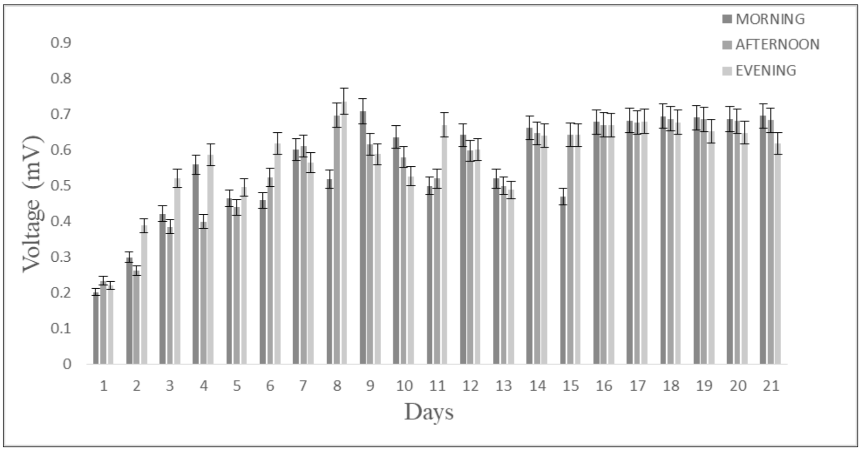

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Figure 5 Voltage generation of cow dung obtained from Ilesha Garage farm using carbon-carbon electrode

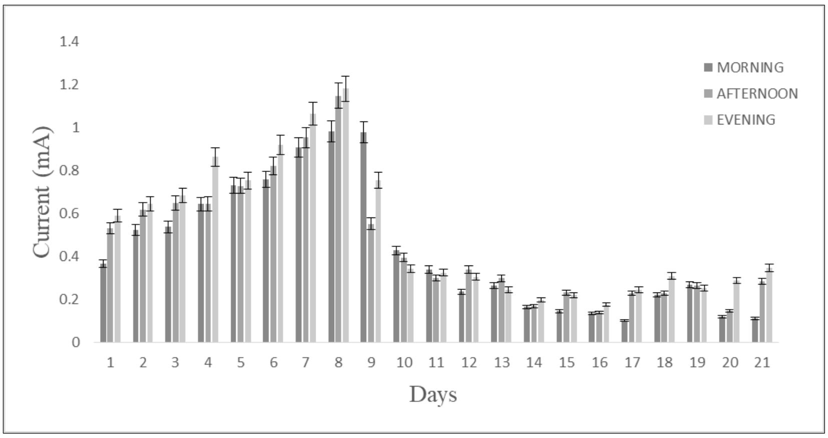

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Figure 6 Electric current generation of cow dung obtained from Ilesha Garage farm using carbon-carbon electrode

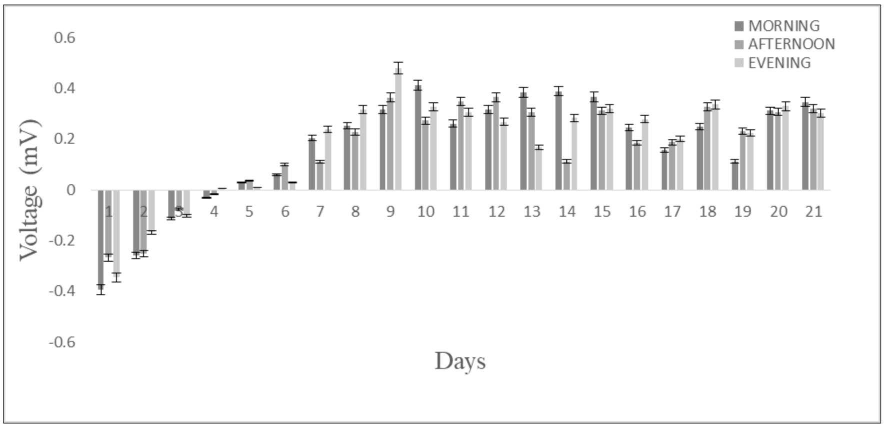

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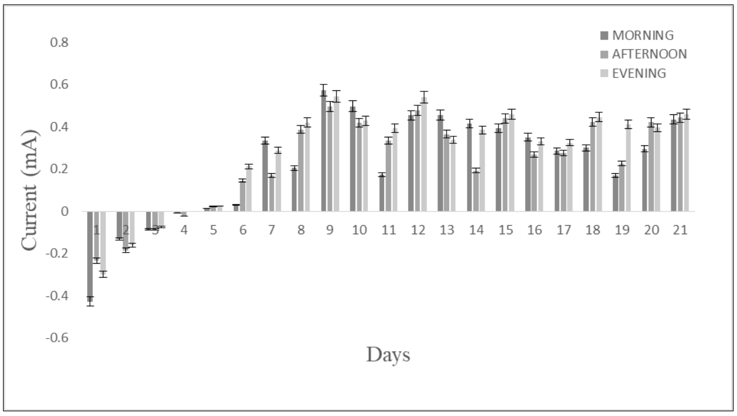
Figure 7 Voltage generation of cow dung obtained from Ilesha garage farm using carbon-aluminium electrode

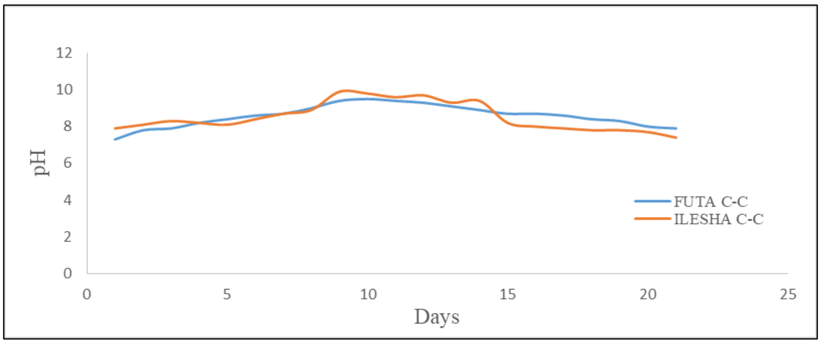


Error bar: +/- 2 SE

Figure 8 Electric current generation from Ilesha garage cow dung using carbon-aluminium electrode

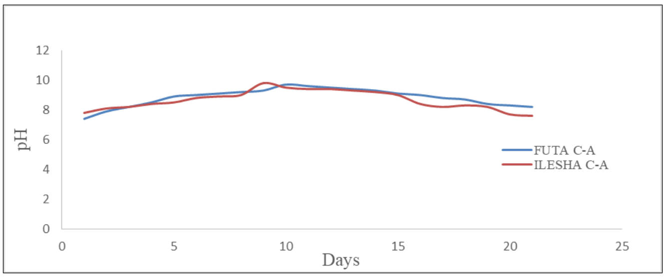
3.17. pH measurement of cow dung from FUTA farm and Ilesha Garage farm

The pH was measured daily for 21days and the pH ranged from neutral to alkaline. The highest and lowest pH of cow dung from FUTA farm using the carbon-carbon electrode were 9.5 and 7.3 on day 10 and day 1 respectively. The highest and lowest pH of cow dung from FUTA farm using the carbon-aluminium electrode were 9.7 and 7.4 on day 10 and day 1 respectively. The highest and lowest pH of cow dung from Ilesha Garage farm using the carbon-carbon electrode were 9.9 and 7.4 on day 9 and day 21 respectively. The highest and lowest pH of cow dung from Ilesha Garage farm using the carbon-aluminium electrode were 9.8 and 7.6 on day 9 and day 21 respectively.



KEY: FUTA C-C: Cow dung from FUTA farm using carbon-carbon electrode ; ILESHA GARAGE C-C: Cow dung from Ilesha Garage farm using carbon-carbon electrode

Figure 9 pH of cow dung obtained from FUTA farm and Ilesha Garage farm using carbon-carbon electrode

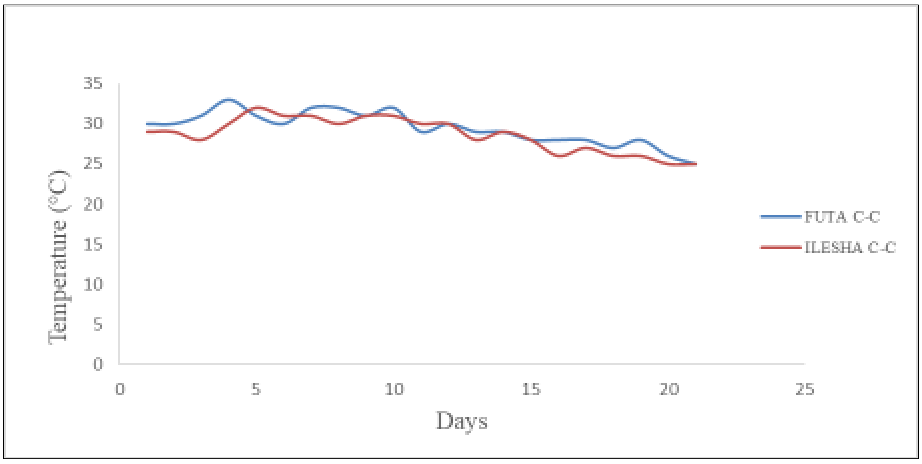


KEY: FUTA C-A: Cow dung from FUTA farm using carbon-aluminium electrode ; ILESHA GARAGE C-A: Cow dung from Ilesha Garage farm using carbon-aluminium electrode

Figure 10 pH of cow dung obtained from FUTA farm and Ilesha Garage farm using carbon-aluminium electrode

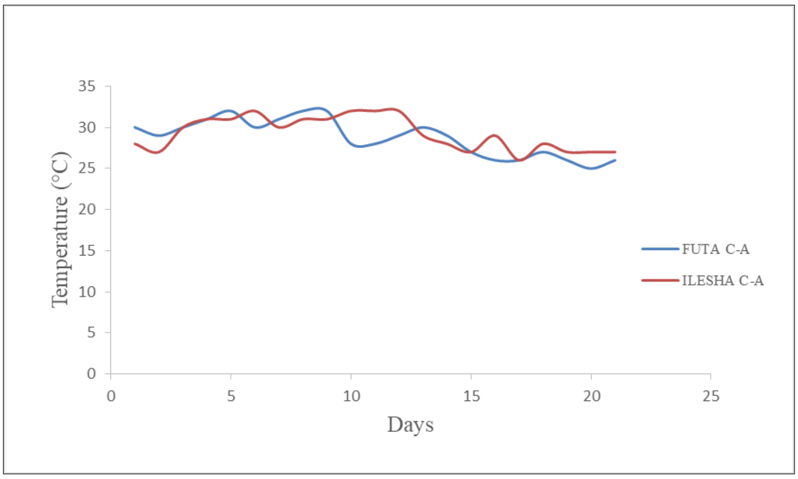
3.18. Temperature of cow dung from FUTA farm and Ilesha Garage farm

The temperature was measured daily for 21 days and the temperature ranged from 25 °C to 33 °C. The highest and lowest temperature of cow dung from FUTA farm using the carbon-carbon electrode were 33 °C and 25 °C. The highest and lowest temperature of cow dung from FUTA farm using the carbon-aluminium electrode were 32 °C and 25 °C. The highest and lowest temperature of cow dung from Ilesha Garage farm using the carbon-carbon electrode were 32 °C and 25 °C. The highest and lowest temperature of cow dung from Ilesha Garage farm using the carbon-aluminium electrode were 32 °C and 26 °C.



KEY: FUTA C-C: Cow dung from FUTA farm using carbon-carbon electrode ; ILESHA GARAGE C-C: Cow dung from Ilesha Garage farm using carbon-carbon electrode

Figure 11 Temperature of cow dung obtained from FUTA farm and Ilesha Garage farm using carbon-carbon electrode



KEY: FUTA C-A: Cow dung from FUTA farm using carbon-aluminium electrode ; ILESHA GARAGE C-A: Cow dung from Ilesha Garage farm using carbon-aluminium electrode

Figure 12 Temperature of cow dung obtained from FUTA farm and Ilesha Garage farm using carbon-aluminium electrode

4. Discussion

The production potential of cow dung from FUTA farm and Ilesha Garage farm for electric current and voltage generation was evaluated. The cow dung obtained from FUTA farm and Ilesha Garage farm was dark green in colour and semi-solid. The content of cow dung from FUTA farm contained both grass and corn residue while that of Ilesha

Garage farm contained only grass residue. This result is similar to a report of Kiyasudeen *et al.* [11] in which it was suggested that the content of the cow dung samples is due to the diets intake of the cow.

The microbial load of the cow dung sample before electricity generation showed that the cow dung sample from FUTA farm had a higher number of microbial load compared to the sample from Ilesha Garage farm. There was a reduction in the microbial load of the cow dung after electricity generation compared to the initial microbial load before electricity generation this could be due to nutrient depletion or exhaustion in the substrate, production of metabolic waste product leading to an increase in cell death of organisms. This result is in harmony with the result of Adegunloye and Faloni [12], in which it was stated that the microorganisms are important in the release and transfer of electrons which brings about the generation of voltage and current. The identified organisms are in accordance with the organisms identified in the study of Sawant *et al*. [13], Orji *et al.* [14], Thilagam *et al.* [15] and Adesiji *et al.*[16]. The presence of these organisms could be from the intestinal tract of the cow or from the surrounding soil environment.

The proximate composition of the cow dung across the two locations showed high abundance in the carbohydrate content and there was no much significant difference in the moisture content, crude protein, crude fibre, crude fat and ash content. The amount of proximate composition obtained from the two positions could be due to the type of feed consumed by the cow [11]. Cow dung from Ilesha Garage farm had a higher value in the ash content and crude protein. According to the results obtained the crude protein content of cow dung samples was relatively high, crude protein is the most important dietary nutrient in the samples are rich in microbial colonies. Proper evaluation of crude protein reflects the quality of protein intake or of the feed. This result is in harmony to the results of Kiyasudeen *et al.*[11], in which high crude protein content was reported in fresh cow dung samples from different locations.

The result of the dissolved oxygen and phosphate obtained is lower compared to the investigation of Kneitel and Croel [17] with a value of 68 mg/l and 655 mg/l respectively. The BOD and COD obtained is similar compared to the report of Hammad *et al.* [18] and Abdulkarim *et al.*[19]. Although the COD obtained were higher than those obtained in Hammad *et al.* [18] and lower than those obtained in Abdulkarim *et al.* [19] while the BOD obtained were the same with the report of Hammad *et al.* [18] and higher than those obtained in the report of Abdulkarim *et al.*[19]. Electrical conductivity determines the capability of cow dung to allow electrical current to pass through it. The electrical conductivity was generally high in all the cow dung samples although Ilesha Garage cow dung had the highest electrical conductivity. This result obtained is higher compared to the investigation of Adebayo *et al.* [20] where the electrical conductivity obtained was 2398 Ns/cm. The high electrical conductivity obtained could be attributed to the presence of some salts in the sample [21]. The organic matter, total solids and total volatile solids are similar to the report of Maduekeh *et al.* [22] and Kpera *et al.*[23]. The total volatile solids is in accordance with the report of Maduekeh *et al.* [22] but a higher value was obtained in the total solids and organic matter as in the report of Maduekeh *et al.* [22] and Kpera *et al.* [23]. The mineral composition of the cow dung which are potassium, phosphorus, lead, iron and sodium varied across the cow dung samples. The result of phosphorus, lead and iron obtained are lower compared to the reports of Maranon *et al.* [24] and Salihu *et al.* [25] but the result of potassium and sodium were higher compared to the report of Salihu *et al.* [25].

The study shows that there was a gradual increase in the voltage and current generated followed by a sudden rise and a gradual decline across the observation period. This agrees with the report of Parkash *et al.*[26]. The gradual increase in the voltage and current generated might be due to an increased microbial activity, formation of biofilm and enough nutrient availability while the gradual decline may be due to a reduced microbial activity, accumulation of metabolic by-product and depletion of nutrient availability. The maximum voltage generated from FUTA cow dung is in accordance with the study of Adesiji *et al.* [16] where a voltage of 0.78 mV was generated using a carbon-carbon electrode and cow dung as substrate. The maximum electric current generated is similar with the study of Thiagarajan *et al.* [27] where a current of 1.59 A was generated using a cow dung as substrate. The carbon-carbon electrode generated the highest amount of voltage and current compared to the carbon-aluminium electrode this might be due to biocompartibility and conductivity in the cathode chamber. In general, the cow dung from FUTA farm generated the highest voltage and current. Similar result was obtained by Adegunloye and Olotu, [28] in which it was ascertained that the difference in the result of the samples from different locations was due to the higher microbial growth observed which aided more current and voltage generation. On the day of highest electric current and voltage generation (day 8 and 9), the whole MFC set up were connected in series excluding the control and the set up was able to lit a green LED bulb.

The pH showed a sudden rise followed by a gradual decrease which is similar to the report of Agho *et al.*[29]. It was observed that the pH had an impact on the amount of voltage and current obtained. This is because the pH has the ability to affect microbial activity and disturb electron and proton generation mechanism [30].

The temperature had an influence on the amount of voltage and current generated. The result showed that the higher the temperature, the higher the amount of voltage and current generated and vice versa. This result is similar to the report of Harshitha *et al.* [31] and it was ascertained that the microbial activity and metabolic performance of bacterial is dependent on the temperature. In a study by Yong *et al.*[32], it was stated that the temperature range of 30 °C - 45 °C are more beneficial in obtaining a higher output.

5. Conclusion

This study has shown that the fabricated of MFC using cow dung has the potential to produce electric current. The result showed that the amount of voltage and current generated is dependent on the type of electrode used, biomass of the substrate, pH and temperature. The connection of the whole set up in series with the aid of a flexible wire was able to lit a green LED bulb. Hence, this experiment showed the feasibility and the ability of cow dung to produce electric current using a double chamber MFC.

Further research should be carried out on the use of MFC for generation of electricity on a larger scale, optimizing the parameters involved, genetic modification of the microorganisms responsible for the transfer of electrons, use of other waste products, modification and treatment of the electrodes and the modification of MFC design to improve the amount of electric current produced.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

Author's contribution:

The study was collectively executed by all authors. PIO: conceived and prepared the manuscript. DVA and DOB: substantial contributions to the conception. All authors read and approved the final manuscript.

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Availability of data and materials

The data can be accessed and shared to the public.

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