Paper ID: A109

Syngas Exploitation from Novel Catalytic Steam Reforming of Palm Oil Mill Effluent over Lanthanum Nickel Trioxide

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EXTENDED ABSTRACT

The exhaustion of fossil fuels is foreseen with the increasing world energy demand that provoked by substantial growth of world's population. To address this issue, numerous viable renewable energy resources had been utilized, *viz.* solar, wind, geothermal, tidal, and biomass energies by virtue of their abundance and green approach. Differ from other renewable energies, biomass energy is qualified to be the true surrogate for fossil fuels since it offers a waste to energy approach that unbounded by climatic, seasonal, and regional constraints. In a steam reforming process, the biomass which are carbonaceous substances can be thermally converted into combustible gaseous products primarily syngas, via oxidation with steam at elevated temperature [1]. Essentially, syngas become attractive due to its wide applications, *viz.* synthetic fuel for energy generation and chemical intermediates for many downstream chemicals such as methanol, hydrogen, and acetic acid [2].

At present, Malaysia is well-known as the preeminent exporter of refined palm oil although it serves as the second-largest producer of the oil in the world, behind only to Indonesia. In Malaysia, the wet palm oil milling process that incorporated steam for sterilization purpose is more preferred than the dry milling process since the latter is unsuitable for massive production [3]. Ahmad and co-workers (2003) proclaimed that approximately 2.5 – 3.75 tons of POME yielded for each ton of crude palm oil processed [4]. Obviously, the flourishing development of local oil palm industry has backfired by the generation of tremendous palm oil mill effluent (POME) wastewater, which ulteriorly bring disastrous effect to the ecosystem if discharged untreated into the waterway. Prevalently, the open ponding system was adopted by > 91% of palm oil mills in Malaysia, nonetheless, it was discouraged by its features, such as unpleasant smell associated, land-intensive, sluggish degradation, and greenhouse gases dissipation [5]. Table 1 summarizes the typical characteristics of raw POME.

Table 1: Typical characteristics of raw POME [6-7]

Parameter	Description
Appearance	Thick brownish slurry
pH	4 – 5
COD (ppm)	15,000 – 100,000
BOD (ppm)	10,250 – 43,750
Water (%)	95 – 96
Total solids (%)	4 – 5
Suspended solids (%)	2
Oil (%)	0.6 – 0.7

Since POME possess high loading of organic pollutants, it is envisaged that POME could be converted into syngas via catalytic steam reforming, which simultaneously give birth to a novel POME treatment method as well as a brand-new syngas production pathway. The conventional steam reforming of hydrocarbons has been successfully carried out over Ni-based catalysts, but the active metal Ni is prone for carbon laydown [8]. In order to minimize carbon deposition, two possible efforts can be undertaken, namely introducing light rare earth metal such as La as catalyst support and also synthesizing catalyst with smaller active metal particle sizes. Coincidentally, these two efforts can be accomplished concurrently by synthesizing catalyst in the form of pervoskite template (ABO_3 where A = lanthanide series and B = transition metal). It was found that the common $LaNiO_3$ perovskite catalyst exhibits excellent coke resistance, which can attributed to the lattice oxygen possessed by La and smaller Ni particle sizes obtained [8].

Specifically, this research aims to study the catalytic steam reforming of POME over sol-gel synthesized $LaNiO_3$ perovskite catalyst at elevated temperature. The physisochemical properties of $LaNiO_3$ catalyst prior and after the steam reforming was obtained via five insightful characterization techniques, *viz.* X-Ray Diffraction (XRD), Field Emission Scanning Electron Microscopy with Energy Dispersive X-Ray Analysis (FESEM-EDX), Fourier Transform Infrared Spectroscopy (FTIR), N_2 Physisorption, and Thermogravimetric Analysis (TGA). Meanwhile, the raw POME was vacuum filtered once to prevent clogging of bulk solids in the HPLC pump during steam reforming, which subsequently stored in a 4^{o}C chiller to prevent any microbial degradation. To examine the constituents, some pre-treated POME was freeze dried for further characterization with the aid of FTIR, GC-MS, and ^{13}C-NMR. Simultaneously, the steam reforming of POME was performed to study the steam reforming activity of $LaNiO_3$ from the aspects of temperature, POME flow rate, catalyst weight, and weight-hourly space velocity (WHSV). Throughout the steam reforming, the collected liquid sample was tested for COD, BOD, TSS, colour intensity, and pH while the gaseous sample was analyzed via gas chromatograph (GC). Figure 1 illustrates the diffratograms of uncalcined and calcined $LaNiO_3$ perovskite catalysts, whereby the crystallinity of $LaNiO_3$ greatly increased after calcination at 850^{o}C for 4 h.

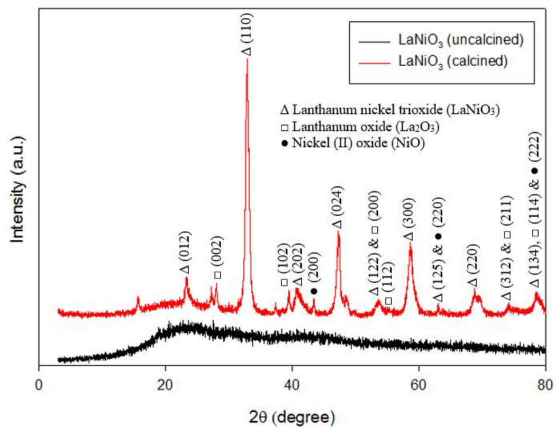

Fig. 1: XRD patterns of $LaNiO_3$

Conclusively, catalytic steam reforming of POME over sol-gel synthesized $LaNiO_3$ perovskite catalyst is a feasible novel POME treatment method, which enables substantial syngas exploitation from undesired POME wastewater that abound in Malaysia. It is believed that the successful scale-up of this process able to eliminate the over dependency of palm oil mills on obsolete open ponding system, which permits more effective use of land bank and also generation of electricity for workers who resided in isolated oil palm plantation area.

Keywords: Syngas; Palm oil mill effluent; Steam reforming; Wastewater treatment; Lanthanum nickel trioxide.

Acknowledgment
This work is made possible through the Fundamental Research Grant Scheme (FRGS) provided by the Ministry of Higher Education (MOHE) Malaysia with a grant number of RDU170116.

References

[1]Huber, G. W., Iborra, S., & Corma, A. (2006). Synthesis of Transportation Fuels from Biomass: Chemistry, Catalysts, and Engineering. Chemical Reviews 106: 4044-4098.

[2] Indarto, A., & Palguandi, J. (2013). Syngas: Production, Applications, and Environmental Impact. Nova Science Publishers, NY.

[3] Wu, T. Y., Mohammad, A. W., Jahim, J. M., & Anuar, N. (2010). Pollution control technologies for the treatment of palm oil mill effluent (POME) through end-of-pipe processes. J Environ Manage 91: 1467-1490.

[4] Ahmad, A. L., Ismail, S., & Bhatia, S. (2003). Water recycling from palm oil mill effluent (POME) using membrane technology. Desalination 157: 87-95.

[5]*MPOB. (2016). Oil Palm & the Environment. http://www.mpob.gov.my/en/palm-info/environment/520- achievements/ (accessed 27.12.2016)*.

[6] Madaki, Y. S., & Lau, S. (2013). Palm Oil Mill Effluent (POME) From Malaysia Palm Oil Mills: Waste Or Resource. International Journal of Science, Environment and Technology 2: 1138-1155.

[7] Tabassum, S., Zhang, Y., & Zhang, Z. (2015). An integrated method for palm oil mill effluent (POME) treatment for achieving zero liquid discharge – A pilot study. Journal of Cleaner Production 95: 148-155.

[8] Guo, J., Lou, H., Zhu, Y., & Zheng, X. (2003). La-based perovskite precursors preparation and its catalytic activity for CO_2 reforming of CH_4. Materials Letters 57: 4450-4455.