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Gasifier selection, design and gasification of oil palm fronds with preheated and unheated gasifying air

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HIGHLIGHTS

- A novel laboratory-scale single throat downdraft gasifier was developed.
- An air and steam inlet height adjustment mechanism was incorporated in the gasifier.
- Preheating the gasifying air improved the percentage of combustible gases.
- The syngas of oil palm fronds was comparable with that from other biomass feedstock.

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ABSTRACT

Oil palm frond biomass is abundantly available in Malaysia, but underutilized. In this study, gasifiers were evaluated based on the available literature data and downdraft gasifiers were found to be the best option for the study of oil palm fronds gasification. A downdraft gasifier was constructed with a novel height adjustment mechanism for changing the position of gasifying air and steam inlet. The oil palm fronds gasification results showed that preheating the gasifying air improved the volumetric percentage of H_2 from 8.47% to 10.53%, CO from 22.87% to 24.94%, CH_4 from 2.02% to 2.03%, and higher heating value from 4.66 to 5.31 MJ/Nm^3 of the syngas. In general, the results of the current study demonstrated that oil palm fronds can be used as an alternative energy source in the energy diversification plan of Malaysia through gasification, along with, the resulting syngas quality can be improved by preheating the gasifying air.

1. Introduction

The oil palm waste generated in Malaysia could provide 82.21% of the nation's total energy obtainable from biomass waste. The contribution of oil palm fronds (OPFs) generated from pruning and re-plantation constituted 46.71% (97 million tons per year) of the total oil palm waste on a wet basis. In terms of energy content, the contribution of OPF was about 43.16% (405.1×10^6 GJ) (CBBR, 2010; Shuit et al., 2009; Wahid, 2010). The pruning of OPF is carried out during harvesting of fruit bunches. Harvesting is done throughout the year and each oil palm tree is visited in 2-week intervals for a lifespan of about 25 years (Yacob, 2012; Yusoff, 2006).

Some efforts have been made to use fronds for the production of pulp and animal roughage and it is possible to use OPF and its ash as adsorbent for toxic gas and heavy metals; however, most fronds are still dumped at the plantation where some of the biomass serves in preventing soil erosion and promoting soil conservation (Hassan et al., 1996; Shuit et al., 2009; Yusoff, 2006). Hence, there is an opportunity to use this biomass waste for energy generation. Gasification is an option for energy generation by utilizing the biomass waste obtained from oil palm fronds (Sumathi et al., 2008).

Gasifiers are classified into three major categories depending on the solid–gas contact mode: (1) fixed or moving bed, (2) fluidized bed, and (3) entrained flow gasifiers. Each category has sub-classes. The gasifier design determines the application range. Fixed or moving bed gasifiers are applicable for smaller units within the range of 10–10,000 kW, fluidized-bed are more appropriate for intermediate units within the range of 5–100 MW, and entrained-flow gasifiers are used for large-capacity units above 50 MW (Basu, 2010).

Fixed bed gasifiers are the simplest gasifiers and are more suitable gasifiers for small-scale applications (Hsi et al., 2008; Reed and Das, 1988). In fixed bed gasifiers, the feedstock moves downward by gravity, and therefore, the bulk density of the feedstock has to be high enough for continuous downward flow during the gasification process. Hence, fixed bed gasifiers are more suitable

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