Oil palm frond as a sustainable feedstock in a biorefinery to produce biochemical product and biofuel

S.K. Tnah[1], T.Y. Wu[1,2,*], C.B.T.L. Lee[1], V.Z. Ong[1]

[1] Chemical Engineering Discipline, School of Engineering, Monash University, Jalan Lagoon Selatan, 47500 Bandar Sunway, Selangor Darul Ehsan, Malaysia.
[2] Monash-Industry Palm Oil Education and Research Platform (MIPO), School of Engineering, Monash University, Jalan Lagoon Selatan, 47500 Bandar Sunway, Selangor Darul Ehsan, Malaysia.
Keywords: Biomass valorization, Lignocellulosic biomass, Waste management, Waste reuse
Presenting author email: wu.ta.yeong@monash.edu

Introduction and study objectives

Exponential growth of petroleum refineries over the past centuries undoubtedly bring forth the living quality of the entire humanity. However, massive consumption on the depleting fossil fuels can never be the solution to cop for the growing demands of energy and material in the near future. Not to mention the utilization of fossil fuels in the conventional refineries is the main contributors to the environmental issues such as global warming and climate change. The concept of biorefinery has been emerged as the potential alternative in order to diminish the domination of fossil fuels. Biorefinery emphasizes on the conversion of lignocellulosic biomass, the renewable resources into a wide variety of value-added bio-based products (Peleteiro *et al*., 2016).

In Malaysia, palm oil industry is an irreplaceable economic activity due to its high global demand in both food and non-food industries. Oil palm plantation which supplies the feedstock is certainly generating large quantities of raw biomass. Based on the latest information, a total land area of 5,811,145 hectares has been preserved for oil palm plantation. The major oil palm biomass produced in the oil palm plantation include oil palm fronds (OPF) and oil palm trunk. One hectare of oil palm planted area produces approximately 10 tonnes of OPF and 7.70 tonnes of oil palm trunk. This implies the annual generation of OPF and oil palm trunk reaches as high as 58.1 million tonnes and 44.7 million tonnes respectively. Even though OPF has been occupying the majority among the oil palm biomass, it is merely utilized as mulch in the local plantation (Ong *et al*., 2019). Such underutilization of OPF further drives the valorization of OPF into different chemicals and fuels. This review highlights three crucial steps involve in the production of both chemicals and fuels using OPF as the lignocellulosic biomass feedstock.

Results and conclusion

Lignocellulosic biomass is a well-known recalcitrant material due to the presence of lignin-carbohydrate complex. Lignin serves as a protective barrier in this complex, inhibiting the effective hydrolysis of cellulose and hemicellulose (Liu *et al*., 2017). Pretreatment known as delignification is required in order to disrupt lignin structure, decrease cellulose crystallinity and increase surface area for all kind of biomass including the OPF. Pretreated OPF offers higher accessibility and more susceptible for the enzymatic attack towards the cellulose (Ong *et al*., 2019). Pretreatment of biomass can be classified into mechanical, chemical, physiochemical and biological. Deep eutectic solvent (DES) can be designed accordingly and utilized as a potential green solvent for the chemical pretreatment of OPF (Loow *et al.*, 2017).

Hydrolysis of pretreated OPF is performed to breakdown the polysacharrides into their respective monomeric sugars such as glucose and xylose. In recent years, enzymatic hydrolysis is mostly utilized for the pretreated OPF due to relatively higher sugar yield, lower environmental impact and milder operating conditions as compared to the acid hydrolysis. The extracted sugars will then be utilized in the subsequent step for production of either chemicals or fuels.

<u>Production of chemicals and fuels</u>

Chemical modification is required for the production of bio-based chemicals such as furfural, 5-hydroxymethylfurfural (5-HMF), levulinic acid and xylitol. Furanic derivatives such as furfural and 5-HMF are regarded as the initial platform chemicals which can be further processed into a wide variety of value-added products (Machado *et al*., 2016; Zuo *et al*., 2017). Furfural and 5-HMF are the dehydrated products of xylose (pentose) and glucose (hexose) respectively. Levulinic acid is formed from the rehydration reaction of 5-HMF and is served as a potential precursor of biofuels. Xylitol is the hydrogenated product of xylose which is often used as a sugar substitute.

Fermentation is performed for the production of bio-based fuels such as bioethanol, biobutanol and biodiesel. Sugars obtained in the hydrolysis process are fed as the nutrient sources for the fermentation of microorganisms. This process can be conducted via two different methods for bioethanol production, either separate hydrolysis and fermentation (SHF) or simultaneous saccharification and fermentation (SSF). SSF process combined the enzymatic hydrolysis and fermentation together in a single step. SSF process poses several advantages over SHF process such as lower cost, lower energy consumption and shorter duration.

Acknowledgements

This study is supported by Ministry of Higher Education, Malaysia under Fundamental Research Grant Scheme (FRGS/1/2019/WAB01/MUSM/02/1). Additionally, the authors would like to thank Monash University Malaysia for providing S.K. Tnah, C.B.T.L. Lee and V.Z. Ong with PhD scholarships.

Reference:

1. Liu, Y., Chen, W., Xia, Q., Guo, B., Wang, Q., Liu, S., Liu, Y., Li, J., Yu, H. (2017). Efficient cleavage of lignin–carbohydrate complexes and ultrafast extraction of lignin oligomers from wood biomass by microwave-assisted treatment with deep eutectic solvent. ChemSusChem, 10, 1692-1700.
2. Loow, Y.-L., New, E.K., Yang, G.H., Ang, L.Y., Foo, L.Y.W., Wu, T.Y. (2017). Potential use of deep eutectic solvents to facilitate lignocellulosic biomass utilization and conversion. Cellulose, 24, 3591-3618.
3. Machado, G., Leon, S., Santos, F., Lourega, R., Dullius, J., Elizabete Mollmann, M., Eichler, P. (2016) Literature Review on Furfural Production from Lignocellulosic Biomass. Nat Resour, 7, 115-129.
4. Ong, V.Z., Wu, T.Y., Lee, C.B.T.L., Cheong, N.W.R., Shak, K.P.Y. (2019). Sequential ultrasonication and deep eutectic solvent pretreatment to remove lignin and recover xylose from oil palm fronds. Ultrason Sonochem, 58, 104598.
5. Peleteiro, S., Santos, V., Garrote, G., Parajó, J.C. (2016). Furfural production from Eucalyptus wood using an acidic ionic liquid. Carbohydr Polym, 146, 20-25.
6. Zuo, M., Le, K., Li, Z., Jiang, Y., Zeng, X., Tang, X., Sun, Y., Lin, L. (2017). Green process for production of 5-hydroxymethylfurfural from carbohydrates with high purity in deep eutectic solvents. Ind Crop Prod, 99, 1-6.