Energy 266 (2023) 126435

Contents lists available at ScienceDirect

Energy

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

Optimization of up-flow velocity and feed flow rate in up-flow anaerobic sludge blanket fixed-film reactor on bio-hydrogen production from palm oil mill effluent

Azam Akhbari [a,*], Shaliza Ibrahim [b], Muhammad Shakeel Ahmad [a]

[a] Higher Institution Centre of Excellence (HICoE), UM Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R&D, University of Malaya, Jalan Pantai Baharu, 59990, Kuala Lumpur, Malaysia
[b] Institute of Ocean and Earth Sciences (IOES), University of Malaya, Kuala Lumpur, 50603, Malaysia

ARTICLE INFO

Keywords:
Palm oil mill effluent
Up-flow anaerobic sludge blanket fixed-film reactor
Bio-hydrogen
Response surface methodology
Microbial community analysis

ABSTRACT

The present study aims to optimize key operational parameters of the up-flow anaerobic sludge blanket fixed-film (UASFF) reactor using response surface methodology (RSM). A central composite design (CCD) has been applied to accomplish thirteen experimental runs given two main variables, namely feed flow rate (Q_f), and up-flow velocity (V_{up}). The maximum hydrogen content, hydrogen production rate (HPR), hydrogen yield (HY), and COD removal were achieved at 55%, 4800 mL H_2/cycle, 321 mL H_2/g-COD, and 24.33%, respectively at Q_f 8 L/cycle (HRT = cycle = 10.5 h) and V_{up} 2.0 m/h. The performance of the parameters from the optimum identified area was assessed at Q_f 5.5 L/cycle (HRT = 15.3 h), and V_{up} 1.8 m/h, resulted in a maximum hydrogen content, HY, and HPR of 72%, 340 mL H_2/g-COD, and 5100 mL H_2/cycle, respectively. At optimum conditions, *Clostridium sensu stricto 1* was found to be the dominant hydrogen-producing bacteria in the system. The results of this study may provide a practical basis for developing a UASFF reactor prototype based on empirical data.

1. Introduction

The devastating climatic calamities such as flash floods, drought, localized heat waves, etc. due to energy-hungry industrialization and lifestyle modernization warrant a total shift from fossil fuels to sustainable, clean, and green energy sources [1]. Hydrogen has been demonstrated as an environmentally friendly energy carrier that contains high energy content (122 kJ/g) [2,3]. Several processes can be used to produce hydrogen such as partial oxidation of heavier hydrocarbons, coal gasification, and hydrocarbon reforming, however, these processes are not environmentally friendly due to the emissions of greenhouse gases [4]. In recent years, increased interest in the biological production of hydrogen using microorganisms by dark fermentation as a sustainable technology has been observed [5–11]. One of the most suitable raw materials in the Malaysian context is palm oil mill effluent (POME). Over the last few years, palm oil consumption has greatly increased globally. In 2020, 72 million tons of palm oil production has been reported, of which 19.14 million tons have been generated by Malaysia [12]. For each ton of crude palm oil, 5.0–7.5 tons of water has been used, and 50% has been discharged from different stages of mill processing as POME [13,14]. In conjunction with strict protocols on the discharge effluent standards and the importance of sustainable progress, a promising approach to producing biogas along with wastewater treatment via anaerobic digestion has been widely studied and pragmatic in industries [15]. Therefore, the application of anaerobic digestion of POME for bio-hydrogen and biogas production can contribute to moderating the discharged pollutants to the environment and energy crisis solution by applying safer options [16,17]. A variety of reactor configurations have been used to produce bio-hydrogen, such as continuous stirred tanks, anaerobic sequence batch reactors, and up-flow anaerobic sludge blanket reactor (UASB) [18]. A UASB reactor is an attractive high-rate system in the anaerobic treatment process due to its compactness, low operating costs, low sludge production, and biogas production. More than 1000 UASB units are operating worldwide today. Some advantages of this technology for wastewater treatment are high biomass concentration reserved in the reactor, superior settling characteristics of sludge at higher OLRs, a high degree of waste stabilization, and minimal nutrient requirements. However, some disadvantages exist, such as foaming and sludge floatation at elevated OLRs, and long start-up time [19]. The application of UASB reactors for the

* Corresponding author.
E-mail addresses: Akhbari.azam@gmail.com, azamakhbari@um.edu.my (A. Akhbari).

https://doi.org/10.1016/j.energy.2022.126435
Received 8 August 2022; Received in revised form 21 November 2022; Accepted 14 December 2022
Available online 17 December 2022