ARTICLE IN PRESS

INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2018) 1–9

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Effect of recirculation on bioelectricity generation using microbial fuel cell with food waste leachate as substrate

Prachi Vikas Moharir*, Ajay Raghunath Tembhurkar

Visvesvaraya National Institute of Technology, Nagpur, 440010, Maharashtra, India

ARTICLE INFO

Article history:
Received 1 February 2018
Received in revised form
14 March 2018
Accepted 9 April 2018
Available online xxx

Keywords:
Microbial fuel cell
Recirculation
Bioelectricity
Food waste leachate

ABSTRACT

Recirculation is one of the effective techniques used to upsurge the output of anaerobic reactors. The present study investigates the effect of recirculation of anolyte on bioelectricity generation using food waste leachate in two chamber Microbial Fuel Cell (MFC) with carbon electrodes and Ultrex as proton exchange membrane (PEM). The MFCs are operated in fed-batch mode at varying COD concentrations of 500–1250 mg/L with the hydraulic retention time of 17 h for recirculation. Maximum current density, power density and columbic efficiencies of 100.34 mA/m^2, 14.42 mW/m^2 and 10.25% respectively for MFC without recirculation and 150.30 mA/m^2, 29.23 mW/m^2 and 14.22% respectively for MFC provided with recirculation are obtained at COD of 1250 mg/L. Comparative performance analysis of the cells indicates that recirculation enhances the bioelectricity production in MFC. Scanning Electron Microscope (SEM) and Fourier Transform Infrared Spectroscopy (FTIR) analyses are also done to find the changes in PEM.

Introduction

Most of the Municipal Solid Waste (MSW) generated from the cities is disposed in open dumps or in improperly designed and operated sanitary landfills leading to problems such as ground water pollution due to leachate percolation [1,2]. Food Waste (FW) which is the major component of MSW (30–55%) [3,4] is often more difficult to dispose because of its highly putrescible nature. Disposing FW in landfills leads to the formation of hazardous liquid called leachate which percolates down and can contaminate the ground water leading to many health related issues [5–7]. As in FW management hierarchy, reduction in FW generation is the most preferred option [8] but its recovery in terms of FW to energy is equally important and needs virtuous attention of the research community [9]. Various technologies have been used to convert food waste to a valuable product. Some of which are composting and anaerobic digestion which have been practiced for years [10–15]. These practices have their own advantages in terms of producing compost and biogas. However considering the present and future demand of the energy and the depletion of natural energy resources there is a need to produce direct usable energy from waste which can cater the demand and help in the management of the waste generated.

Microbial Fuel Cell (MFC) is a device which utilises microorganisms as a catalyst to convert the chemical energy embedded in the substrate into electrical energy [4,6,16,17]. It is considered as the green, safe, clean and direct source that converts any organic waste into electricity [5,7]. Recently,

* Corresponding author.
E-mail addresses: prachi.moharir@gmail.com (P.V. Moharir), artembhurkar@gmail.com (A.R. Tembhurkar).

https://doi.org/10.1016/j.ijhydene.2018.04.072

variety of substrates has been used in MFC for its conversion to bioelectricity. Some of these include sodium acetate, glucose and sucrose [18], landfill leachate [19,20], macroalgae [21], synthetic wastewater [22], cow's urine [23], activated sewage sludge supplemented with acetate [24], mixed kitchen waste, whey from dairy industries, fisheries residues and pulp waste from citrus juice production [25]. However, high biodegradability, high energy content and inexhaustible quantity make FW a potential substrate for bioelectricity generation [26].

Studies have been reported in past which confirm the successful use of FW as a substrate for electricity generation using MFC [3–7,26–29]. Most of the studies reported in the past are directed towards increasing the efficiency of the cell. For FW specifically, studies have been done of which some have focus on effect of organic loading rate on performance of MFC [6,26], effect on various anolyte ionic strengths and pH on MFC [4], studying the effect of using various inoculums on MFC performance [3], optimizing the substrate Chemical Oxygen Demand (COD) for maximum power [5], usage of food waste leachate from biohydrogen production [30].

Recirculation is one of the effective ways to mix the contents in the reactor. It also ensures a close contact between substrates and microbes and reduces the temperature variation in the chamber [31]. The importance of recirculation and its effect has been reported by many studies for anaerobic digestion of waste [32–35]. However the application of recirculation in MFC is still sparing. Recirculation can enhance the bioelectricity production in MFC by enhancing the proton transfer ability [36].

Hence in the present research, an attempt is made to investigate the effect of recirculation on the performance and bioelectricity generation for MFC which utilises food waste leachate as substrate at varying organic concentration. The leachate was obtained through hydrolysis and acidification of food waste from Leaching Bed Reactor (LBR). The leachate obtained was then diluted to get the desired organic concentration which was later fed to the microbial fuel cell for the present research.

Materials and methods

Collection and characterization of food waste

The kitchen waste (KW), which contains food waste and vegetable waste (VW), was collected in plastic bags from hostel mess of an educational institution. The components of the FW were then separated manually and weighed. The weight of each component was expressed as percentage of the total weight of FW. Stale or leftover vegetables and vegetable peelings was the major component of the vegetable waste of the hostel mess. All the components were grinded to make a homogeneous paste and it was analysed further for its characteristics. The average composition of hostel mess FW is found to be 28% Indian curry, 19% Indian bread, 44% rice and pulses and 9% salad. The characteristics of the kitchen waste and the bulking material (BM) used are mentioned in Table 1. All the parameters were measured according to the Standard Methods for the Examination of Water and Wastewater 20th edition of the American Public Health Association [37].

Table 1 – Characteristics of hostel food waste, vegetable waste and bulking material [38].

Parameter	KW		BM	
	FW	VW	SD	CS
Density (kg/m^3)	978	687.23	255.32	676
pH	5.82	5.45	5.92	6.25
MC (%)	76.67	94.51	14.47	10.08
TS (%)	23.42	5.49	85.53	89.92
VS (%)	98.48	98.89	97.12	92.45
VS/TS	4.2	18.01	1.13	1.03
COD (mg/L)	166222.2	36444.44	–	–
Carbon (%)	57.12	57.36	–	–
Nitrogen (%)	3.20	2.89	–	–
C/N	17.85	19.85	–	–

(SD) Saw Dust; (CS) Coconut Shell; (MC) Moisture Content; (TS) Total Solids; (VS) Volatile Solids; (C/N) Carbon to Nitrogen ratio.

Production and characterization of food waste leachate

The food waste leachate was produced in a leaching bed reactor of volume 850 ml. The LBR is previously described in the study done by Moharir and Tembhurkar [38]. The LBR consisted of a bottom bed of aggregates (90.51% passing 10 mm sieve) to act as a filter bed occupying 250 ml volume of reactor. The working volume of 600 ml was filled with the mixture of food waste, vegetable waste and bulking material in the ratio of 40%, 50% and 10% respectively by their volume. The bulking material used in the study is the combination of saw dust (SD) (93% passing through 1.18 mm sieve) and crushed coconut shell (CS) (95% passing through 4.75 mm sieve). Water was continuously added to the reactor from the top of LBR at the rate of 0.17 ml/min. The schematics of the LBR are shown in Fig. 1. The leachate was collected from the bottom of LBR. The characteristics of the leachate are given in Table 2. All the parameters were measured according to the Standard Methods for the Examination of Water and Wastewater 20th edition of the American Public Health Association [37].

MFC arrangement and operation

Laboratory scale two chamber MFC was fabricated with total/working volume of 1.35/1.0 L in each compartment. Carbon rods (each with surface area of 127.23 cm^2) were used as anode and cathode. The anode chamber was made airtight and cathode chamber was kept open to air. 4 carbon rods were used as anode which constitutes the surface area of ~509 cm^2 and 2 carbon rods were used as cathode which constitutes the surface area of ~255 cm^2. The anodes were submerged in anolyte while the top portion of the cathode was in contact with air. The PEM used in the study was Ultrex (Membranes International INC, USA). Two openings were made in the anode compartment so as to facilitate recirculation of the anolyte. A small opening was made at the top of the anode chamber for the exit of the gases. All the connections were made using copper wires. Variable resistance was used in the study. Fig. 2 shows the schematics of the MFC set-up.

The MFC was operated at two modes i.e. MFC without recirculation (R1) and MFC with recirculation (R2). The

Please cite this article in press as: Moharir PV, Tembhurkar AR, Effect of recirculation on bioelectricity generation using microbial fuel cell with food waste leachate as substrate, International Journal of Hydrogen Energy (2018), https://doi.org/10.1016/j.ijhydene.2018.04.072