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EFFECT OF BACTERIAL COMMUNITIES ON THE PERFORMANCE OF MICROBIAL FUEL CELL FORMED WITH DAIRY WASTE

V.D. Patil[1], D.B.Patil[2], M. B. Deshmukh[3], S. H. Pawar[4]
[1] Department of Applied sciences, T.K.I.E.T., Warananagar 416 113
2 Department of Chemistry, Vivekananda College, Kolhapur 416003
[3]Department of Chemistry, Shivaji University, Kolhapur 416 004
[4] D.Y.Patil university, Kolhapur- 416 006

ABSTRACT

To reveal the effect of mixed culture on the performance of MFC for the disposal of dairy waste and to produce electricity. Microbial fuel cells are formed with anode chamber consisting of dairy waste using four different cultures of microbes collected from brick factory soil, activated sludge, rice field soil and *Enterobacter aerogenes*. The performance of all the MFC cells is studied in terms of their electrical output. The bacterial communities are found to affect the performance of MFCs. The MFC formed with microbes collected from rice field soil is found to be more suitable for the optimum conversion of dairy waste into electrical energy. The physical and chemical properties of diary waste are studied before and after MFC treatment. Electricity generation is possible by the in situ anaerobic degradation of organic matter from dairy waste by mixed cultures. In this process the bacteria collected from rice field soil are found to be most efficient to dispose of dairy waste and electricity generation. Dairy waste can be disposed of by using MFC technique and the electricity can also be generated simultaneously.

Key Words: Microbial fuel cell, mixed culture, pure culture, salt bridge, electricity.

INTRODUCTION

Among electrochemical cells, MFCs are special types of biofuel cells, producing electric power by utilizing microorganisms [1]. The microbial fuel cell uses hydrogen fuel and oxygen to produce electricity. MFC converts organic matter into electricity by using bacteria as biocatalyst [2- 4]. The conventional MFC is a two chamber system, consisting of anode and cathode separated by a proton exchange material .This system has been half biological, because only the anode side contains electrochemically active microorganisms, while the cathode is abiotic. The microorganisms function as biocatalysts, motivating the degradation of organic materials to produce electrons, which travel to the cathode side via an electric circuit. The presence of free electrons on the cathode of MFCs initiates a reduction of oxygen to produce water [1]. In biological fuel cells, the catalyst is either microorganisms as simple as Baker's yeast or an enzyme. Biological fuel cells convert the chemical energy of carbohydrates, such as sugar and alcohol directly into electric energy. As most of the organic substrates undergo combustion with the evolution of energy [5]. Recently, efforts have been made to treat domestic waste water using MFC and simultaneously to produce electricity due to environmental concerns and the need to reuse waste [6]. Anaerobic sewage sludge is a good candidate for inoculating MFC as it is easily obtained from a waste water treatment plant and it contains highly varied bacterial communities that contain electrochemically active strains of bacteria [7]. MFCs have operational and functional advantages over the technologies currently used for generating energy from organic matter [8].

The development of MFC is however; still in it's infancy with the need of considerable improvements with respect to power out put and accessible substrates. Thus, most MFCs still require their fuel to be of low molecular nature. The majority of herbal biomass however consists of macromolecular compounds including complex carbohydrates like starch and cellulose [9]. The direct oxidation of microbial hydrogen shows a number of potential advantages. Thus, it does not require the separation and purification of the gas for its subsequent conversion in conventional fuel cells .MFCs shows promise as a method to treat waste water and to produce electricity at the same time [10].

Conventional biological wastewater treatment processes, such as activated sludge, are energy demanding processes. Energy use for wastewater aeration can account for up to 50% of operating costs, with typical requirement of Approx.500Wh/m3, orApprox.1kWh for oxidation of 1 kg organic compounds removed during treatment [11]. Aerobic treatment processes also produce large amount of residual solida which are costly to treat and dispose [12-15]. The high energy requirements of these processes makes it important to investigate methods to reduce operational cost through process optimization or the use of more energy efficient anaerobic processes [16-18].

Microbes in the anodic compartment produce electrons and protons from the oxidation of organic matter, with CO2 and biomass as final product. There has been rete interest in usig MFC's for wastewater treatment [19], and power generation has been shown using a variety of wastewaters including both domestic and industrial wastewaters[20-25]

The aim of the present study was to investigate the disposal of dairy waste with MFC and simultaneously exploiting it for microbial electricity generation. The mixed culture (eg. Rice soil, Brick factory soil and Activated sludge) containing hydrogen producing microorganisms can in fact serve as a catalyst in MFCs. It varies with a substrate and hence the performance of MFC, depends on the nature of microbes. We have attempted in the present investigation first time for the disposal of dairy waste with variety of cultures in MFCs such as activated sludge from dairy waste plant, rice field soil, brick factory soil and pure culture (*E. aerogenes)*. The performance of MFC formed with dairy waste added with different cultures is studied and attempted to reveal the suitable culture for the maximum performance of MFC to dispose of dairy waste for clean environment.

MATERIALS AND METHODS

Inoculum sources

The performance of MFC was studied for four different cultures of the microbes collected from , a) ativated sludge from waste water plant (Warana dairy) b)surface soil from rice farm(village Sangrul) c) brick soil (Warananagar India)and d) *E.aerogenes*.

MFC construction

Two chamber MFC was constructed in our laboratory as shown in figure 1. The MFC consisted of two vessels (500ml capacity) with graphite electrodes (12 x 1.2. cm). The vessels were joined by a salt bridge. Anode chamber was filled with dairy waste and culture, while the cathode was filled with 1 N potassium ferricyanide solution as an electrolyte where air was provided using air sparger. The anode chamber was stirred with magnetic stir bar and operated at room temperature (30 ^{o}C).The electrodes were attached using copper wire with all exposed metal surfaces sealed with a non- conductive material (M-seal).

ANALYSIS

The voltage (V) across an external resistor (1000Ω) in the MFC circuit was continuously recorded at the intervals of 30 min for all the cells. The current (I) and Power out put were calculated. At the instant of maximum current production by MFC, the load resistance was varied from 10 Ω to 10 MΩ and power output was measured. Chemical properties such as BOD, COD pH of dairy waste were measured before and after operation of MFC. The physical status of dairy waste before and after MFC treatment was studied with optical density measurement.

RESULTS AND DISCUSSION

MFC with dairy waste:

The electrical generation in MFC by using mixed microbial culture with dairy waste has been studied by employing a fuel cell geometry designed and fabricated in our laboratory. The open circuit voltage of the MFC was measured for about 100 hrs. The variation of Voc with time is shown in figure2 for four types of cells formed with the microbes from different sources such as a) activated sludge, b) brick soil, c) rice field soil and d) *E. aerogenes*. It is seen that the Voc increases with time sharply, at the beginning, attends the maximum value and then decreases slowly. This behavior of Voc with time‘t’ is attributed to the rate of utilization of dairy waste by microbes. The origin of voltage in MFC can be understood by considering the chemical reactions occurring at cathode and anode compartments given as follows:

At anode: $C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24\,H^+ + 24\,e^- + E_0 = 0.014$ V ….. (1)

At cathode: $6O_2 + 24\,H^+ + 24\,e^- \rightarrow 12H_2O + E_0 = 1.23$ V …….. (2)

Considering the above two reactions the maximum open circuit voltage expected theoretically for MFC is of the order of 1.216 V. However, in the present investigation the value of Voc observed is comparatively smaller than theoretical value. This lower value is attributed to the number of factors consisting of the voltage drop (loss) across the salt bridge, the nature of microbes, the interphase between microbes and electrodes and the transport mechanism of charge from microbes to the electrode etc.

The magnitude of open circuit voltage was found to be different for the cells formed with different cultures. The MFC system formed with rice field soil shows the maximum Voc of the order of 0.589V.Where as the lowest value of Voc is observed in the MFC cell formed with *E. aerogenes* and it is of the order of 0.425V as shown in fig 2. The maximum value of Voc is attributed to the presence of hydrogenase rice field soil. This was tested and confirmed by microbial test carried out at Nikhil laboratory Sangli.The magnitude of the hydrogenase is of the order of 2 colony forming unit (Cfu)/gm and anaerobic bacterial count was 10 Cfu/gm.

Power Generation from Dairy Waste:

In order to use the MFC as the source of electricity, we have studied the out put current ‘I’ of the cell with time. The magnitude of the current was estimated from the voltage drop V_{RL} (as shown in fig. 1) by using the relation I = $V_{RL}/_{RL}$ where $_{RL}$ was taken as a fixed load resistance having the magnitude of 1000 Ω.The variation of ‘I’ with time ‘t’ is shown in figure 3 for all the cells formed with different cultures. In general, it is found that current increases with time attends the maximum value and then decreases with time for all the cells studied. The low magnitude of the current at the initial operation of the cell is attributed to warming up period for the microbes to take part in the process of decomposition of organic matter. The decrease in the current at the later stage of the operation of the cell is attributed to the lowering of the organic matter in the anode compartment of the cell .From the figure 3 it is seen that the maximum current is observed for the cell formed with rice field soil. This is in support of the observation made in case of large value of Voc discussed earlier.

The electrical characteristic of the MFC in terms of the current and voltage are studied with external load resistance R_L .The power out put of cell was estimated from the magnitudes of the current and the voltage observed from the cell recorded at different time. The variation of V_{RL} with time is shown in figure 4. Utilizing the data of figure 3 and figure 4, the power out put of the cell was estimated at the time of optimum performance of the cell. It is well known that the power output of the cell depends on its impedance. Hence, the power output was measured at different load resistance R_L. The variation of power with load resistance R_L is shown in figure 5 for all the four cells studied. It is found that the power out put of the cell is different for different cultures (microbes) used in MFC. It is seen that the power output is maximum for the MFC cell formed with rice field soil culture. Further, it is noted that the maximum power is available at the load resistance $R_L = 1000\ \Omega$.

Disposal of Dairy waste:

The chemical and physical properties of dairy waste were measured before and after the treatment with MFC. It has been observed that the MFC has decreased the COD value of dairy waste from 300 to 166 mg/l. Similarly the BOD has also been decreased from 400 to 150 mg/l. The pH of the dairy waste was measured before and after MFC and found to change from initial value of 4 to 6. The above observations indicate that the MFC technique can be a potential method for disposal of dairy waste in view of the environmental protection.

The physical properties of dairy waste were studied by using the optical density (O.D) measurements of dairy waste before and after MFC operation and the variation of O.D. with λ is shown in fig. 6. It is seen that the optical density of the dairy waste after its treatment with MFC is found higher than that of untreated the high optical density after MFC treatment is attributed to the formation of the turbidity in the diary waste. The turbidity is arised due to the conversion of soluble organic matter into non soluble organic matter by the microbes in the MFC. Filtration of turbid diary waste solution gives rise to clear water to dispose off for its further use.

In conclusion treatment of diary waste with MFC helps to both produce electricity and dispose of diary waste.

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Figures:

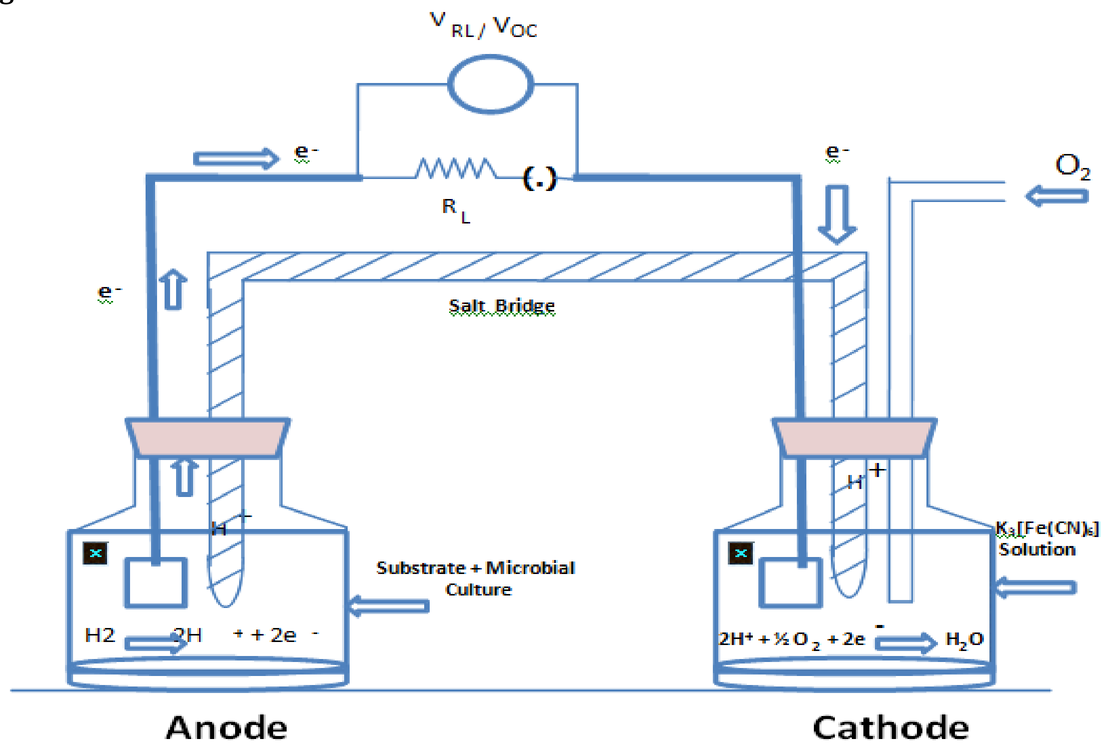

Figure 1 Schematic picture of lab-scale MFC

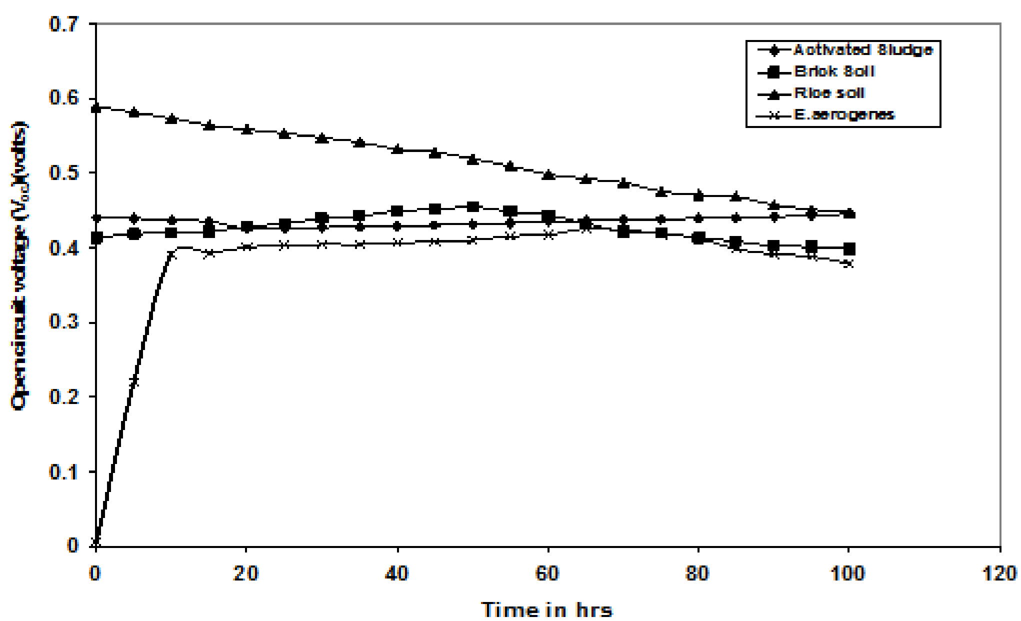

Fig.2 Variation of open circuit voltage with time for dairy waste based MFCs with different cultures from (a) activated sludge from dairy waste disposal plant, (b)brick soil, (c) rice field soil and (d) E. aerogenes.

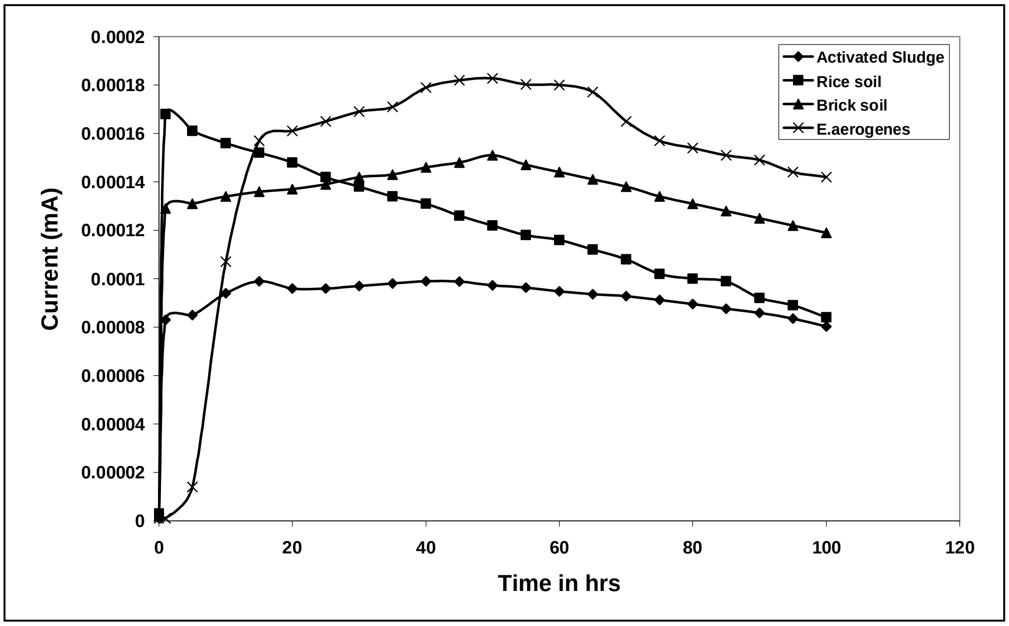

Figure 3. Variation of current with time for dairy waste based MFCs with different cultures from (a) activated sludge from dairy waste disposal plant, (b) rice field soil, (c) brick soil and (d) E. aerogenes.

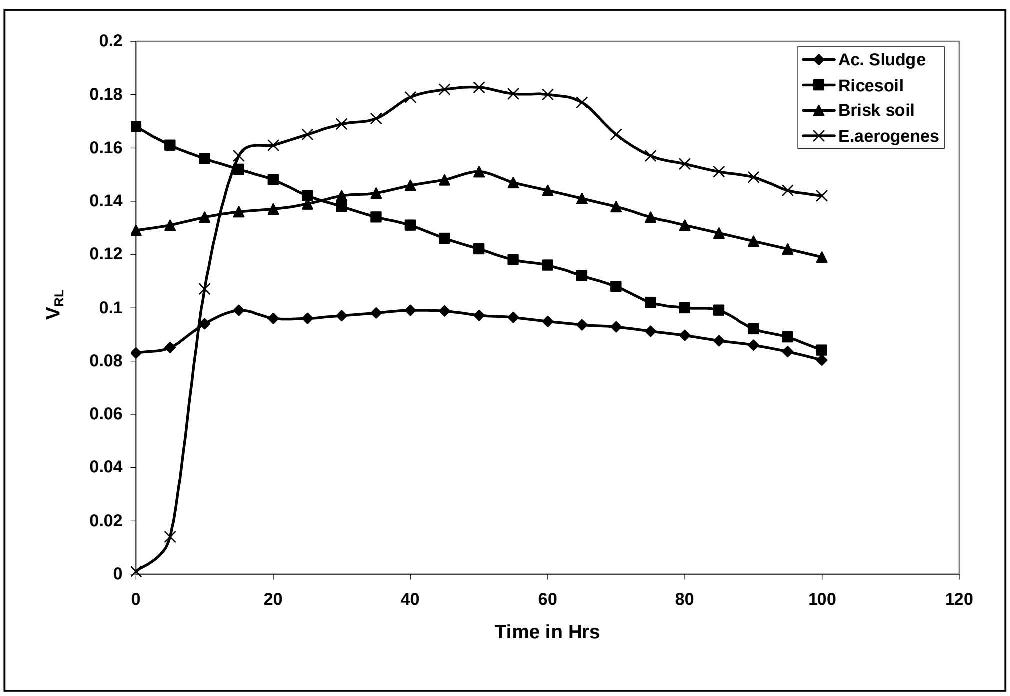

Fig. 4. Variation of voltage drop across load resistance R_L=1000 Ω with time for dairy waste based MFCs with different cultures from (a) activated sludge from dairy waste disposal plant, (b) rice field soil, (c) brick soil and (d) E. aerogenes.

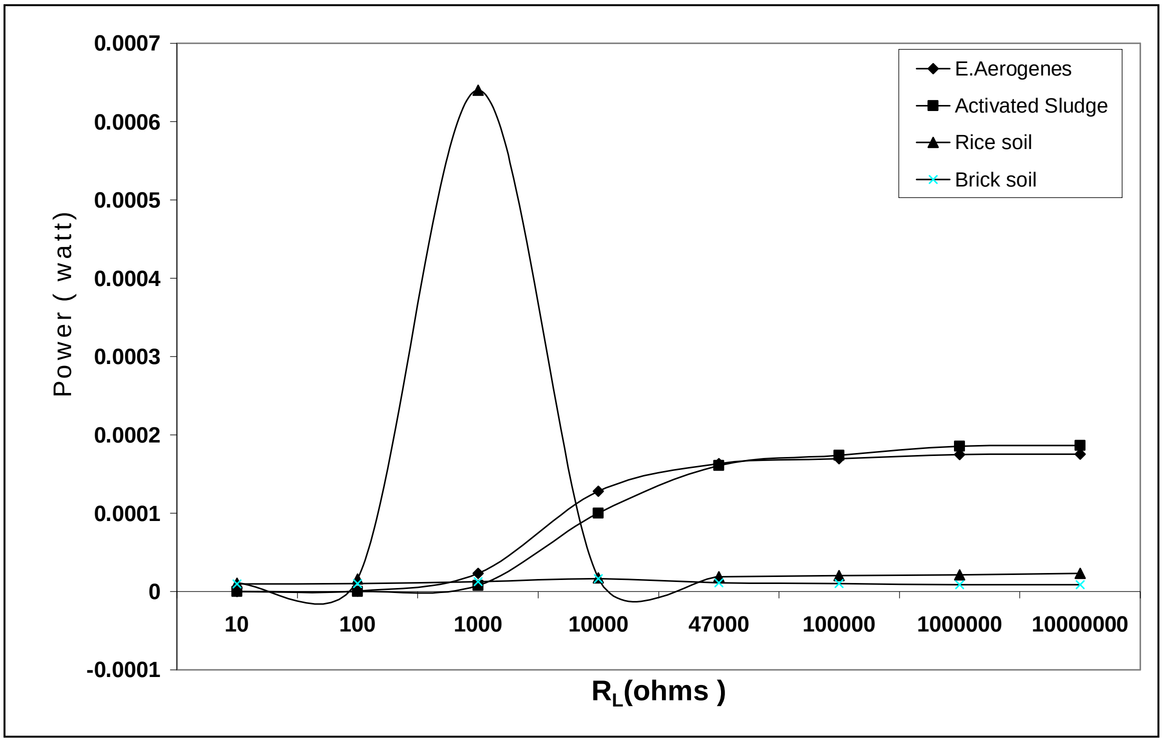

Figure 5 Variation of power output with load resistance RL for the MFCs formed with different cultures (a) E. aerogenes, (b) activated Sludge, (c) rice field soil and (d) brick factory soil.

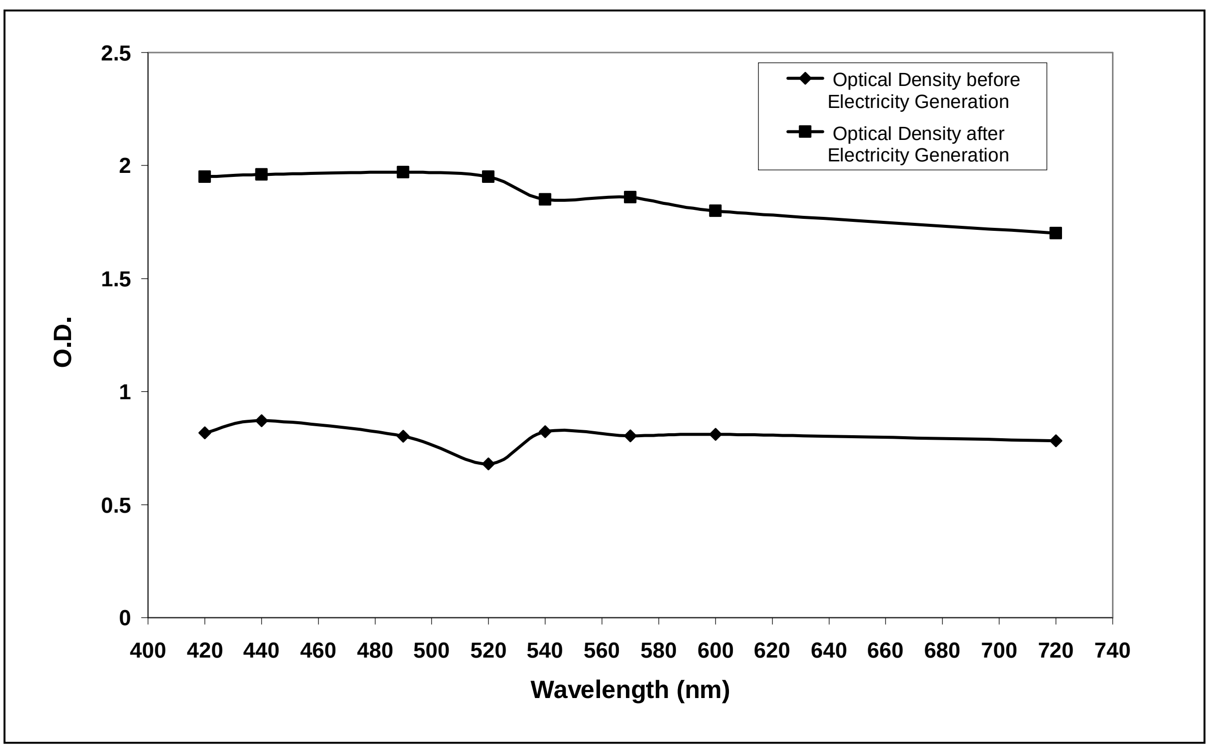

Figure 6 Variation of optical density with wave length (a) before electricity generation (b) after electricity generation.