Full Paper

Solid Fuels From Decanter Cake And Other Palm Oil Industry Waste

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Graphical abstract
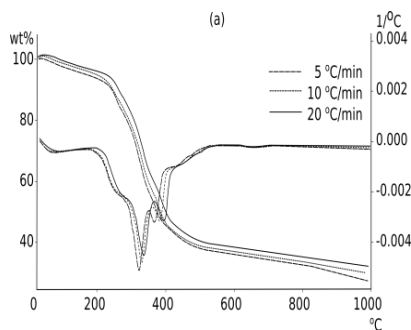
Abstract

Palm oil milling plant generates about 4 – 5 wt % of decanter cake from the total weight of fresh fruit bunch processed. The decanter cake was dried overnight in an oven at 105 °C to reduce moisture content before it could be used as solid fuel. Thermogravimetry analysis, pyrolysis and combustion of the dried decanter cake were performed to characterise it. The proximate analysis indicated that the dried decanter cake contained 5 wt% moisture, 65 wt% volatile, 11 wt% fixed carbon and 19 wt% ash. The calorific value of the solid fuel from decanter cake was determined using oxygen bomb calorimeter. Its' higher heating value (HHV) was determined to be 17.96 MJ/kg, comparable to that of other biomass either from palm oil waste or other agricultural waste. The solid fuel from decanter cake is found to be a suitable replacement for other biomass and coke based solid fuels.

Keywords: Palm oil, solid fuel, decanter cake, waste to energy

1.0 INTRODUCTION

The combustion of solid fuels, historically, has been the primary source of energy for industrialization throughout the world. Wood waste, trees and crops grown as fuel, tire-derived fuel, municipal solid waste, animal wastes, and a host of industrial by-products and wastes to a certain extent are being used to generate thermal energy for process industry and for electricity generation [1]. Biomass is an attractive energy source because it is widely available in large quantity at relatively low price and because it is renewable. Biomass is the third largest primary energy source in the world, after coal and oil. It remains the primary source of energy for more than half of the world's population, and provides about 1250 million tons oil equivalent (Mtoe) of primary energy which is about 14% of the world's annual energy consumption [2].

Malaysia currently is the world's largest producer and exporter of palm oil with the production of 16.99 million tonnes of CPO in 2010 from 4.85 million hectare of plantation area [3]. Even though the industry contributes major income for the country, it raises environmental concern due to the waste generated. From the processing of fresh fruit bunch (FFB), palm oil milling plant produces 23.5 wt% as crude palm oil (CPO), 5.2 wt% as crude palm kernel oil (CPKO) while the other 71.3 wt% is released into the environment in the form of solid or aqueous phases. The major solid phases generated from the milling operations are empty fruit bunches, palm fiber, and palm kernel shell. These solids are currently considered as by-products since they could be used

for economic purposes such as for solid fuels. Palm oil decanter cake is a by-product from palm oil milling decantation process. The production rate of decanter cake amount to about 4 – 5 wt % of fresh fruit bunch processed. The ultimate composition of decanter cake varies depending on plant site location. Its' major constituents are C, H, O, and N. Decanter cake may also contains P and Mg [4]. Currently decanter cake finds limited application as fertilizer and ruminant nutrition ingredients. The capability of decanter cake as adsorbent for heavy metal removal from aqueous solution have also been investigated [5].

2.0 EXPERIMENTAL

Decanter cake and POME sludge were obtained from palm oil milling plant owned by LKPP Corporation Sdn. Bhd. in Lepar Hilir, Kuantan. Fresh decanter cake and other samples were dried in oven at 105 °C overnight to reduce moisture content. Dried decanter cakes were labeled as DDC and were ready tested and characterized. Carbonised decanter cake were prepared by heating up DDC in closed crucible at 500, 600, and 700 °C using a muffle furnace for 1 h, and labeled as CDC500, CDC600 and CDC700 respectively. POME sludge, empty fruit bunch, palm fiber and palm kernel shell were obtained from LKPP Corporation Sdn. Bhd., while oil palm trunks, leaves and stalks were collected from plantation nearby. Wood charcoal was bought from local market.

Thermogravimetry analysis was carried out with a Mettler Toledo TGA/DSC 1 instrument equipped with STARe Software System. Analysis was carried out in a nitrogen atmosphere at a flow rate of 50 ml/min while combustion was done in the flow of pure oxygen at 50 ml/min. Three heating rates of 5, 10 and 20 °C/min have been used to increase the temperature from 25 to 1000 °C. Proximate analysis was carried out in A Mettler Toledo TGA/DSC 1 according to the methods described by Mayoral *et al.* [6]. Higher heating value of samples was determined using IKA C200 oxygen bomb calorimeter.

3.0 RESULTS AND DISCUSSION

Figure 1a shows the characteristic thermogravimetry and first differential thermogravimetry curves for DDC at three heating rate. Based on the thermogravimetry curves, volatilization starts at about 200 °C. The highest mass loss rate is reached at 324, 330 and 337 °C for heating rate of 5, 10 and 20 °C/min, respectively. The volatilization process continued until about 710 °C. The main peak, in the first differential thermogravimetry, associated to cellulose volatilization, is deformed at low temperature by hemicelluloses pyrolysis and at higher temperature by lignin volatilization. Broad peak in

region of 620 – 710 °C reflects the volatilization of inorganic matter contained in DDC. From the plots, it is shown that at lower heating rate, volatilization process occurs at lower temperature because longer contact time is provided compared at higher heating rate.

In the combustion of DDC, as shown in Figure 1b, the main volatilization occurs in region of 195 – 420 °C, with the main peak for mass loss at 285, 297 and 316 °C for heating rate of 5, 10 and 20 °C/min, respectively. It reveals that presence of oxygen shifted the peaks to low temperature while significantly increasing the mass loss rate. Similar with the pyrolysis process, lower heating rate provide longer contact time to oxidize volatile, and completely deformed at lower temperature compared to higher heating rate.
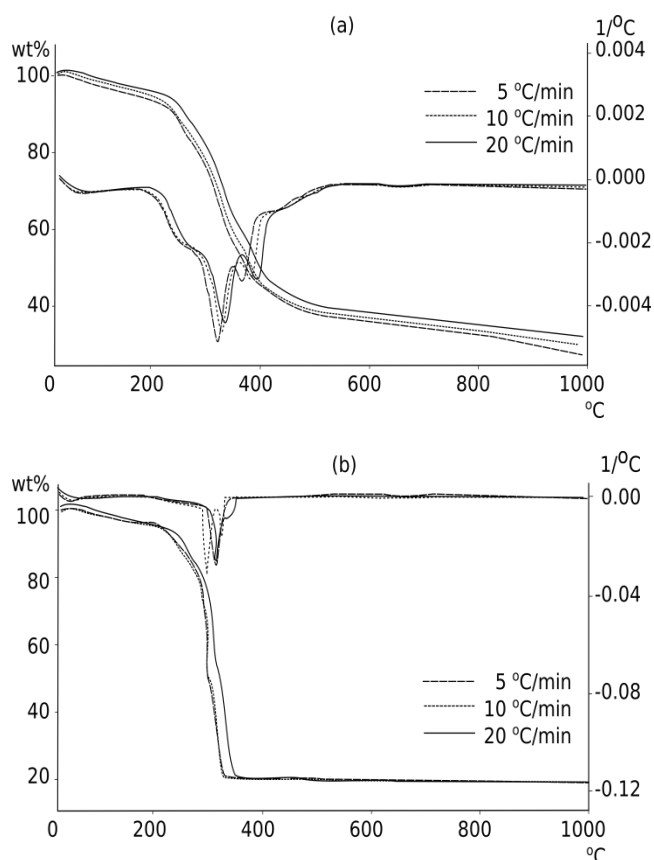

Figure 1 TGA and DTG plot for DDC pyrolysis (a) and combustion (b) at three different heating rates

The purpose of proximate analysis is to determine moisture, volatile, fixed carbon and ash content of materials. It is widely used in solid fuel characterization to show the ratio of combustible and incombustible component, and also to predict the combustion properties of solid fuel for instance its heating value. The TGA plot was divided into 3 stages as shown in Figure 2. In the first stage, the drying process has taken place to remove moisture. Drying process is carried out in temperature range of 25 –

105 °C. Weight lose in this stage is recognized as moisture content. The second stage is the volatilization of solid in nitrogen atmosphere from 105 to 850 °C. All of volatile matters were degraded in this stage. The third region is the combustion in oxygen environment at 850 °C to oxidize all fixed carbon content leaving the ash at the end of the process. The fixed carbon was calculated by the summation of percentages of moisture, ash, and volatile matter subtracted from 100.
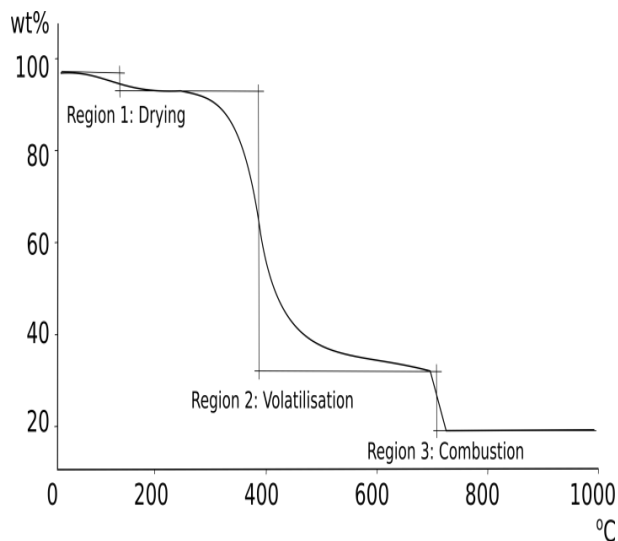

Figure 2 Proximate analysis of DDC using TGA plot

Dried decanter cake was found to have relatively high content of volatile matter, 64.85% and it is comparable to that of other type of palm oil waste, sludge and woody biomass as shown in Table 1. The volatile matter may relate to the lignocellulose content of DDC, which come from debris of fiber, EFB, trunks and kernel shell during palm oil extraction process. Ash content in DDC being 18.9% is higher than that of other palm oil waste like EFB (7.93%), fiber (&.18%) and kernel shell (3.30%). It is caused by the presence of impurities such as soil, sand and other inorganic matter in FFB processed. This value is however lower than that of other sludge. Higher ash content as shown in POME sludge contributes to the lower combustion quality of materials since ash is incombustible matter.

Generally, the heating value of a fuel may be reported on two bases, the higher heating value or gross calorific value and the lower heating value or net calorific value. The higher heating value (HHV) refers to the heat released from the fuel combustion with the original and generated water in a condensed state, while the lower heating value (LHV) is based on gaseous water as the product. In this study, the heating value was presented on HHV base as in Table 1.

The HHV of DDC was measure to be 17.96 MJ/kg. This value is similar to that of other sludge and is comparable to that of other biomass solid fuel. High content of volatile matter indicated that most of calorific value in DDC combustion was contributed by volatile matter. The HHV of DDC is about half of that of good quality coal, which had HHV of about 30 MJ/kg [11]. In several cases, carbonisation of biomass can improve the quality of solid fuel, particularly their fixed carbon content and heating value [12], but in this study, transforming DDC into carbonaceous material resulted in lower quality solid fuel. The HHV values decreased to 13.36, 14.97 and 12.37 MJ/kg when the DDC was pyrolysed at 500, 600 and 700 °C respectively. The high temperature treatment resulted in the loss of carbonaceous material through volatilization. The higher the temperature the more significant is the loss of volatiles. This again indicates that most of calorific value in DDC combustion originated from the volatile matter.

The HHV of the solid fuel from decanter cake is as high as that of EFB, fibre and palm kernel shell which are within the range of 18 – 20 MJ/kg. This makes decanter cake a potential solid fuel to partially replace palm fibre and the palm kernel shell as solid fuel in palm oil milling plant. This replacement would enable the plant to sell the palm fibre and kernel shell to generate additional revenue. POME sludge shows lower HHV compared to that of other waste and has low potential usage as solid fuel.

Table 1 Proximate analysis and HHV of DDC, and other solid fuel

Solid fuel	Moisture %wt	Volatile %wt	Fixed Carbon %wt	Ash %wt	HHV, MJ/kg	Reference
DDC	5.00	64.83	11.27	18.90	17.96	This study
CDC500	4.49	20.95	26.67	47.89	13.36	This study
CDC600	4.48	17.70	30.69	47.14	14.97	This study
CDC700	5.88	14.33	23.96	55.83	12.37	This study
POME Sludge	4.43	35.97	11.15	48.45	8.90	This study
Empty fruit bunch	6.84	72.34	12.88	7.93	18.00	This study
Palm fiber	6.78	69.53	16.51	7.18	18.80	This study
Palm kernel shell	1.71	72.27	22.72	3.30	20.30	This study
Palm trunk	4.37	65.96	23.65	6.02	15.55	This study
Palm leaf	2.99	72.74	18.46	5.81	19.14	This study
Palm stalk	4.24	70.36	21.63	3.77	16.95	This study
Wood charcoal	2.65	32.17	60.47	4.71	28.05	This study
Pistachio soft shell	9.25	67.85	8.69	14.21	18.57	[7]
Olive cake ᵃ		62.10	34.60	2.80	21.60	[8]
Sewage sludge ᵃ		18.02	50.44	31.54	18.02	[9]
Paper mill sludge ᵃ		48.74	6.01	45.25	18.74	[10]

ᵃ Dry basis

4.0 CONCLUSION

In this study the thermal characteristics of dried decanter cake were investigated to explore its' use as solid fuel. The compositions of combustible matter in decanter cake are comparable with other biomass-based solid fuel. The HHV was also found to be as high as that of other biomass especially the palm kernel shell. In this respect the dried decanter cake could be used to replace the palm kernel shell and palm fibre as solid fuel on site. Carbonisation of decanter cake produces solid fuel with lower higher heating value. POME was found to have high ash content and low HHV value. As such, it's potential to be used as solid fuel is low.

Acknowledgement

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