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Note from the field

Self-sustained carbonization of oil palm biomass produced an acceptable heating value charcoal with low gaseous emission

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ABSTRACT

Charcoal production with higher heating value (HHV) requires high capital investment and high energy requirement for large scale production. In this study, charcoal production under self-sustained carbonization from oil palm biomass was proposed and tested at pilot scale, whereby temperature and exhaust gas flow rate were monitored but not controlled. This proposed system under self-sustained carbonization, whereby oil palm biomass is combusted to provide the heat for carbonization in inadequate oxygen is preferable to the industry due to its simplicity, ease of operation and low energy requirement. Moreover, the gaseous emissions are below the permitted level set by the environmental authorities. The considerable HHV obtained was between 23 and 25 MJ/kg with low gaseous emissions. The results obtained are acceptable and comparable to other studies on oil palm biomass conducted under controlled conditions with electrical heating elements.

1. Introduction

The utilization of biomass as a biofuel with low sulphur and nitrogen creates less environmental pollution and fewer health risks than fossil fuel combustion. The application of biofuel helps to reduce the problem of gaseous pollutants emissions and their climate impact, particularly on issues related to greenhouse gases or global warming (Rousset et al., 2011). The palm oil industry generates biomass in the form of oil palm empty fruit bunch (OPEFB), mesocarp fibre and palm kernel shell (Sumathi et al., 2008). A typical palm oil mill produced 69,000 dry ton OPEFB per year (Yoshizaki et al., 2013). Therefore the palm oil industry has the potential to produce clean renewable energy from oil palm biomass. Furthermore, the biomass is produced daily at each mill, with no additional cost for collection (Omar et al., 2011). Currently, only mesocarp fibres and palm kernel shell are used as fuel to generate steam and electricity for palm oil mills requirement (Yusoff, 2006), while raw OPEFB is partly sold for mulching purpose (Yoshizaki et al., 2013). Compared to mulching, conversion of raw OPEFB into charcoal for fuel can give 3.5 times higher value when sold as a fuel for power generation (Anuradda and Rangan, 2001; Menon et al., 2006).

Carbonization conducted in the absence or inadequate presence of oxygen to produce a high calorific value fuel is a promising technology for biomass utilization (Adam, 2009). Moderate carbonization temperatures between 300 and 700 °C produced good quality charcoal with HHV between 18 and 27 MJ/kg as fuel for power generation (Hooi et al., 2009). There have been several reports on the production of charcoal from different sizes of OPEFB with an HHV under controlled carbonization temperature using external energy sources, such as an electrical heating element or a furnace (Razuan et al., 2011; Sugumaran, 2009; Sukiran et al., 2011). The self-sustained carbonization, whereby oil palm biomass is combusted to provide the heat for carbonization in inadequate

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oxygen to produce charcoal using biomass feedstock without an electrical heater is more preferable to the industry due to its simplicity, ease of operation and low energy requirement. Therefore, in this study, the application of self-sustained carbonization in a pilot scale for the production of considerable HHV of OPEFB charcoal with low gaseous emission was conducted.

2. Materials and methods

Pressed-shredded and dried OPEFB biomass was obtained from Seri Ulu Langat Palm Oil Mill, Dengkil, Selangor, Malaysia. The particle size of pressed-shredded OPEFB biomass was 100–150 mm. The samples were pulverised and sieved into a half range of 30–99 mm and a quarter size range below 29 mm using a Sima FG 560 × 450 heavy duty grinder. The carbonization process for each particle size was run at least twice to ensure reproducibility. The HHV values of raw OPEFB and charcoal were analyzed from three to five times, from five different locations in the reactor using a Parr 1261 bomb calorimeter.

Combustion of OPEFB biomass was conducted in a pilot-scale brick carbonization reactor, as shown in Fig. 1. The reactor was built with double walls of clay bricks (1000 mm × 1000 mm external dimension, 220 mm thick). The double walls of bricks stone were used to provide a natural insulation of the reactor (Adam, 2009). Approximately 30 kg of OPEFB was carbonized per batch of operation. The bed heights for the particle having sizes below 29 mm, 30–99 mm and 100–150 mm were 0.25 m, 0.40 m and 0.51 m, respectively. After the OPEFB sample was fed into the reactor, the fire was started manually at the top of the reactor using a portable propane gas burner for approximately 3–5 min. The cover of the reactor was then closed completely, and the carbonization temperature was self-sustained on its own using OPEFB biomass as the fuel. All parts of the reactor, especially the stainless steel cover, were closed tightly to avoid any entrance of oxygen. The temperatures inside the reactor were monitored using three k-type thermocouples positioned at different heights from the bottom of the reactor, i.e., T1 (0.46 m), T2 (0.25 m) and T3 (0.04 m). A tray was installed 0.02 m from the bottom, so there is an empty space at the bottom of the reactor to circulate smoke before it can be discharged through the 3 m chimney. The temperatures were automatically recorded every 60 s using a data logger. The carbonization time was recorded once the temperature at T2 reached 300 °C (Spokas et al., 2012). The gas emission from the carbonization process was discharged through an upward stainless steel chimney pipe that was 0.07 m in diameter, and the exhaust gas flow rate was measured using a gas flow meter. The gaseous pollutants and particulate matter below 10 μm (PM$_{10}$) were measured at the top of the reactor chimney using a gas analyzer (MRU Vario Plus, Germany) and PM$_{10}$ analyser at every 30 min. The gaseous pollutants determined were CO$_X$, NO$_X$, SO$_X$, HCl and CH$_4$. The carbonization for each batch of the experiment was stopped using sprayed water once the temperature of the bed at T3 decreased below 300 °C. The charcoal product was removed from the reactor and dried to achieve a moisture content below 5%. The dried charcoal was weighed for a yield calculation and analysed for HHV. The experiments were repeated to ensure reproducibility.

3. Results and discussion

Fig. 2(a)–(c) shows the temperature profiles measured at different OPEFB particle sizes under self-sustained carbonization. Although three (3) thermocouples were used to monitor the temperature at different positions (top, middle and bottom) in the reactor throughout the tests, only temperatures at the middle and

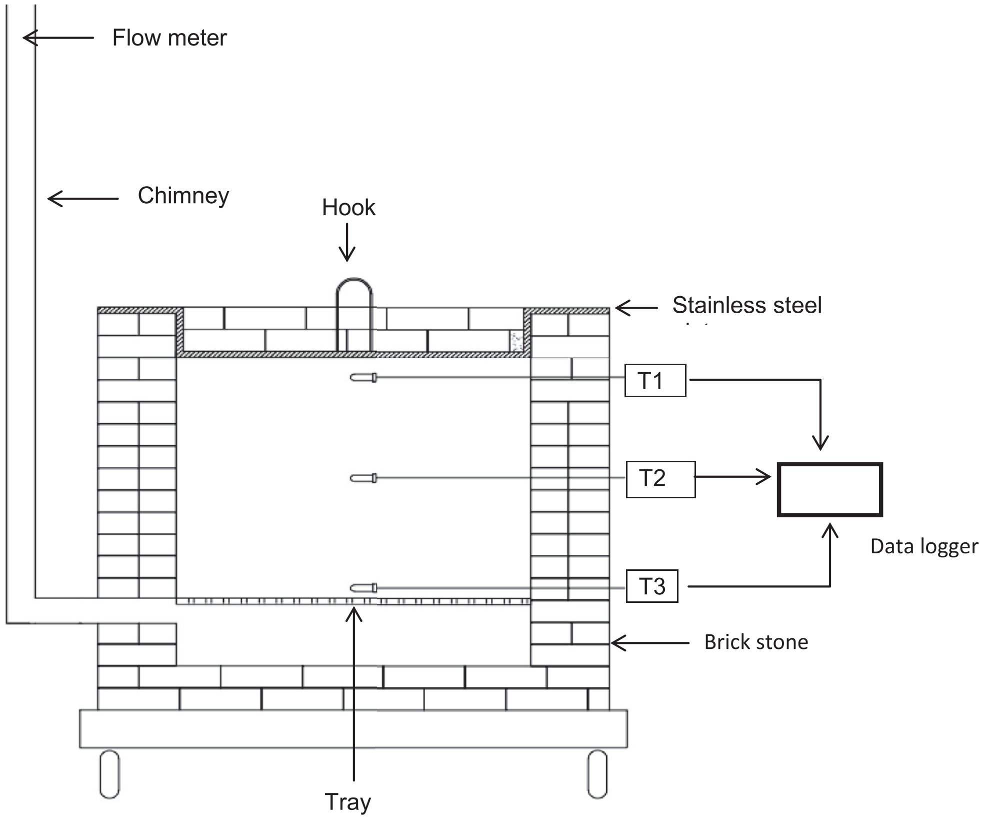

Fig. 1. Schematic diagram of the pilot-scale brick carbonization reactor.