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Bio-hydrogen production from palm oil mill effluent (POME): A preliminary study

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ABSTRACT

Raw palm oil mill effluent (POME) from a cooling pond and sludge from anaerobic pond of the POME treatment plant at Labu palm oil mill were collected for the study. The treatment of POME was carried out under anaerobic fermentation process, with an objective to produce bio-hydrogen via microflora. The experiments were conducted in 500 mL bioreactor under mesophilic operation at 37 °C with different pH (4.5, 5.0, 5.5, and 6.0) and sludge percentage values (2.5, 5, 7.5, and 10% (w/v)). The source of inoculum was used in POME sludge as hydrogen producing bacteria. From batch experiments, the maximum hydrogen production yield obtained was 5.988 ± 0.5 L H_2/L-med at 10% POME sludge (w/v) with an optimum pH of 5.5 and mesophilic temperature of 37 °C. Methane free biogas consist of 36% maximum hydrogen and 64% carbon dioxide was produced during the process.

Introduction

For many years, the world is highly dependent on the utilization of fossil fuel to fulfill its energy needs. However, the extensive use of fossil fuel has tremendously increased CO_2 emission, which is the main cause of global warming and reached 34 billion tons in 2011 [1]. Therefore, it has become important to develop appropriate long-term strategies based on renewable and sustainable fuels to overcome energy scarcity and environmental issues associated with utilization of fossil fuel. Renewable energy produced from biomass seems to be clean and promising alternative to fossil fuel; particularly, for a tropical region due to the plenty of vegetation and agricultural waste. Among the alternative fuel options, hydrogen production from biomass has become an attractive alternative to fossil fuels with high heating value for numerous applications relating to power and heat generation, and transportation [2,3]. Biomass-derived hydrogen offers various advantages such as zero carbon emissions whereby hydrogen utilization via combustion or via fuel cells produces intense heat with pure water as products [4]. Moreover, it is deemed as a future energy carrier that can be consumed for many ways such as in liquid fuel upgrading, combustion and in fuel cell. Currently, hydrogen is widely produced from thermochemical, electrochemical and biological processes. However, the biological production of hydrogen via anaerobic fermentation route using microorganism is, technically, more feasible, environmental friendly and cost effective that offers the potential production of usable hydrogen.

To develop the hydrogen production via anaerobic fermentation using microflora bacteria as future sustainable fuel, research investigations into different aspects have been reported [4–6]. Ren et al. [4] and Venkata et al. [6] investigated hydrogen production via anaerobic fermentation using different pretreatment methods. The studies found that

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inoculum pretreatment is one of the major characteristics, which plays a major role to select the requisite microflora to enhance H_2 production. Therefore, pretreatment of parent anaerobic inoculum potential approach which facilitates to increase the hydrolysis step, decreasing the influence of limiting rate step, improving stability of hydrogen production process and strengthen the anaerobic digestion to enrich hydrogen production [7,8]. Though such research efforts have somewhat resulted in process improvements in the hydrogen production via anaerobic bacteria. However, challenges related with appropriate yields, rates and other process parameters to achieve commercial scale production of hydrogen are yet need to be addressed.

Palm oil mill effluent (POME) is an appropriate substrate for hydrogen production in terms of yield. Malaysia, Thailand and Indonesia are the higher contributor of POME. One tonne of palm oil produces approximately 5.5–7.5 tonnes of POME [9]. Presently, Malaysia has 432 palm oil mills and the large portion of its economic comes from the palm oil industry by generating approximately USD 20 billion of revenue per year and provides employment for thousands of peoples [10,11]. Nevertheless, the production of one tonne of crude palm oil (CPO) requires 6–8 tonnes of water, and over 50% of the water ends up as wastewater [12,13]. Due to vast processing of palm oil, large volumes of wastewater are generated, which are commonly outlined as palm oil mill effluent (POME). POME consists of organic content including high BOD (25,000 mg/L), COD (53,630 mg/L), and oil and grease (8370 mg/L) [14]. This indicates that POME is suitable source for biological treatment processes, thus making anaerobic digestion the most economical and applicable approach to treat POME [15]. Currently, in most of the palm oil industries, methane production is a common practice to treat POME through series of biological treatments processes (anaerobic/aerobic/facultative digestion). However, hydrogen production could be a novel alternative approach. Thus, the aim of this work was to determine the economically acceptable and promising method to attain higher hydrogen in an environmental friendly manner. Hence, this study employs, the use of small scale batch process reactor for hydrogen production from POME using anaerobic microflora.

Experimental section

Palm oil mill effluent (POME)

Raw POME was collected from the palm oil mill (Labu Oil Mill, Negeri Sembilan, Malaysia). From environmental perspectives, fresh POME is a hot and acidic brownish colloidal suspension. The POME was used as a substrate for culture medium. The samples were immediately transferred to the laboratory and stored in a cold room at 4 °C until further use. The characteristics of the raw POME are summarized in Table 1. In addition, other parameters also were tested including chemical oxygen demand (COD), pH, total suspended solids (TSS) and volatile suspended solids (VSS) were determined in accordance with the procedures described in the standard methods [16].

Table 1 – Characteristics of POME.

Parameters[a]	Average concentrations
Physical characteristics	
Total suspended solid (TSS)	47,690 ± 156
Volatile suspended solid (VSS)	30,870 ± 105
Temperature (°C)[a]	80 ± 1
Ph[a]	3.4 ± 0.1
Chemical property	
COD	69,500 ± 240
BOD_5	37,750 ± 143
Total nitrogen	692 ± 45
Total protein[b]	12.31
Total fat[b]	12.95
Total carbohydrates	22.27×10^{-3}
Reducing sugar	11.26×10^{-3}
Non-reducing sugar	37.75×10^{-3}

[a] Except for pH and temperature, all other parameters are in mg/L.
[b] Unit in % TS.

Inoculum (seed sludge)

The selection of inoculum or culture is very important to improve bio-hydrogen production. The used of mixed cultures give more stable production thus it is suitable for practical application. The sludge was initially passed through a mesh screen to remove any fragment. The total volatile solids concentration of the sludge was 31,600 mg/L and the total suspended solids was 38,000 mg/L respectively.

Experimental set-up

In this study, 500 mL serum bottles were used as batch reactors. Fig. 1 shows a schematic diagram of a batch reactor. The culture medium contained 400 mL of POME with different parameters. Firstly, four 500 mL serum bottles were used for each run at 10% w/v sludge at pH 4.5, 5.0, 5.5, and 6.0. Raw POME and POME sludge were tested the pH value and acclimatized at room temperature for three days before they were used for the experiments.

The pH initial value of raw POME is 3.4 and POME sludge is 6.7 respectively. After the POME sludge was measured of 10% w/v sludge (40 mL) and inserted into the serum bottles, raw

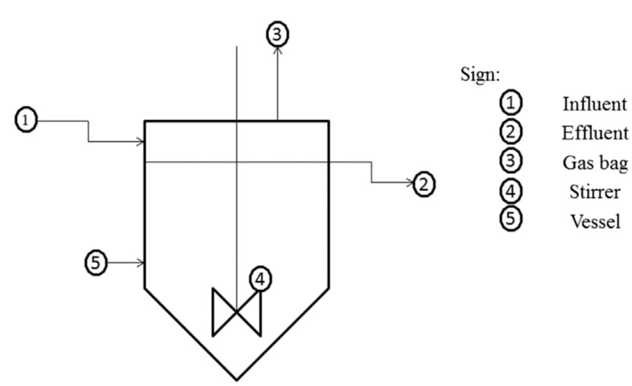

Fig. 1 – Schematic diagram of a batch reactor used in this study.