Physical Characteristics Study of Saw Dust as Liquid Fuels Application

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***Abstract*— The objective of this research is to analyses the characteristics of saw dust biomass as an alternative for liquid fuel application through analyzing of its physical properties (proximate analysis, heating value, Fourier-Transform Infrared Spectroscopy (FTIR) and thermogravimetric analysis (TGA)). Biomass was good solutions for an alternative for energy production due to its low cost, energy saving and environmental friendly. This study shows the usage saw dust biomass as an alternative for biofuel production towards the environment. The saw dust has high heating value of 3.0394 MJ/kg. Based from the proximate analysis, the saw dust has high volatile matter (60.47%), low fixed carbon content (21.71 %), low ash content (10.86 %) and low moisture content (6.96 %) which indicates it can be used as liquid fuel. On the other hand, FTIR analysis shows the result of the functional group obtains in the sample while TGA analysis produced the result on the mass loss achieved by saw dust sample during pyrolysis which is at 65.8% with high decomposition rate at 3.57 mg/min.**

Keywords*— Biomass, Saw Dust, Physical Properties, Liquid Fuel

I. Introduction

The land of Malaysia is very valuable which contributes on the economic growth due to its natural resource of non-renewable and renewable energy. Nowadays, non-renewable energy of fossil fuels such as oil, natural gas and coal is still the main current contributors of energy supply towards transportation and power generations. Their limited in resource has led on intensive research on alternative source for energy supply.

Besides that, these current energy supply from fossil fuels is one of the major pollution contributors towards the environment causing global warming. In order to overcome this issue, new resource need to be exploit as back up sources to meet the demands in the future.

Research on the renewable energy has gain interest among the researchers for future needs as to meet the demands and supply. With this regard, biomass with their unique characteristics and can be treated on many ways to produce fuel as part of the energy source [1]. While, saw dust which is a form of biomass can be one of the promising solutions as it helps on better living environment and renewable energy source. Thus, saw dust is a valuable feedstock for biofuel production that can be the potential alternatives of fossil fuels.

On the other hand, saw dust briquette with having advantages on higher heating intensity, cleanliness and very convenience as it only needs small space for storage [2]. Therefore, detailed study on the characterization of saw dust is important to discover their fuel properties and efficiency to be a valuable feedstock for energy supply.

It is vital to obtain the characterization of biomass in order to know the capability in utilising biomass as material and energy feedstocks. Through some experimental physical analysis, the efficiency performance of biomass can be obtained. Besides that, the compatibility of biomass for alternatives of fossil fuel can also be determined based on the analysis result.

The detail physical characterization properties of biomass can be obtained based on proximate and ultimate analysis, calorific heating value, analysing elemental and functional groups by Fourier-Transform Infrared Spectroscopy (FTIR) and determination of kinetic parameters by Thermo-Gravimetric Analysis (TGA).

II. METHODOLOGY

A. Sample preparation

The selected biomass of wood saw dust was procured within Shah Alam, Selangor. The sample is then grinded and sieved using (Octagon 2000, Endecotts) in order to obtain size of sample below 1mm. Upon sieving, the sample is then kept overnight inside the desiccator at room temperature.

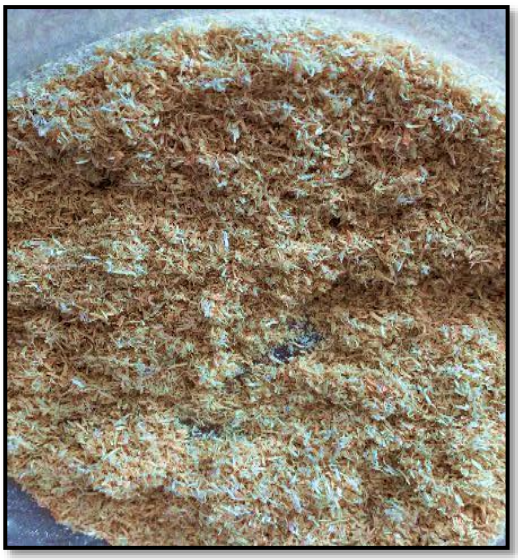

Figure 1: The saw dust sample after sieved.

B. Heating Value Determination

Bomb calorimeter was used for the determination of calorific value or heating value. The test on calorific study was performed based on ASTM E711-87[3]. The weight of saw dust is recorded on the crucible at 1g and placed inside a closed steel container. The fuel sample together with the decomposition vessel was immersed into the inner vessel after the cover of measurement cell automatically closed. The

sample is burnt for 15 minutes and the calorific value was recorded based on the digital screen.

C. Proximate Analysis

Moisture content, volatile matter, ash content and fixed carbon content of saw dust samples was determined through proximate analysis.

Moisture content is based on the analysis on oven-dry method. The saw dust sample is weighed at 3g and placed inside the oven at 110℃ for 30 minutes as followed on (ASTM D4442-07, 2007) [4]. Upon drying the sample was collected and transfer to a fresh desiccator and left cooled until it reached room temperature and weighed again. Weighing of samples must be used with closed weighing jars or containers. The moisture content, MC (%) can be obtain through the equation 1.1 shown below.

$$\text{MC, \%} = \text{(A-B) / B x 100} \quad (1.1)$$

Where;
A = original mass, g
B = oven-dry mass, g

Volatile matter content was obtained based on the weight loss resulting from heating refuse-derived fuel of the saw dust sample under condition stated by (ASTM E897-88, 2004) [5]. Saw dust sample at 1g is placed at crucible and heated at high temperature ranging at 950 ℃ ± 50 ℃ in a furnace for 7 minutes. Prior heating the samples, the cover must be ensured closed tightly. The volatile matter content is obtained as follows:

$$V_{ad} = \left[\frac{(A-B)}{A} x\ 100\right] - M_{ad} \quad (1.2)$$

Where:
A = weight of saw dust sample, g
B = weight of saw dust sample after heating, g
M_{ad} = moisture as determined, %
V_{ad} = volatile matter as determined

Based on (ASTM E830-87, 2004) [6], ash content of biomass sample was determined by weighing the residue after burning under controlled conditions at specified temperature and pressure. 1g of saw dust sample is prepared and placed inside the crucible prior heating in the furnace. The furnace initially starts at low temperature and further increased gradually until temperature ranges at 575 ℃ ± 25 ℃. The percentage of ash content are calculated using following equation:

$$Ash\ Content, \% = [(A - B)/C] x\ 100 \quad (1.3)$$

Where;
A = weight of ash residue in the container, g
B = weight of empty container, g
C = weight of ash analysis sample, g

Finally, the fixed carbon was determined based on (ASTM D5681- 98a, 2004) [7]. The total percentage of fixed carbon was obtained by subtracting the total percentage of other components which includes percentage of moisture content, volatile matter and ash content with 100 %. The equation 1.4 below was used for the determination of fixed carbon percentage:

$$Fixed\ Carbon, \% = 100 - (MC + V_{ad} + Ash) \quad (1.4)$$

D. Thermogravimetric Analysis

Sample of saw dust at 15 mg was placed inside the TGA analyser under an inert atmosphere with continuous supply of nitrogen gas. The result obtained from the analyser represent the thermal properties of the sample at constant heating rate. Besides that, it also shows results on the percentage of lignin, hemicellulose and cellulose of the saw dust biomass sample.

E. Fourier-Transform Infrared Spectroscopy (FTIR) Analysis

The FTIR analysis was conducted using the FTIR analyser (Spectrum One FT-IR Spectrometer, Perkin Elmer). The equipment of the FTIR analyser applied the principle of vibration and rotation on motion of the molecule and emitted infrared spectrum of the organic compound and provides a finger print of the compound forms. The analyser depicts the chemical compounds and functional groups of the biomass feedstock sample.

III. RESULTS AND DISCUSSION

A. Characterization of Saw Dust Biomass

Table 1 represents the result performed on the heating value of saw dust sample. The analysis conducted on heating value of saw dust was 3.0394 MJ/kg. The result was then compared with literature review study as shown in Table 1.

Table 1Heating value of saw dust

Analysis	Result
This study	3.0394 MJ/kg
Literature review [8]	4.82 MJ/kg

Based from Table 1, the heating value of the present study is lower than the result from the literature review. This might be due to the high percentage of moisture content in the biomass sample anlalysed which reflects on lower net energy [9]. Thus. there is shared energy consumed for evaporation of water and heating the saw dust which results on lower heating value of saw dust sample compared to the literature study.

Proximate analysis describes result on the percentage of moisture content, fixed carbon, ash content and volatile matter of the saw dust sample as shown in Table 2.

Table 2. Proximate analysis of saw dust

Proximate Analysis	Result
Moisture Content	6.96 %
Fixed Carbon	21.71 %
Ash Content	10.86 %
Volatile Matter	60.47 %

The performance of the saw dust sample from proximate analysis was analysed through comparison of results with other literature review. The data on the various proximate analysis result depicted in Table 3.

Table 3 Comparison of proximate analysis result of saw dust.

Proximate Analysis	This Study	[10]	[11]
Moisture Content	6.96 %	13.44%	9.67 %
Fixed Carbon	21.71 %	16.51 %	76.82 %
Ash Content	10.86 %	0.81 %	1.8 %
Volatile Matter	60.47 %	69.24 %	76.82 %

Based on the percentage of moisture content, this study produced the lowest result which are beneficial for higher energy yield compared to other literature reviews.

Furthermore, as for the percentage of fixed carbon, this study produced 21.71% which lies in between both of the literature reviews result. This indicate that the fixed carbon percentage is at optimum condition for good fuel material purposes which are vital towards heat generator in burning process [12].

On the other hand, the result on ash percentage for this study is the highest compared to other literature reviews result. High value of ash content in biomass is not desirable due to its poor fuel characteristics property. The difference on the ash content for this study compared to the literature review results is due to low alkali matter presents in the sample as the sample compared with different types of saw dust [13]. However, the ash content produced from the saw dsut sample is still desirable for fuel properties as it still indicates in low ash content category in the range of 5% to 20% [14].

Volatile matter for this study also gave the lowest result compared with other literature reviews which is also due to the different types of saw dust analysed. However, the saw dust used in this study still indicates positive behavior on biomass selection for fuel usage as the result is with in the range of 60% to 90% [15].

B. Fourier-Transform Infrared Spectroscopy (FTIR) Analysis

The result of the FTIR analysis was shown in the Fig.1. The graph depicted the functional group and chemical compound present in the saw dust sample obtained from the FTIR analyzer. The wide peak ranging from 3600 cm^{-1} to 3000 cm^{-1} represent the O-H stretching vibrations and the formation of C-O-C stretching vibrations reflects on the peak in the range of 1300 cm^{-1} to 1000 cm^{-1} [16]

Table 2 shows the chemical behavior of saw sample. The functional group presents such as C-O-C and O-H chemical bond in the saw dust sample. The functional groups of alcohol and phenol presence due to the conversion of volatile material when heating of the saw dust biomass

Table 2 FTIR analysis of saw dust sample

S.I No.	Peak Wavenumber (cm^{-1})	Transmittance (%)	Identification of functional groups [17]
1	1027.08	78.75	C-O-C stretching vibration band
2	1230.00	90.87	C-O-C stretching vibration band
3	3341.13	91.09	O-H chemical bond
4	3750.24	93.99	O-H chemical bond

C. Thermogravimetric Analysis (TGA)

Fig.2 illustrated the trend of weight loss of saw dust sample by thermogravimetric analysis (TGA). The analysis runs at heating rate of 50 ℃/min in nitrogen atmosphere. The maximum weight loss achieved at 7.24 mg which about 65.8% of total weight. The saw dust sample can withstand high temperature due to its high decomposition rate of saw dust which initiated at temperature of 390 ℃ and at a rate of 3.57 mg/min The mass loss initiates at temperature around 100℃ which due to the loss of residual water.[17]

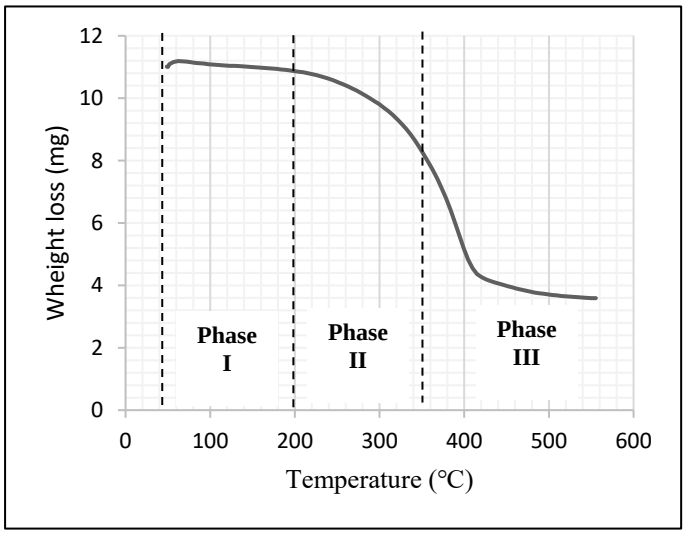

Fig.2: TGA analysis

The saw dust undergoes slow pyrolysis at three different phases which were; first at temperature ranges between 50℃ and 200℃, second phase temperature between 200℃ and 450℃ followed by the third phase at temperature above 450℃ [18].

The main phenomena that occur during the initial stage was the dehydration of saw dust where this process is endothermic. Besides that, components such as water, carbon monoxide and carbon dioxide were excreted from the matrix.[19] This occurred at the temperature between 50℃ and 200℃.

During phase II (200-450℃), the main decomposition occurs. Hemicellulose and cellulose decompose during pyrolysis. The amorphous structure of hemicellulose undergo conversion at temperature between 200℃ and 350℃ [20].

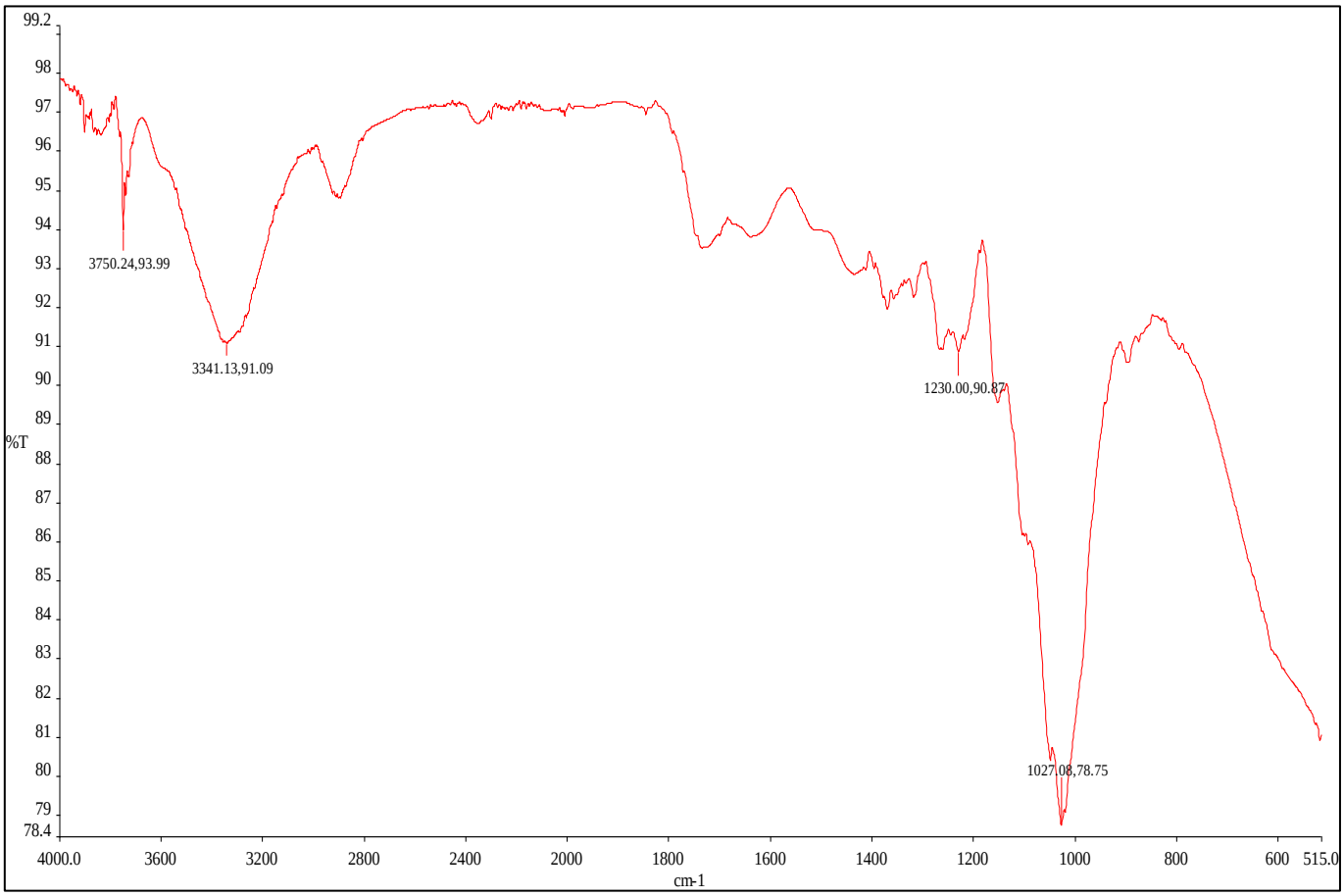

Fig.1: FTIR analysis result of saw dust sample

In the final phase which at phase III, pyrolysis gases and tars were released by lignin. [21]. There were several mechanisms involves in this region consisting of chemical reactions, random nucleation, phase boundary mechanisms and diffusion. [22].

I. Conclusion

Nowadays major issues regarding the climate changes due to the emissions of greenhouse gases and increasing demand on usage of energy due the technological changes and population must be overcome. The utilization of saw dust biomass provide solutions as an alternative on energy production with low-cost and efficient energy. This analysis on characterization of saw dust as liquid fuel which was beneficial as an alternative on the natural gas due to its eco-friendly and cost saving. The saw dust biomass consists of high calorific value of 3.0394 MJ/kg, low moisture content of 6.96 %, low fixed carbon percentage of 21.71 %, low ash content of 10.86 % and high volatile matter of 60.47% which gave good implications on usage of liquid fuel. Based on the FTIR analysis, the functional group presented consisting of alcohol and phenol potentially on production of syngas and methane that is useful for energy production. In TGA, the maximum weight loss achieve was 65.8 % at temperature of 390℃.

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