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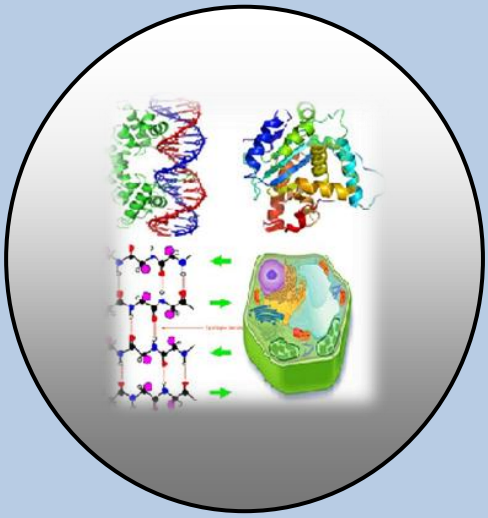

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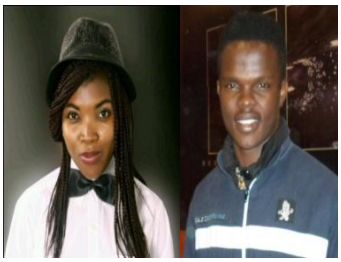

Akaluka, C.K. , Adeleye S.A.
http:// www.sasjournals.com
http:// www.jbcr.in
jbiolchemres@gmail.com
info@jbcr.in

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Abattoir Wastewater Treatment and Energy Recovery using a Biocathode Microbial Fuel Cell

Akaluka, C. K., Braide, W., Orji, J. C., Adeleye, S.A, Egbadon, E. O. and *Okey Mbata, C.C.
Department of Microbiology, Federal University of Technology, P.M.B 1526, Owerri, Imo State, Nigeria.
***Department of Biochemistry, Federal University of Technology, P.M.B 1526, Owerri, Imo State, Nigeria.**

The capacity of Microbial fuel cells to produce voltage and concurrently treat abattoir waste water was investigated. Two H-shaped (dual chamber) microbial fuel cells (DCMFC) were constructed with four transparent polyacrylic containers (1litre volume each), Two agar salt bridges were prepared in 10cm (length) by 3cm (diameter) polyvinylchloride (PVC) pipes each containing 2% molten agar and 1M sodium chloride. Graphite rod shaped electrodes for anode and cathode with dimension 12cm length by 1.2cm diameter where used. The waste water served as anolyte while the catholyte was made up of 1% glucose thereby modifying the cathode to become a biocathode. The open circuit voltage (OCV) and current readings were taken at 3 hours interval and maximum OCV of 557mV was recorded. Also, The physicochemical and microbial characteristics of the MFCs revealed that the pH decreased by 0.2 after treatment; COD, BOD, Ammonia, TSS, and Total Nitrogen decreased by 84.03%, 57.9%, 99.9%, 12.6% and 99.9% respectively. However, Phosphate increased by 16.88%. The bacterial isolates from the raw abattoir wastewater were Staphylococcus aureus, Bacillus cereus, Bacillus subtilis, Enterococcus faecalis, Enterobacteraerogenes, Escherichia coli and Micrococcus luteus while Enterococcus faecalis and Staphylococcus aureus were isolated from the biocathode.
Keywords: Biocathode, Microbial Fuel Cells, Physicochemical, Anolyte and Catholyte.

INTRODUCTION

More than 1.6 billion people live without access to electricity and an eco friendly environment globally. Experts estimate that 60-70% of the Nigerian population lack access

to clean environment and electricity (CREDC, 2007). Although oil, natural gas and coal are the resources for energy production today, these cannot sustain the teaming population in the future and also are not environmentally friendly as they contribute to air pollution (Logan, 2008). Currently, the solution to the looming energy crisis is to develop alternative sources of energy that is renewable and sustainable. On the other hand, waste water treatment is another global issue that is eating up the finances of industries and Nations (Ghanapriya *et al*., 2012). Existing treatment cost is estimated to be very expensive that some developing countries discharge the waste water untreated to the environment. Microbial fuel cells are unique in that they can produce energy as well as treat wastes (Rahimnejad *et al*., 2012; Logan *et al*., 2007; Liu *et al*., 2005). Electricity can be generated in microbial fuel cells using mixed cultures enriched from domestic waste water (Liu *et al*., 2005), animal waste (Min and Logan, 2004) and anaerobic sewage sludge (Liu *et al*., 2005). It has been demonstrated that a wide range of substrates (cellulose, sugars and acetone) can be used to capture electricity from organic matter using bacteria. Several configurations and outputs has also been reviewed (Logan *et al*., 2015). The flexibility of microorganisms to use a range of fuels especially wastes makes microbial fuel cell an ideal technology for renewable bioelectricity generation from biomass (Logan, 2009). Although the power densities currently generated from MFCs are too low to be considered as a viable alternative energy source (Frank*et al*., 2010). Much research efforts have been directed in this field in recent years (Liu *et al*., 2012; Wang and Ren, 2013; Rahimnejad *et al*., 2012). Abattoir waste water contains large loads of organic matter coming from the cow blood, rumen contents and wash water. The use of abattoir wastewater as a substrate for MFC that has a potential for degrading has been investigated (Momoh and Neayor, 2010a; Ghanapriya *et al*., 2012). Proper treatment of animal waste and resource recycling to reduce its environmental impact are currently important issues for the livestock industry (Ghanapriya *et al*., 2012). The process of power generation and simultaneous treatment of abattoir wastewater in large scale systems can become practicable with proper design and reactor configuration (Momoh and Naeyor, 2010a). In this research, the potential of MFCs to generate electricity and treat abattoir waste water was investigated by enriching the catholyte with analytical glucose so as to encourage growth of microorganisms thereby converting it to a biocathode.

MATERIAL AND METHODS

Collection of Abattoir Wastewater

Wastewater was collected from an abattoir at Relief market, Egbu road, Owerri, Imo state, Nigeria. They were collected aseptically into sterile bijou bottles for microbiological analysis and clean plastic containers for physicochemical analysis. The wastewater served as inoculum and organic substrate sources for the Microbial Fuel Cell without any modification such as adjustment of pH or addition of nutrients (Min *et al*., 2005a). The abattoir wastewater collected aseptically in sterile bijou bottles were transported to the microbiology laboratory immediately for analysis.

Microbiological analysis of raw Abattoir Wastewater

Prior to use in MFC, the abattoir wastewater was serially diluted ten-fold and plated out on Nutrient agar, EosinMethylene Blue agar, MacConkey agar and Mannitol Salt agar in duplicates using the spread plate technique. The plates were incubated at 37^{o}C for 24-48 hours.

Characterization of bacterial isolates

Distinct colonies from the plates were purified by sub culturing on Nutrient agar at 37°C for 24 hours. The isolates were then identified through microscopy (gram stain reaction, motility, sporulation and capsules were determined) and the following biochemical tests; catalase, oxidase, coagulase, methyl red, indole, Vogues Proskauer, citrate and carbohydrate fermentation tests; glucose, fructose, maltose, lactose and sucrose (Cheesbrough, 2000). The identities of the isolates were determined using standard manuals (Buchanan and Gibbon, 1984).

Physicochemical analysis

The following physicochemical analysis were carried out in a chemistry laboratory; conductivity, pH, total dissolved solid (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), phosphate, ammonia, total nitrogen and total suspended solid (TSS) according to American Public Health Association manual (1998). The physicochemical parameters were determined before and after the MFC experiment.

Estimation of biochemical oxygen demand

The respirometer was calibrated according to manufacturer's instruction. The abattoir wastewater was diluted with distilled water at a ratio of 1:10. One hundred milliliters of the diluted abattoir wastewater was transferred into the respirometer with the magnetic stirrer in place. The alkaline bung was filled with potassium hydroxide and the BOD sensor head was placed to cover the respirometer container. The BOD sensor was set and the initial dissolved oxygen (DO) value taken. Another respirometer containing 100ml of distilled water was set up which served as control. The respirometers (sample and control) were incubated at 20 ± 1°C in an incubator that had a stirring device. The time for incubation was taken. Readings of the BOD sensor was taken after 5 days. Difference in the dissolved oxygen (DO) between the final reading and initial reading was corrected for the 1:10 ratio dilution and recorded as BOD (APHA, 1998).

Chemical Oxygen Demand

The Chemical Oxygen Demand (COD) was determined using the closed reflux colorimetric method (APHA, 1998). The Tubetests heater was calibrated and the control was set to150°C and the safety shield was put in position. Two milliliter of the abattoir wastewater was transferred into the COD Tubetests tube using a clean standard laboratory pipette. Each Tubetests tube contained standard sulphuric acid, potassium dichromate and silver sulphate catalyst as prepared by the manufacturer. The caps of the COD Tubetests tubes were replaced tightly and each tube was gently inverted to mix the contents until all the precipitate was suspended. The Tubetest was labelled properly and placed in the Tubetests heater at 150°C with the safety screen in position.

Reagents blank was prepared by adding 2ml of deionized water into the Tubetests tube and placing it in the heater at the same time and temperature as the sample. The tubes were digested for two hours at 150°C and then the heater turned off. The tubes were removed and allowed to cool to room temperature. The reagent blank was used to zero the photometer at 490nm wavelength before the sample tubes were read and recorded (APHA, 1998).

pH

The pH meter was calibrated with a pH 7 buffer solution. The electrodes were rinsed with deionized water, damped lightly and inserted into the abattoir wastewater in a clean beaker. The pH reading was taken and recorded (APHA, 1998).

Phosphate

The abattoir wastewater was diluted with deionized water at a ratio of 1:20. Using a clean pipette, 5ml of the diluted wastewater was transferred into Tubetest cuvette and one Wagtech phosphate test tablet added into the tube and crushed with an applicator. Each phosphate test tablet contains the reagents; ammonia molybdate, ammonium metavanadate, hydrochloric acid, activated carbon and phenolphthalein indicator. After the test tablet had dissolved in the wastewater, it was allowed to stand for 15 minutes for the reaction to take place.

A blank was prepared along with the sample which contained the crushed test tablet in distilled water, allowed to stand for 15 minutes. The reagent blank was inserted in the photometer set at 490nm with phosphate test selected on the machine. It was zeroed with the reagent blank and reading of the sample tube was taken at the same wavelength (APHA, 1998).

Ammonia

The abattoir wastewater was diluted in distilled water at a ratio of 1:5. Using a clean pipette, 5ml of the diluted waste water was transferred into a test tube. 0.6ml of the NH4 reagent 1 (containing sodium chloride) was added to the sample. Then cap measurement of NH4 reagent 2 (containing a chlorinating agent) was added and the mixture was shaken vigorously and allowed for 5 minutes. Then 4 drops of NH4 reagent 3 (containing thymol) was added, mixed and allowed to stand for 5 minutes.

Reagent blank was prepared including all the reagents mentioned above while the sample was replaced with distilled water. Then it was poured into a cell/curvette and used to zero the photometer. Then the sample readings were taken with the photometer (APHA, 1998).

Conductivity

The conductivity meter was calibrated using potassium chloride of 0.01M (745.6mg of anhydrous KCL was dissolved in 200ml distilled water and diluted to 1000ml in a volumetric flask). The conductivity cell was rinsed with 0.01M KCL solution three times and in the fourth time, the temperature was adjusted to 25.0 ± 0.1°C. The probe in the standard KCl solution was adjusted to read 1412µmho/cm.

The probe was then inserted in a beaker containing the sample (wastewater), the temperature was adjusted to 25°C and the sample conductivity was taken (APHA, 1998).

Total Dissolved Solids (TDS)

The total dissolved solid was derived from half of the value of the conductivity measurement of the abattoir wastewater.

Total Nitrogen

Abattoir wastewater was dispensed into the alkaline persulfate digestion reagent pyrex tube at a volume ratio of 2 to 1. It was capped tightly and mixed properly then digested on a heater at 100-110ºC for 1 hour. When the digestion cycle was complete, the alkaline persulfate pyrex tube was removed from the heater and allowed to cool. After cooling, the total nitrogen was determined using a colorimeter at 540nm.

Total Suspended Solids (TSS)

A glass-fiber filter disk of a filtration apparatus was washed and vacuumed three times with 20 ml portions of reagent grade water. The filter was then inserted on an aluminum weighing dish and weighed. The filter apparatus was assembled and wet with the reagent-grade water. The abattoir wastewater was stirred to homogeneity and 10ml of the wastewater was pipetted onto the glass-fiber filter. The filter was then washed with successive 10-ml volume of reagent-grade water allowing complete drainage between washings and it was continuously suctioned for 3 minutes after filtration was complete. The filter was removed and weighed in the aluminum weighing dish. The total suspended solid (mg/ml) was determined as follows:

100(A-B)/ sample volume

Where A= weight of filter + dried residue in mg and

B= weight of filter in mg

Construction of H-shaped Microbial Fuel Cell

The microbial fuel cell was constructed according to methods described by Adeleye and Okorondu, (2015). It consists of an anode, a cathode and sometimes a membrane or separator between the electrodes (Rahimnejah *et al*., 2012). The anode chambers containing abattoir wastewater and the cathode chambers of the MFCs containing glucose water. In an MFC, the bacteria that oxidise a substrate are kept physically separated from the electron acceptor by a proton exchange membrane (Liu *et al*., 2004). The Proton Exchange membrane that separated the bacteria from oxygen, allows charge transfer between the electrodes (Logan, 2008). Organic matter (carbon source) is oxidized at the anode by microorganisms, called exoelectrogens, which transfer electrons to the electrodes (Werner *et al*., 2013). Through anaerobic metabolism of organic substances, by microorganisms electrons and protons are liberated (Banik *et al*., 2012).

Two H-shaped (dual chamber) microbial fuel cells (DCMFC) were constructed with eight transparent polyacrylic containers (1litre volume each). The containers were perforated and attached with an inner adapter using epoxy glue. Twoagar salt bridges were prepared in 10cm (length) by 3cm (diameter) polyvinylchloride (PVC) pipes each. The agar salt bridges contained 2% molten agar and 1M sodium chloride (Min *et al*., 2005b). Two containers were linked with an agar salt bridge interconnection. One chamber served as the anode and the other linked chamber served as the cathode.

Graphite electrodes for anode and cathode with dimension 12cm by 1.2cm where used. The electrodes were sanded lightly to increase the surface area for bacteria growth and attachment (Logan, 2008). Holes were bored in the lid of the anode and cathode chambers to allow the passage of coated copper wires which were connected to the stainless steel wires wound around the graphite electrodes. A second hole was bored on the lid of the cathode chambers to contain glucose solution; this was done to allow for aerobic respiration.

Determination of Open Circuit Voltage (OCV) and current generated in the MFC using different catholytes at room temperature

A total of two MFCs were set up at room temperature 30± 3°C. Nine hundred milliliters of abattoir wastewater were added into each anode chambers of the MFC set up (A and B) as shown in figure 1. Then Nine hundred milliliters of 1% glucose solution were added to the cathode chambers of the MFCs (A and B) as shown in figure 1.

Graphite electrodes were submerged in the anolytes and catholytes up till 10.5cm height and were connected with copper wires passing through the MFC lids. The anode chambers were covered tightly to enable an aseptic anaerobic microbiological condition while the cathode chambers for glucose were loosely tightened to enable aerobic respiration.

The copper wires connecting the electrodes from the MFC were connected to the probes of a multimeter and open circuit voltage (OCV) and current readings were taken at 3 hours interval for 20 days. A digital air thermometer was kept in the room housing the MFC setups, the air temperatures were monitored and recorded every 3 hours for 20 days.

Figure 1. H-shaped (dual Chamber) Microbial Fuel Cell set up.

RESULTS

The physicochemical parameters obtained from the experiment was used to calculate waste water treatment efficiency (WWTE) using the relation

$$WWTE = \frac{initial - final}{initial} \times 100$$

In this research, the chemical oxygen demand, biochemical oxygen demand, total suspended solids, ammonia, and total nitrogen reduced by 84.03%, 57.9%, 12.62%, 99.99% and 97.14% respectively. The pH of the abattoir wastewater decreased by 0.2.

Table 1. Initial and final physicochemical parameters of the abattoir waste water.

Parameters of physicochemical analysis	Before MFC treatment	After MFC treatment (glucose catholyte)
COD (mg/ml)	9350	1493
BOD (mg/ml)	2600	1095
TSS (mg/ml)	3250	2840
pH	7.2	7.0
Phosphate (mg/ml)	480	561
Conductivity (µs)	5.5	8.0 µs
Ammonia (mg/ml)	1.2	<0.01
TDS (ppm)	2.8	3.98
Total Nitrogen (mg/ml)	1.05	0.03

Determination of Open Circuit Voltage (OCV) and Current Generated in the MFC Using Different Catholytes at Room Temperature

The results of the estimation of the Open circuit voltage (OCV) using glucose catholyteis shown in Figure 2. The maximum open circuit voltage obtained was 557 mV. The OCV was 256 mV on the first day and rose gradually to give a maximum value of 557 mV on the 234th hour (≈10th day). After the 234th hour, the voltage dropped gradually to 433 mV on the 20th day.Using glucose as a catholyte, a biofilm was formed on the cathode which fed on the glucose solution in the cathode chamber. The biofilm accepted electrons from the anode chamber through the copper wires in the MFC. The glucose solution became cloudy at the end of the 20 days.

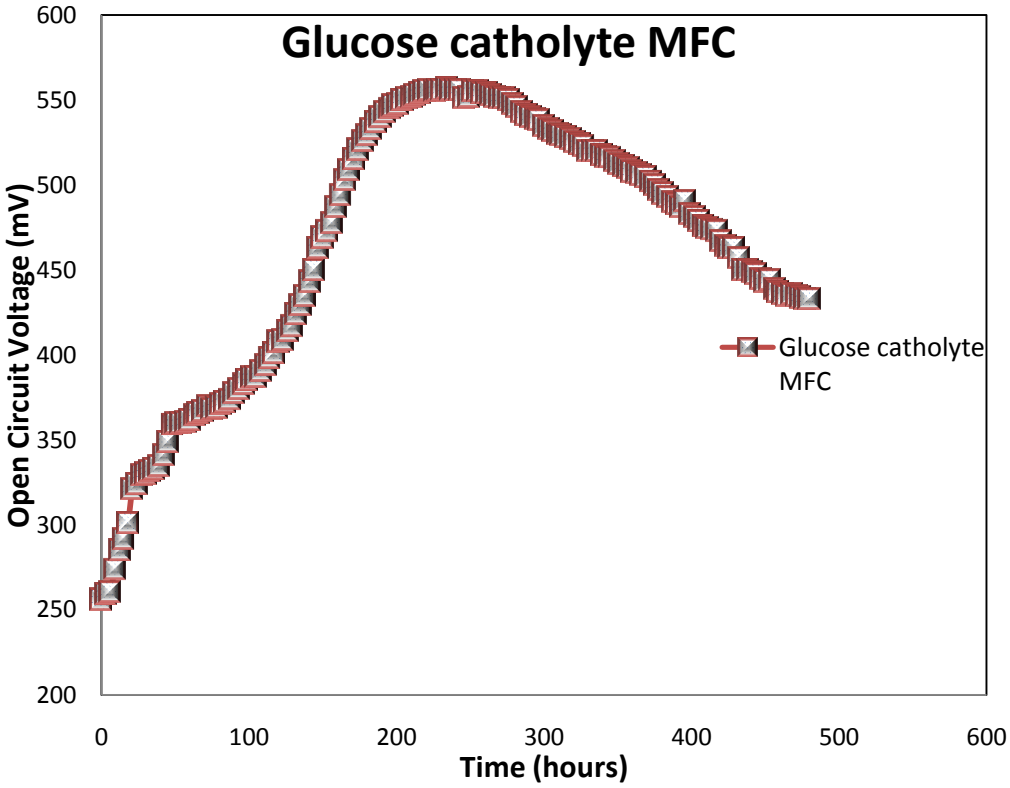

Figure 2. OCV in Millivolts Generated from Abattoir Wastewater Using MFC and Glucose Catholytes.

Comparison of the Microbiological Properties of the Abattoir Wastewater before and After Use in the MFC

The comparison of the microbiological properties of the raw abattoir wastewater and the used abattoir wastewater (after use on the H shape MFC for 20 days) is shown in Table 2. A large reduction in the population of microorganisms in the abattoir wastewater was observed in this study. Table 2 shows all the bacteria isolated from the abattoir wastewater before and the after use in the MFC. The bacteria isolated from the biofilms on the anode and biocathode of the MFC were alsoreported. The biochemical tests used to identify specific isolates in this study is presented in Tables 3, 4 and 5.

Table 2. Comparison of the microbiological properties of the raw abattoir wastewater and the used abattoir wastewater.

Bacterial Isolates before MFC treatment	Bacterial isolates after MFC treatment	Bacterial isolates on Anode (Exoelectrogenic bacteria)	Bacterial Isolates on Cathode (Electron acceptor)
Staphylococcus aureus	*Staphylococcus aureus*	*Enterococcus faecalis*	*Enterococcus faecalis*
Bacillus cereus	*Bacillus cereus*	*Bacillus cereus*	*Staphylococcus aureus*
Bacillus subtilis	*Bacillus subtilis*	*Escherichia coli*	
Micrococcus luteus	*Enterococcus faecalis*		
Enterococcus faecalis	*Escherichia coli*		
Enterobacter aerogenes	*Enterobacter aerogenes*		
Escherichia coli	*Klebsiella pneumoniae*		

DISCUSSIONS

The bacterial isolates from the raw abattoir wastewater were *Staphylococcus aureus*, *Bacillus cereus, Bacillus subtilis, Enterococcus faecalis, Enterobacter aerogenes, Escherichia coli* and *Micrococcus luteus*. The bacterial isolates from this study can be compared with some of the isolates from the abattoir wastewater research work done by Adesemoye *et al*., (2006) in which *Bacillus* spp and *Micrococcus luteus* were both isolated from the abattoir wastewater. In this study, *Escherichia coli* was isolated and this organism serves as an indicator of faecal contamination of abattoir wastewater and yet was not eliminated by the process. *Micrococcus luteus* which was previously isolated from the raw wastewater did not emerge after MFC treatment for 20 days. This may be because of the effect of reduced oxygen treatment for 20 days on the aerobic bacteria. *M. luteus* is an obligate aerobe (Woodward and Kell, 1991), thus this organism does not strive under anaerobic conditions.

The results of the physicochemical parameters represented in Table 1 presents the treatment capacity of the MFCs using glucose ascatholytes. The pH was initially at 7.2(near neutral) but decreased by 0.2 after treatment. The pH has been shown to be vital for the performance of an MFC. MFC performance peaks at pH 7 which is due to the microbial requirement for adaptation at that pH (Elakkiya and Matheswaran, 2013). The abundance and activity of microbial community are controlled by pH.

The chemical oxygen demand was9350 mg/mlbut finally became 1493mg/ml therefore obtaining about 84.03% treatment efficiency by the MFC. This parameter can be compared with the report by Ghangrekar and Shinde (2007) which gave a COD removal efficiency of 88% within 16-35 days. Elakkiya and Matheswaran (2013) reported a COD removal of 91% using a dairy wastewater in a dual chamber MFC. Liu *et al*., 2004 reported a COD removal efficiency of 80% for domestic wastewater.

Table 3. Characteristics of Bacterial Isolates from Abattoir Wastewater Prior to its Use in MFC (Before Electricity Generation).

Group	Colony	Colonial	Microscopic characteristics			Carbohydrate Fermentation						Biochemical Tests						Identity of Isolates
	Code	Morphology	Gram	Mot	Spore	Cap	G	F	M	L	X	Ca	Oxi	Coa	Ind	MR	VP	Cit	
THBC	NAW1	Golden yellow moist and shiny	+S	-	-	-	+	+	+	+	-	+	-	+	-	-	+	-	*S. aureus*
	NAW2	Creamy and flat	+R	+	+	-	+	+	-	-	-	+	-	-	-	-	+	+	*B. cereus*
	NAW3	Creamy and Low convex	+R	+	+	-	+	+	-	+S	+	+	-	-	-	-	+	+	*B. subtilis*
	NAW4	Yellow moist and shiny	+S	-	-	-	-	-	-	-	-	+	-	-	-	-	+	+	*M. luteus*
	NAW5	Creamy tiny circular	+S	-	-	-	+	+	+	+	-	-	-	-	-	-	+	+	*E. faecalis*
TEC	EMAW1	Metallic sheen	-R	-	-	-	+G	+G	+G	+G	+	+	-	+	+	-	-	-	*E. coli*
	EMAW2	Pink with purple dot	-R	+	-	-	+G	+G	+G	+G	+	+	-	-	-	+	+	+	*E. aerogenes*
TCC	MCAW1	Pink moist and shiny	-R	+	-	-	+G	+G	+G	+G	+	+	-	-	+	+	-	-	*E. coli*
	MCAW2	Pink mucoid	-R	+	-	-	+G	+G	+G	+G	+	+	-	-	-	-	+	+	*E. aerogenes*
TSC	MSAW1	Golden yellow low convex	+S	-	-	-	+	+	+	+	-	+	-	+	-	-	+	-	*S. aureus*

Keys: THBC = Total heterotrophic bacteria count, TEC = Total enterobacteriaceae count, TCA= Total coliform count, TSC= Total *Staphylococcus aureus* count, Gram= Gram staining reaction, Mot= Motility, Spore= Spore formation, Cap= Capsule, G- Glucose, F=Fructose, M=Maltose, L= Lactose, X=Xylose, Ca= Catalase, Coa=Coagulase, Oxi= Oxidase, Ind=Indole, MR=Methyl Red, VP=Vogues Proskauer, Cit=Citrate Utilisation, $+^{G}$ = positive plus gas production, +S = positive and spherical, +R= positive and rod-shaped.

Table 4. Characteristics of Bacterial Isolates from Abattoir Wastewater after Use in the MFC.

Group	Colony	Colonial	Microscopic characteristics			Carbohydrate Fermentation					Biochemical Tests							Identity of
	Code	Morphology	Gram	Mot	Spore	Cap	G	F	M	L	X	Ca	Oxi	Coa	Ind	MR	VP	Cit	Isolates
THBC	NAWA1	Golden yellow moist and shiny	+S	-	-	-	+	+	+	+	-	+	-	+	-	-	+	-	*S. aureus*
	NAWA2	Creamy and flat	+R	+	+	-	+	+	-	-	-	+	-	-	-	-	+	+	*B. cereus*
	NAWA3	Creamy and Low convex	+R	+	+	-	+	+	-	$+^{S}$	+	+	-	-	-	-	+	+	*B. subtilis*
	NAWA4	Creamy tiny circular	+S	-	-	-	+	+	+	+	-	-	-	-	+	-	-	+	*E. faecalis*
TEC	EMAWA1	Metallic sheen	-R	+	-	$+^{G}$	$+^{G}$	$+^{G}$	$+^{G}$	$+^{G}$	+	+	-	+	+	-	-	-	*E. coli*
	EMAWA2	Pink with purple dot	-R	+	-	$+^{G}$	$+^{G}$	$+^{G}$	$+^{G}$	$+^{G}$	+	+	-	-	-	+	+	+	*E. aerogenes*
TCC	MCAWA1	Pink mucoid	-R	+	-	$+^{G}$	$+^{G}$	$+^{G}$	$+^{G}$	$+^{G}$	+	+	-	-	-	+	+	+	*E. aerogenes*
	MCAWA2	Pink moist and shiny	-R	+	-	$+^{G}$	$+^{G}$	$+^{G}$	$+^{G}$	$+^{G}$	+	+	-	-	+	+	-	-	*E. coli*
	MCAWA3	Creamy raised convex	-R	-	+	$+^{G}$	$+^{G}$	$+^{G}$	$+^{G}$	$+^{G}$	+	+	-	-	-	-	+	+	*K. pneumoniae*
TSC	MSAWA1	Golden yellow low convex	+S	-	-	+	+	+	+	+	-	+	-	+	-	-	+	-	*S. aureus*

Table 5. Characteristics of Bacterial Isolates from Anode and Glucose Biocathode MFC.

Group	Total	Colony	Colonial	Microscopic characteristics			Carbohydrate Fermentation						Biochemical Tests						Identity of Isolates
	Count(cfu/ml)	Code	Morphology	Gram	Mot	Spore	Cap	G	F	M	L	X	Ca	Oxi	Coa	Ind	MR	VP	Cit	
Anode THBC	8.2×10^5	NA/AN1	Creamy Low convex	+S	-	-	-	+	+	+	+	-	-	-	-	-	+	-	+	*E. faecalis*
		NA/AN2	Creamy dull and dry	+R	+	+	-	+	+	-	-	+	-	-	-	-	-	+	+	*B. cereus*
TEC	3.5×10^5	EMB/AN1	Metallic sheen	-R	+	-	-	+G	+G	+G	+G	+	+	-	+	+	-	-	-	*E. coli*
TCC	6.5×10^5	MCA/AN1	Pink moist and shiny	-R	+	-	-	+G	+G	+G	+G	+	+	-	+	+	+	-	-	*E. coli*
Cathode THBC	9.8×10^6	NA/CA1	Creamy Low convex	+S	-	-	-	+	+	+	+	-	-	-	-	-	+	+	+	*E. faecalis*
TSC	7.0×10^5	MSA/CA1	Golden yellow low convex	+S	-	-	-	+	+	+	+	-	+	-	+	-	-	+	-	*S. aureus*

The totals suspended solids, biochemical oxygen demand, ammonia and total nitrogen of the used wastewater also decreased. The 57.9% decrease in BOD MFCs were as a result of the dissolved oxygen consumed by the indigenous microorganisms. Total nitrogen and ammonia for decreased by 99.9% respectively. This large decrease in values may have been as a result of dentrification and ammonia oxidation activities that took place in the anode chamber under reduced oxygen conditions (Min *et al*., 2005a).

Contrary to nitrogen, phosphate increased by 16.88%. An explanation for this may be that the low redox potential in the anode cells leads to a release of inorganic phosphate from organic matter (Min *et al*., 2005a). Conductivity and total dissolved solids (TDS) increased in the abattoir wastewater which may be as a result of mineralization that took place during the running of the MFC. The MFC was operated at room temperature of 30 ± 3°C for 20 days in a batch mode. The abattoir wastewater was not buffered and no external microorganism was introduced into the anode. The indigenous exoelectrogenic organisms in the abattoir wastewater broke down the organic matter in the abattoir wastewater and thereby generated electricity. The open circuit voltage (OCV) and current readings were taken at 3 hours interval. The maximum OCV readings were 557mV. The maximum OCV for glucose biocathode (557 mV) was as a result of the difference between the potential at the anode (where exoelectrogenic microorganisms donated electrons to the graphite) and the cathode (where microorganisms that formed biofilm on the graphite accepted electrons while feeding on glucose) (Logan, 2008). The OCV started at 256 mV and gradually climbed until the 234th hour when the maximum was 557 mV. Followed by a constant dropping towards the end of the MFC experiment. This also shows that the glucose may have been depleted and organisms in the biocathode needed more nutrients to function effectively as electron acceptors.

The maximum OCV generated in this study (Figure 2) was low when compared to the report of Momoh and Naeyor (2010b) and Adeleye and Okorondu, (2015). This low OCV will translate to low power density (Logan, 2008). The possible cause of the low OCV and current readings observed in this study may be as a result of the high strength abattoir wastewater which has an COD of 9350 mg/l used in the set-up and poor utilization of the graphite anodes (Momoh and Naeyor, 2010b). Also, H shape or dual chamber MFC has high internal resistance (Logan, 2008) which may have contributed to the low OCV. The electricity supply in the H shape microbial fuel cell was erratic. Therefore, research is needed to combat the internal resistance and produce better electrodes and devices that will trap the electricity for upscaling purposes (Logan *et al*., 2015).

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Corresponding author: **Adeleye, S.A., Department of Microbiology, Federal University of Technology, P.M.B 1526, Owerri, Imo State, Nigeria.**
Email: cynthia.akaluka@futo.edu.ng adeleyesamuela@gmail.com