



Data Article

Experimental dataset on the effect of electron acceptors in energy generation from brewery wastewater via a microbial fuel cell



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ABSTRACT

This research data set contains data related to experimental dataset on the effect of the electron acceptors in energy generation from brewery wastewater via a microbial fuel cell. The presented data gives information on the generation of electricity and waste minimization as various electron acceptors adopted in microbial fuel cells. Dual-chamber microbial fuel cell (MFC) system was assembled with aluminium mesh electrode as an anode and sulfonated tetrafluoroethylene membrane for proton exchange as a cathode at 500–2000 mg/L chemical oxygen demand (COD). A 0.4 and 0.6 M of Potassium permanganate (KMnO_4) and potassium cyanide $\text{K}_3[\text{Fe}(\text{CN})_6]$ were used anaerobically as a mediator for electron acceptor in the cathode chamber. Further more, The pH, COD, total nitrogen, biochemical oxygen demand, total phosphorous, total suspended solid and electrical conductivity for the raw brewery wastewater were measured. In addition, the voltage generated and the current density have been obtained for both (KMnO_4) and $\text{K}_3[\text{Fe}(\text{CN})_6]$ electron acceptors. Moreover, the COD removal efficiency, Coulombic efficiency, voltage generation, current, and power density were measured.

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Specifications Table

Subject	Chemical Engineering
Specific subject area	Chemical Engineering, Energy and Environmental Engineering
Type of data	Tables, Figures, Image
How data were acquired	Electrical conductivity (Oyster conductivity meter), pH (Model HI9024, HANNA), total nitrogen (HACH DR900 photometer), pH meter (Model HI9024, HANNA Instrument), total phosphorus (HI713-25 Phosphate LR reagents), total suspended solids (TSS) (HACH DR900 photometer) have been used for data collection. The chemical oxygen demand value was measured using photometer based on American society for testing,1995.Standard test method for a chemical oxygen demand (dichromate oxygen demand of water) was employed [1]. Voltage generation and current density were measured using a digital multimeter (Fluke multimeter 87, USA). The voltage generated in the microbial fuel cell system was recorded using the digital voltmeter at an interval of 12 h for 20 days. The corresponding current generated, power outage, power density and current density were calculated using Eq. (1), (2), (3) and (4) according to Ohm's law. The polarization curves were determined from the voltages and currents obtained by varying changing external resistors ranges from (2000–50) Ω . Based on each value, power and current density were determined using equations (3) and (4). Afterwards, the polarization curve was plotted in terms of current and power density vs voltage followed by power density curve which was initially obtained from the tabulated value of current against power density. The internal resistance of the microbial fuel cell (MFC) was determined according to the method employed for polarization slope method which was reported somewhere else [2,3]. The removal efficiency of MFC for each COD concentration of the wastewater sample was calculated using equation (5). The data has been analyzed with an error bar using sigma plot version 14.0.
Data format	Raw, analysed and filtered
Parameters for data collection	The voltage generated in the MFC system was measured with a digital voltmeter with an interval of 12 h for 20 days. The corresponding current generated, power outage, power density, and current density were calculated according to Ohm's law. The polarization curves were obtained from a plot of voltages and currents whereas the power density curve was found from the plot of power density and current density. The internal resistance of the MFC was calculated from the polarization slope. The removal efficiency of MFCs for each COD concentration of brewery wastewater was calculated using the various equations applied in the experimental data.
Description of data collection	Wastewater samples (anaerobic mixed sludge in type) were collected from the dashen brewery industry wastewater treatment plant. A physico-chemical composition of the wastewater samples has been tested before inoculated into the assembled MFC system. Data were measured in terms of COD, Columbic efficiency (CE), voltage generation rate, power density and polarization curves to evaluate the performance of the microbial fuel cell system for different electron acceptors and molar concentrations.
Data source location	GPS Coordinate (Latitude and Longitude):11.370N&37.10E Bahir Dar Institute of Technology, Bahir Dar University, Bahir Dar Ethiopia
Data accessibility	Mendeley data/microbial fuel cell data Data identification number: 10.17632/gydpvxvj8gp.1 Direct URL to data: https://data.mendeley.com/datasets/gydpvxvj8gp/1

Value of the Data

- The data could be valuable for engineers or scholars of the field who optimize the process variables, mitigate the waste management issues and generate energy from the waste.
- The experimental data are needed to optimize microbial fuel cell performance with electron acceptors formulation.
- The experimental data illustrates the effect of two different electron acceptors on the removal and CE, voltage generation rate, polarization curve, power and current density derived from waste sample taken from brewery waste treatment plant.
- The experimental data indicates that the approach applies to possible future research directions in waste water treatment and energy generation using MFC.

1. Data Description

The experimental data set contains data describing the effect of two different electron acceptors on the performance of MFCs in terms of voltage generation, power density, current density, and COD removal efficiency of wastewater obtained from the brewery industry. Table 1 shows the average physicochemical composition values of wastewater used for the experiment. We obtained a COD value of 2700 mg/L, a total nitrogen (TN) value of 42 mg/L, Biological oxygen demand (BOD) value of 1200, a total phosphorous value (TP) of = 55 mg/L, and an electrical conductivity (σ) of 132×10^{-6} S/cm and these values were similar with the literature values reported somewhere else [4,5] indicating that brewery wastewater has the potential for electricity generation using MFC [6,7]. Table 2 illustrates the wastewater sample, distilled water and culture loading volume and Table 3 presents the range of electron acceptor concentrations for KMnO_4 and $\text{K}_3[\text{Fe}(\text{CN})_6]$. Fig. 2 illustrates the effect of electron acceptors for 0.4 M of KMnO_4 and $\text{K}_3[\text{Fe}(\text{CN})_6]$ on the removal and CE based on comparative values obtained from voltage generation curves (Figs. 3–6). Figs. 3 and 4 depict the voltage generation potential of the MFC using 0.4 and 0.6 M of KMnO_4 electron acceptor. Moreover, Figs. 5 and 6 present the voltage generation potential curve of the MFC using 0.4 M $\text{K}_3[\text{Fe}(\text{CN})_6]$ and 0.6 $\text{K}_3[\text{Fe}(\text{CN})_6]$ as electron acceptor.

Table 1

Average physicochemical composition of Dashen brewery wastewater (Note: All values except pH & σ are in mg/L. σ is in $\mu\text{S}/\text{cm}$).

Parameters	pH	COD	TN	BOD	TP	TSS	σ
Values	8.15	2700	42	1200	55	600	132

Table 2

Volume of waste water sample, distilled water and culture loading (Note: All values except COD are in mL. COD value is in mg/L).

Volume of wastewater sample	Volume of culture medium	Volume of distilled water	Total volume of sample loaded to the MFC	COD
1400	100	0	1500	2000
1250	100	150	1500	1500
750	100	650	1500	1000
500	100	900	1500	500

Table 3

Concentration of electron acceptor solution used in the experiment.

Parameters	Cathode ($\text{K}_3[\text{Fe}(\text{CN})_6]$)	Cathode (KMnO_4)
Electron acceptors solution concentration	0.4 M	0.4 M
	0.6 M	0.6 M



Fig. 1. MFC set up used for the experimental tests. Source: photo credit by the present authors.

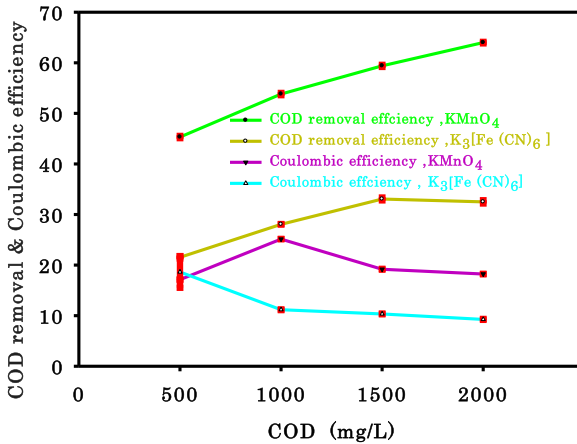


Fig. 2. CE and COD removal efficiency of MFC using 0.4 M KMnO_4 and $\text{K}_3[\text{Fe}(\text{CN})_6]$ as an Electron acceptor with error bar. [Supplementary files provided as DIB at Mendeley data/microbial fuel cell data, <https://doi.org/10.17632/gydpvxj8gp.1>]

Fig. 7 (a) and (b) illustrate the power density and polarization curve. Fig. 7 (a) represents the effect of 0.4 M KMnO_4 electron acceptors on the power generation potential of the MFC. Fig. 7 (b) represents the effects of 0.4 M $\text{K}_3[\text{Fe}(\text{CN})_6]$ on the power generation potential of the MFC.

Fig. 1 indicates an experimental set up of the MFC for inoculation of brewery wastewater. Fig. 2 illustrates the effect of electron acceptors (0.4 M of KMnO_4 and $\text{K}_3[\text{Fe}(\text{CN})_6]$) on the removal and CE based on the comparative values obtained from the voltage generation curves (Figs. 3–6). Figs. 3 and 4 show data for 0.4 and 0.6 M concentrations of KMnO_4 on the voltage generation potential of the MFC with error bar. Moreover, Fig. 5 and 6 depict the effect of 0.4 and 0.6 M concentrations of KMnO_4 and $\text{K}_3[\text{Fe}(\text{CN})_6]$ on the voltage generation potential of the MFC with error bar. The power density and polarization curve (Fig. 7a and b) have presented the effect 0.4 M of KMnO_4 and $\text{K}_3[\text{Fe}(\text{CN})_6]$ on the power generation potential of the MFC. For all experiments each measurement has been done for three times. All calculated values have been found from supplementary materials as DIB at Mendeley Data/Microbial fuel cell data, [10.17632/gydpvxj8gp.1](https://doi.org/10.17632/gydpvxj8gp.1).

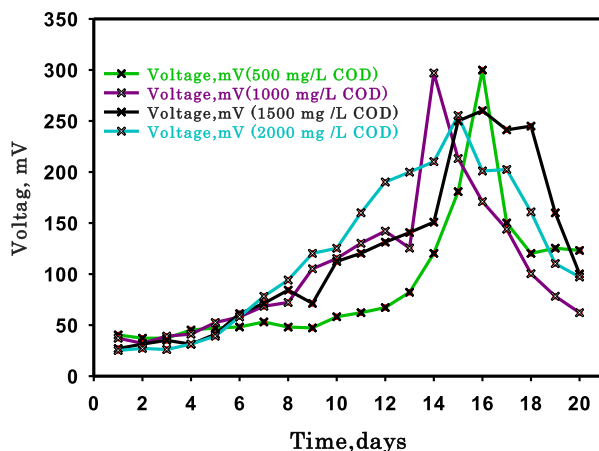


Fig. 3. Voltage generation potential of the MFC using 0.4 M KMnO_4 electron acceptor with error bar. [Supplementary files provided as DIB at Mendeley data/microbial fuel cell data, <https://doi.org/10.17632/gydpvxj8gp.1>]

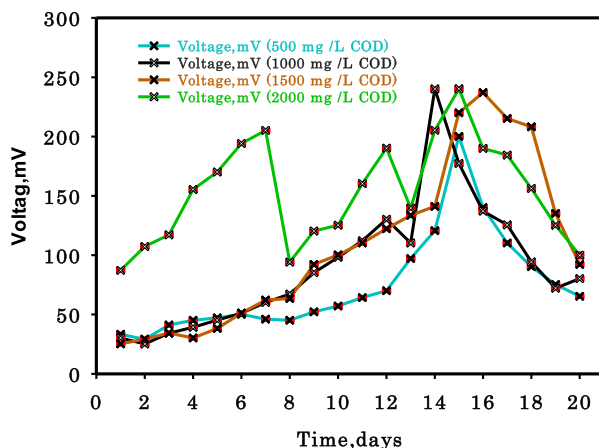


Fig. 4. Voltage generation potential of the MFC using 0.6 M KMnO_4 electron acceptor with error bar [Supplementary files provided as DIB at Mendeley Data/Microbial fuel cell data, <https://doi.org/10.17632/gydpvxj8gp.1>]

2. Experimental Design, Materials and Methods

2.1. Materials, chemicals and reagents

Sulfonated tetrafluoroethylene copolymer (product of DuPont Inc. USA) was used as a proton exchange membrane. The voltage and current generated for the inoculated samples in the MFC were measured using a digital multi-meter (Fluke multimeter 87, USA). Electrical conductivity was measured with a conductivity meter (Oyster conductivity meterTM 34135A-P, India).

Potassium Permanganate (KMnO_4 (98.0%)) and Potassium ferricyanide ($\text{K}_3[\text{Fe}(\text{CN})_6]$ (99.5%)) were used as an electron acceptor in the cathode chamber for MFC setup. KOH (97%) and NaOH (97%) were used for medium (pH regulation). Sulfuric acid (H_2SO_4 (90%)), Nitric acid (HNO_3 (90%)), Potassium dichromate (90% ($\text{K}_2\text{Cr}_2\text{O}_7$)), and Mercuric sulfate (90% (HgSO_4)) were used as reagents for digestion of the samples for COD value determination. Phosphate

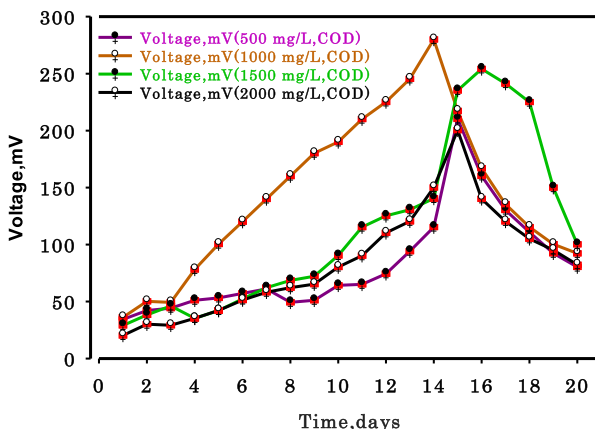


Fig. 5. Voltage generation potential of the MFC using 0.4 M $K_3[Fe(CN)_6]$ electron acceptor with error bar [Supplementary files provided as DIB at Mendeley Data/Microbial fuel cell data, <https://doi.org/10.17632/gydpxvj8gp.1>]

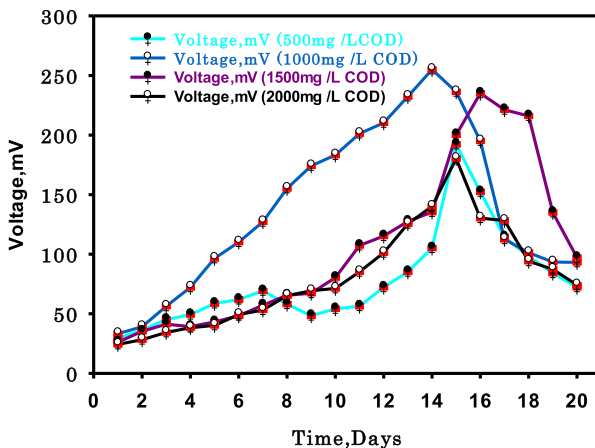


Fig. 6. Voltage generation potential of the MFC using 0.6 M $K_3[Fe(CN)_6]$ electron acceptor with error bar [Supplementary files provided as DIB at Mendeley Data/Microbial fuel cell data, <https://doi.org/10.17632/gydpxvj8gp.1>]

(HI713-25 Phosphate LR reagents) All chemicals and reagents used for this study were purchased from LBS Marg, Mumbai -400086, India and analytical grades.

2.2. Experimental procedure for MFC setup, sample characterization and sample loading

A container with a total volume of 2 L were used in the experiment. A proton exchange membrane was installed between two chambers in a flexible plastic tube (4 cm in length and 3 cm in diameter) to allow proton transfer from the anode to the cathode chamber. Both the anode and cathode chamber consist of graphite electrodes with a dimension of 4 cm by 5 cm [8]. The electrodes were inserted through the holes on the top of the chamber. The anode chamber was kept in anaerobic condition by purging nitrogen gas while the cathode chamber was connected with an oxygen pump to form aerobic condition. The two copper wires were attached

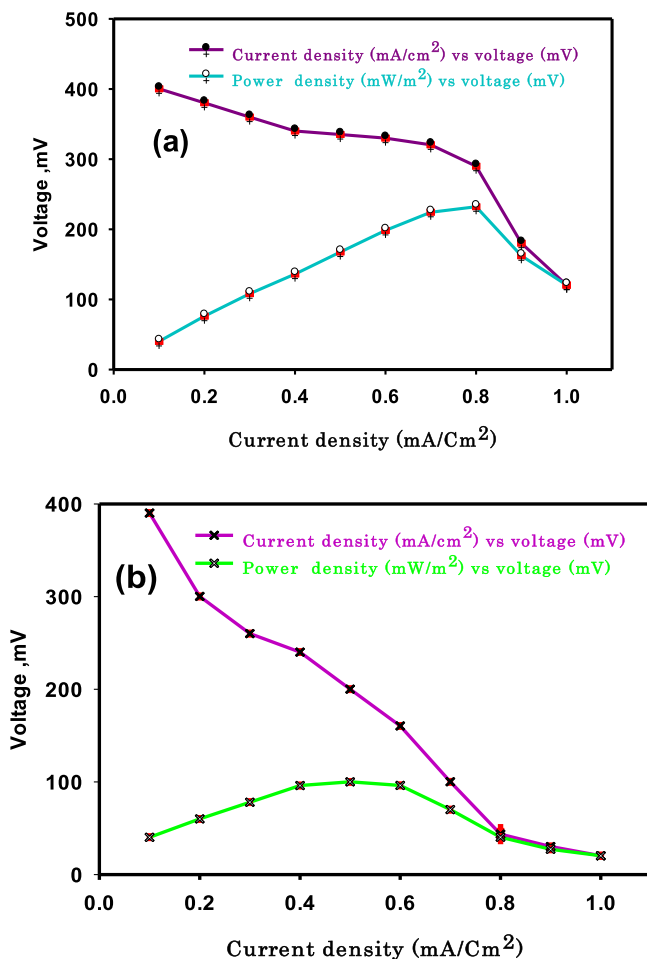


Fig. 7. Polarization and power density curves for a maximum voltage generation efficiency (COD,1000 mg/L) with error bars. 0.4 M KMnO₄ (7a). 0.4 M K₃[Fe(CN)₆] as a final electron acceptor (7b). [Supplementary files provided as DIB at Mendeley data/microbial fuel cell data, <https://doi.org/10.17632/gydpvxj8gp.1>]

to the anode and cathode electrodes. The other two ends of copper wires were connected to a digital multimeter to form an open-circuit voltage. The nutrient broth medium, which has been collected inside the anaerobic digester of the brewery wastewater treatment plant, was used for culturing bacteria. A 50 mL of mixed bacteria was cultured inside a 100 mL nutrient broth medium at 37 °C for 24 h, and then was transferred into the anodic chamber. The MFC was operated in a batch-load mode and inoculated with brewery wastewater and mixed bacterial culture. Anodic chamber with a total volume of 2 L and a working volume of 1.5 L were used. The anodic chamber was fed with mixed microbe (bacteria) and prepared substrates and operated at the anaerobic condition with a constant pH value reported somewhere else [6]. The cathode chamber was fed with a 0.4 M of KMnO₄ and M K₃[Fe(CN)₆] at a pH value of 8.5 with an anaerobic condition (Table 1). The MFC chambers were operated at atmospheric temperature. The voltage and current generated in the MFC were measured using a digital multi-meter (Fluke multimeter 87, USA).

2.3. Physicochemical characteristics of brewery wastewater

Raw brewery wastewater and laboratory cultured microorganisms were collected from dashen brewery treatment and were stored at 5°C until it was fed to the reactor to avoid degradation process of microbes in wastewater [6]. The physicochemical composition of brewery wastewater consisting of chemical oxygen demand (COD), biological oxygen demand (BOD), TN, TP, total suspended solids (TDS), σ and pH values were presented in Table (1) which were analyzed using standard American Water Works Association (AWWA) method.

2.4. Characterization

A standard 10 mL sample was taken and diluted with 50 mL distilled water for a high range COD determination according to the method employed somewhere else [1]. A 2 mL of diluted sample was added to the analytical grade reagents ($K_2Cr_2O_7$ and $HgSO_4$) and digested for 2 hrs at 105 °C. Then the COD values were measured using Spectrophotometer (Spectro UV-2502), and the results were multiplied by the dilution factor of 15. Moreover, the same sample volume was taken and diluted with 50% distilled water for COD determination. Then a 2 mL of sample from 50% diluted sample was taken and further diluted to 40 mL followed by 2 mL of the diluted sample was added to the reagents of 90% (H_2SO_4 , and HNO_3) and digested for 2 hrs at 148 °C from the prepared solution as per the method reported somewhere else [11]. The resulting solution was then cooled to room temperature followed by COD value determination using spectrophotometer. The COD value was multiplied by the dilution factor of 50. An electrical conductivity was measured with a conductivity meter (Oyster conductivity meter). A pH of the samples was measured with a portable pH meter (Model HI9024, HANNA Instrument). For TN measurement using TN persulfate reagent powder with a 5 mL of brewery wastewater was added to the test tube with a reagent. Then it was shaken well and allowed to stay for 2 min for a favor of complete reduction reaction. After 2 min, the instrument was allowed to be blank with a similar sample without reagent followed by the sample was analyzed using a spectrophotometer. For the TP determination using HI713-25 phosphate LR reagents, a 10 mL of brewery wastewater was added to the test kit with reagent followed by thorough mixing of the solution for the complete reaction of the sample. Similarly, a blank was prepared with a similar sample without a reagent. Afterwards, the sample inside the cuvette was measured by a HI96706 portable phosphorus spectrophotometer to measure the TP. TSS was determined by taking a 10 mL sample inside a cuvette using the spectrophotometer. A medium was prepared with nutrient broth for culturing of bacteria. The bacteria were taken from brewery wastewater treatment plant applicable for the process of anaerobic digestion. A 50 mL of mixed bacteria were cultured in a 100 mL nutrient broth medium at 37 °C for 24 h, followed by the bacteria was transferred into the anodic chamber [1,11].

2.5. Electrical capacity of the MFC

The voltage output from the MFC system was recorded using the digital voltmeter at an interval of 12 h for 20 days. The current (I) and power (P) were calculated according to Ohm's law using $I = V/R$ and $P = I \cdot V$ respectively, where V is the measured cell voltage in volts (V), R is the external load resistor in Ohms (Ω), I is current in amperes (A) and P is the power output P in watts (W) [9]. The corresponding power and current density were obtained by dividing the current (V/R) and the power ($I \cdot V$) with the surface area (A in m^2) of the anode. The polarization curves (voltage against current and power density) were obtained from the measured voltage and current values by varying the values of external resistors ranging from (2000, 1500, 1200, 1000, 700, 500, 300, 150, 100, 50 Ω). Besides, the power and current density were determined for each value of resistances. The corresponding power density curve was found from the plot of

current density versus power density. The internal resistance of the MFC was determined according to the method reported somewhere else [10]. The COD removal efficiency of the MFC was calculated by employing 2000 mg/L COD wastewater sample in the anodic chamber followed by replacing it with 1500, 1000, and 500 mg/L COD concentrations. All experiments were performed for 20 consecutive days in batch mode operation. The COD values of the samples were measured before and after the experiments have been carried out to have a comparative values of COD reduction efficiency. COD values of the analyte were measured according to the method reported somewhere else [1]. The COD removal efficiency (η_{COD}) for each brewery wastewater sample was calculated using $\eta_{\text{COD}} = \text{COD}_0 - \text{COD}_t / \text{COD}_0 * 100$, where COD_0 is the initial concentration of COD at time zero and COD_t is the concentration of COD at time, t. The CE of the MFC system was estimated using Eq. (1) according to the method reported somewhere else [2].

$$CE = \frac{8 \int_0^t Idt}{(Fb V_{\text{an}} \Delta\text{COD})} * 100\% \quad (1)$$

where 8 is molecular weight of O_2 , b is the number of electrons exchanged per mole of oxygen, F is the Faraday's constant (96485 C/mole - electrons), V_{an} is the cell internal volume the anode medium chamber, and ΔCOD , is equal to the difference between COD_{in} and COD_{out} (values in g/L).

2.6. Statistical tools used for data presentation and analysis

Microsoft Excel (2019) and sigma plot version 14.0 were used to generate statistical data and plots with an error bar.

All samples were measured three times for each batch and reported with mean followed by standard deviations. Raw experimental measured values were presented in the supplementary materials provided as DIB at Mendeley Data/Microbial fuel cell data, <https://doi.org/10.17632/gydpxvj8gp.1>

CRedit Author Statement

Tegen Dagnew Tessema: Designed the experiments (conceptualization), collected and analyzed the data, wrote the original draft editing, and proof reading; **Temesgen Atnafu Yemata:** supervised and reviewed the paper.

Supplementary Materials

Supplementary material associated with this article can be found in the online version at <https://data.mendeley.com/datasets/gydpxvj8gp/1/> doi:10.17632/gydpxvj8gp.1.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which could have appeared to influence the work reported in this paper.

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