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Fuzzy optimisation for retrofitting a palm oil mill into a sustainable palm oil-based integrated biorefinery

Harresh Kasivisvanathan [a], Rex T.L. Ng [a], Douglas H.S. Tay [b], Denny K.S. Ng [a,*]

[a] Department of Chemical and Environmental Engineering, Centre of Excellence for Green Technologies, University of Nottingham, Malaysia, Broga Road, 43500 Semenyih, Selangor, Malaysia
[b] GGS Eco Solutions Sdn Bhd, Wisma Zelan, Suite G.12A & 1.12B, Ground Floor, No 1, Jalan Tasik Permaisuri 2, Bandar Tun Razak, Cheras, 56000 Kuala Lumpur, Malaysia

HIGHLIGHTS

- Novel systematic approach to retrofit palm oil mill into integrated biorefinery.
- Fuzzy optimisation is used for multi-objective optimisation in retrofit case.
- Pareto optimum analysis is performed for retrofit case.
- Sensitivity analysis is performed to handle any possible uncertainties.

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ABSTRACT

In a typical palm oil processing plant, which is also known as palm oil mill, various types of palm based biomasses (e.g., empty fruit bunch (EFB), palm press fibre (PPF), palm kernel cake (PKC), palm kernel shell (PKS), sludge cake, etc.) are generated from the processing of fresh fruit bunches (FFBs) to produce crude palm oil (CPO) as the main product. At the initial stage, these biomasses are considered as low-value by products or waste. However, due to the maturity of palm biomass processing technologies and new initiatives given by Malaysian government, many of the palm oil mills have started to further process those biomasses into higher value products, such as biofuels, biochemicals, and bio-based food. This paper presents a novel application of the concept of systematic optimisation approach to retrofit a palm oil mill into a sustainable palm oil-based integrated biorefinery. In this work, the retrofit of an existing palm oil processing plant is analysed based on economic performance and the total potential environmental impact of the entire plant. In this context, the challenge lies in maximising the former whilst minimising the latter simultaneously. In the light of addressing this concern, fuzzy optimisation approach is adapted into this work to synthesise a sustainable palm oil-based integrated biorefinery which fulfils the two important objectives. Pareto optimum analysis is also performed to this new retrofit design case in order to determine the optimum pathway with the consideration of both objective functions. Sensitivity analysis is also conducted in this work to determine the effects of cost and price fluctuations on the economic performance. A palm oil mill case study is presented to collectively illustrate the proposed approach.

1. Introduction

Recently, the increase in fossil fuel prices coupled up with the possible depletion of natural resources and population growth on average, have provoked an ongoing public awareness towards the global energy security. In line with this, other key contributing factors such as sustainable development from economic and environmental perspectives have motivated researchers to find other economical alternative sources of energy in replacement of conventional fuels. In search of the sustainable substitute to fossil fuel, biomass has been identified as a potential and reliable source of renewable energy that is able to fulfil the demands of energy. Besides, it can also be converted into other valuable products such as biochemicals, a spectrum of other bio-based food and feed sources, etc., through various thermal, physical and biological conversion technologies [1], in an integrated biorefinery [4].

In the past few decades, there had been a controversy of 'food versus fuel' that appeared as an understatement with regards to any limitations involved between the both [2]. Generally, the subject is far more complex than it had been presented, where some key deciding factors were put against a dispute. They include but are not limited to the world's real food situation background, the

* Corresponding author.
E-mail addresses: kebx1hks@nottingham.edu.my (H. Kasivisvanathan), kebx1nti@nottingham.edu.my (R.T.L. Ng), douglastay@ggs.my (D.H.S. Tay), Denny.Ng@nottingham.edu.my (D.K.S. Ng).

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