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**Syngas Production from Palm Oil Mill Effluent via Catalytic Steam Reforming**

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**EXTENDED ABSTRACT**

This paper reports on the novel application of catalytic steam reforming process to convert palm oil mill effluent (POME) into syngas over a 20wt%Ni/80wt%Al<sub>2</sub>O<sub>3</sub> catalyst. In Malaysia, palm oil industry is the most important agro-based industry, with a total production of 37.2 million tons of crude palm oil for the past two years [1]. During the palm oil extraction, more than 50% of the water consumed would end up as wastewater, commonly known as palm oil mill effluent (POME). In Malaysia, POME waste is considered as one of the major sources of water due to the inefficiency of widely-adopted open ponding treatment system. POME has high organic loading, with reported mean biochemical oxygen demand (BOD) and chemical oxygen demand (COD) values of 25000 ppm and 51000 ppm [2]. Indeed, researchers have explored and demonstrated the feasibility of biogas production from POME waste through bioprocess pathway [3] and chemical process such as photocatalysis process [4]. Once decompose, POME releases biogas which can be recovered as a useful biomass-based energy. However, biogas (mixture of CH<sub>4</sub> and CO<sub>2</sub>) is detrimental to the ozone layer due to their greenhouse gas effects.

From our search in the literature, the idea of generating syngas from POME via catalytic steam reforming pathway has not been explored before. Consequently, a new POME treatment method, with renewable energy conversion pathway is envisaged.

In our study, we employed catalytic steam reforming process to generate syngas from POME waste. Based on past researches [5], Ni-based catalyst is well-known for its cost effectiveness and wide availability. Material such as Al<sub>2</sub>O<sub>3</sub> is often employed as the support for active metal due to its thermal stability and large specific surface area [6]. Hence, steam reforming of POME over a 20wt%Ni/80wt%Al<sub>2</sub>O<sub>3</sub> catalyst was investigated in this pioneering work, aiming at syngas production from the waste, whilst ensuring efficient treatment for POME.

For current study, the catalyst employed, 20wt%Ni/80wt%Al<sub>2</sub>O<sub>3</sub>, was prepared via wet-impregnation method. The prepared catalyst was subjected to thermogravimetric analysis (TGA), X-ray diffractometry (XRD), using Field Emission Scanning Electron Microscopy (FESEM), liquid N<sub>2</sub>-physisorption, from CO<sub>2</sub>-temperature programmed-desorption (TPD) and NH<sub>3</sub>-TPD, as well as POME adsorbability for its physicochemical properties analysis.

TGA results shows that the decomposition of nitrates of the pre-calcined catalyst is completed at 600 K. Hence, the calcination temperature was fixed at higher temperature (1073 K) to ensure the completion of the decomposition process. After calcination, it was found that the catalyst possessed high degree of crystallinity and was impurity-free, judging from the obtained XRD pattern. Furthermore, the BET specific surface area of catalyst was low (2.09 m<sup>2</sup> g<sup>-1</sup>), consistent with smooth surface captured by the FESEM images. CO<sub>2</sub>-desorption and NH<sub>3</sub>-desorption profiles showed a

presence of both acid and basic sites on the surface of catalyst. Finally, FTIR spectrum in POME adsorbability test confirmed the ability of prepared catalyst in adsorbing the organics in the POME.

The catalytic steam reforming of POME was conducted in an isothermal stainless-steel reactor. The temperature of fixed-bed was controlled by a vertically-built split-tube furnace. For the testing, desired amount of filtered POME waste was digitally pumped into the reactor in the presence of  $N_2$  as a diluent gas (20 mL/min). The outlet stream from the reactor was channeled to an ice-bath condenser, to condense the vapor component which subsequently subjected to post-reaction analysis, include chemical oxygen demand (COD), biochemical oxygen demand (BOD), and others. The uncondensed gas sample was collected in gas sampling bag and eluted by using Agilent gas chromatography equipped with two packed bed columns.

In the absence of catalyst, about 7.0% reduction of chemical oxygen demand (COD) was achieved at  $60.0 \text{ mL h}^{-1}$  flow rate of POME, reforming temperature of 873 K and  $20 \text{ mL min}^{-1}$  of  $N_2$ -flow. Significantly, the COD reduction shot up to 93.7% in the presence of catalyst and liquid-hourly-space-velocity (LHSV) of POME of  $90 \text{ mL h}^{-1} \text{ g}_{\text{cat}}^{-1}$  at 873 K. The corresponding biochemical oxygen demand (BOD) reduction recorded was 93.8%. Furthermore, it is also found that the COD and BOD removal are increasing with the LHSV in the range of 30 –  $90 \text{ mL h}^{-1} \text{ g}_{\text{cat}}^{-1}$  (Figure 1), which confirms that both COD and BOD reduction rate is a function of partial pressure of POME. Indeed, higher partial pressure in the reaction has stream increased the chemisorption; hence, the increment in rate of reaction.

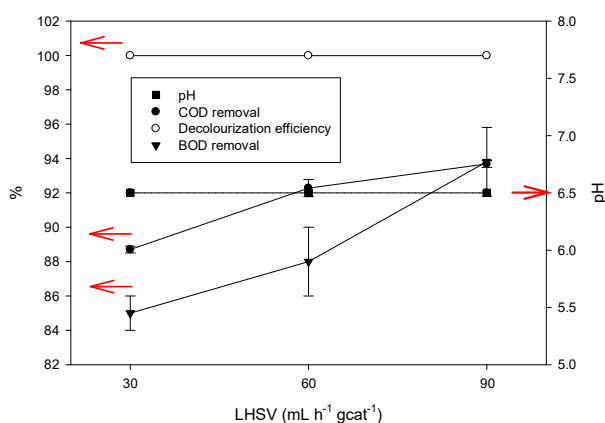


Figure 1. COD reduction, BOD reduction, decolourization efficiency and pH obtained for different LHSV with  $20 \text{ mL min}^{-1} N_2$  at 873 K

However, normalized carbon loss indicates that a high LHSV would favour carbon deposition. In addition to high LHSV, the carbon deposition was also influenced by reaction temperature. High reaction temperature has reduced carbon deposition, as well as organics removal. COD reduction was 99.41% and BOD reduction was 99.52% at 1173 K when LHSV was  $60 \text{ mL h}^{-1} \text{ g}_{\text{cat}}^{-1}$ . In the gas phase, four species were consistently detected, viz.  $H_2$ ,  $CO_2$ , CO and  $CH_4$ , with  $H_2$  as the major component. Based on the results obtained, the  $H_2$  selectivity increased with both LHSV and reaction temperature.

Key words: Palm oil mill effluent; Steam reforming; Syngas; Waste treatment

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