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Feasibility of semi-pilot scale up-flow anaerobic sludge blanket fixed-film reactor for fermentative bio-hydrogen production from palm oil mill effluent

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ABSTRACT

The present study focuses on bio-hydrogen production using palm oil mill effluent (POME) at a semi-pilot scale of an "up-flow anaerobic sludge blanket fixed-film (UASFF) reactor". The reactor was operated in the palm oil mill industry for over 180 days of operation at ambient temperature through dark fermentation process with different organic loading rates (OLR) of 22–36 g-COD/l.d, depending on the COD concentration of POME. By acclimatizing the sludge, the semi-pilot scale UASFF reactor achieved hydrogen content, and hydrogen production rate (HPR) of 20%–68%, and 12 L H_2/d to 39 L H_2/d, respectively with a maximum COD removal of 35%. Moreover, from high through pyrosequencing analysis, hydrogen fermentation was attributed to *Clostridium sensu stricto*, *Lactobacillus*, and *thermoanaerobium spp*. This study offers an extensive approach to developing a semi-pilot scale bio-hydrogen production and, provides further prospects for profitable exploitation which could be a promising approach for reaching sustainability and economic feasibility (using wastewater as a low-cost feedstock) in commercial applications for future studies.

1. Introduction

Bio-hydrogen production has gained considerable attention in recent years due to its high energy density, clean product consumption, and environmental friendliness [1]. Among all current fuels, hydrogen has been deliberated as the most encouraging energy carrier due to its highest energy density and lower heating value (120 MJ/kg) which is 2.5 times higher than fossil fuel [2]. For the development of practical bio-hydrogen production, the dark fermentation method provides a promising approach for an economical and sustainable source of energy [3,4].

Compare to other hydrogen production processes, dark fermentative hydrogen production from renewable resources (including waste or wastewater) seems to be the most practical method [3,4]. The strategy for the selection of feedstock is to focus on availability, cost/cheapness, and organic waste/biodegradability [5,6]. Malaysia is the second largest palm oil producer and exporter in the world with 19.4 and 16.2 million tons of crude palm oil (CPO) and palm oil from 96 million tons of fresh fruit bunches in 2020 [7]. It has been reported that 5–7.5 tons of water for producing one ton of CPO is required, of which 2.5–3 tons, is discharged as palm oil mill effluent (POME) [8].

Palm oil mills have generated approximately 60 million tons of POME annually [9]. Regardless of massive market accomplishments, the palm oil industry still has several concerns about sustainability, mainly linked to the environmental impacts of greenhouse gas (GHG) emissions from POME [9]. POME as high-strength complex wastewater is a main source of pollution due to its high generation volume and organic content [10]. Certainly, POME treatment is one of the significances of the palm oil firms to develop and sustain the industry. Many studies have widely explored the sustainable management of POME to convert this wastewater into a valuable product and minimize the environmental impacts [11–13]. A case study on the palm oil mill processing and environmental assessment of POME treatment was investigated [14]. According to their study, a number of unit processes involved to extract palm oil from fresh fruit bunches (FFB) including sterilization, thresher, digester, screw press, oil clarification section, kernel plant, empty bunch plant, and evaporator plant were discussed completely [14]. POME is the final discharge from the mill processing which needs to be treated

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