Physical Characteristics Study of Dry Leaves as Liquid Fuels Application

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***Abstract*— The study of dry leaves as a liquid fuels application gives the potential to solve the depletion and environmental issue of the oil resources. The abundancy of dry leaves nationwide make it one of the efficient, reliable and sustainable potential sources of energy. Several basic analysis such as heating value, proximate and ultimate analysis are used to analyse the dry leaves properties as a fuel. The results indicate that dry leaves have the heating value of 19.17 MJ/kg while the proximate analysis of dry leaves show that it contains 9.33% moisture, 62.67% volatile matter, 3.67% ash and 24.33% fixed carbon. Elemental analysis conducted on dry leaves gives the values of 75.94% C, 9.81% H, 0.22% N and 14.02% O. Dry leaves have relatively low H:C and O:C ratio, which are 1.55 and 0.16 respectively. Lower ratio indicates that it contain higher energy density and greater amount of heating value. Results obtained were compared to previous literature studies and the samples had a consistent value with the previous reports.**

***Keywords*— Biomass, Biofuel, Heating Value, Proximate Analysis, Ultimate Analysis**

I. Introduction

Technology enhancements and population growth have contribute to the consistent increase in energy consumption. The world's energy consumption is predicted to increase by 48% between 2012 and 2040 [1] . As a results, fossil fuels such as oil, natural gas and coal currently at risk due to the resource limits. Their limited source and fluctuating prices has led to intensive search for an alternative to replace petroleum derivatives as a fuel resource.

The depletion is not the only current problem with fossil fuel use. Burning fossil fuels caused environmental degradation and the waste products produced have created an imbalance in the atmosphere CO_2 levels, which has become the major contributor to global warming [2].

Biomass such as dry leaves are one of the most abundant resources in the world that can potentially replace fossil fuels. It can be the ideal, efficient and cost-saving renewable feedstock for the production of ethanol or other secondary source of fuel. Hence, comprehensive characterization of dry leaves are required in order to derive their benefit of its fuel properties. It is important to know their chemical and physical characteristics to determine significantly whether it can be explored as an economical and environmental energy source.

The efficiency and performance of biomass as a replacement for fossil fuels can be measured by conducting several analysis such as heating value determination, proximate analysis and ultimate analysis.

The heating value is the energy content in a fuel, which refers to the amount of energy liberated as heat when a unit of fuel is completely burnt. It is expressed in calories per gram (cal/g) or Joule per gram (J/g).

Proximate analysis presents the weight percent of moisture, volatile matter (VM), fixed carbon (FC) and ash content in a biomass while the ultimate analysis, which is also known as elemental analysis gives the percentage of constituent elements present in the biomass such as carbon, hydrogen, oxygen, sulfur and nitrogen. Each parameter contributes significantly towards the heating value and burning characteristics of the fuel.

II. Methodology

Experimental phase includes sample preparation, heating value determination, proximate analysis and ultimate analysis. All the analysis conducted were according to ASTM methods.

A. Sample preparation

In this experimental study, dry leaves were collected within the study site area in University Teknologi MARA, Shah Alam. The air-dried feedstock collected was grinded and sieved using cutting mill model SM 2000 (Retsch, Germany) to get homogenous powder of <1mm. Sieved biomass samples were then stored in air-tight containers at room temperature for characterization studies.

Fig. 1: The homogenous powder of dry leaves.

B. Heating Value Determination

The higher heating value of dry leaves samples was determined using a calorimetric bomb model C5000 Control (IKA Works, Germany). The test was performed according to ASTM E711-87 (Reapproved 2004) [3]. The samples were tested three times to obtain the good results.

C. Proximate Analysis

Proximate analysis include the determination of moisture content, volatile matter content, ash content and fixed carbon content in a dry leaves sample. All the tests were performed three times to get the average readings.

Moisture content was determined by using oven-dry method. The percent moisture of the samples was determined according to ASTM D4442-07 (2007) [4] in an oven at 110°C for 30 minutes using approximately 3 g of the sample. The moisture content of the sample is calculated using the formula:

$$MC, \% = (A - B) / B \times 100$$

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

Volatile matter was determined according to ASTM E897-88 (2004) [5]. 1 g of samples in a crucible was heated at 950°C ± 50°C for 7 minutes in furnace. The percentage of volatile matter was calculated as follows:

$$V_{ad} = \left[\frac{A-B}{A} \times 100\right] - M_{ad}$$

Where:
A = weight of sample used, g,
B = weight of sample after heating, g,
M_{ad} = moisture (as-determined), %.

Ash was determined by weighing the residue remaining after burning the prepared analysis sample under rigidly controlled conditions of sample weight and temperature. The ash content was determined according to ASTM E830-87 (2004) [6]. 1 g of samples was placed in the furnace at low temperature and was heated gradually to 575°C ± 25°C. The ash percent in the analysis sample was calculated as follows:

$$Ash, \% = [(A - B) / C] \times 100$$

Where:

A = weight of container and ash residue, g,
B = weight of empty container, g,
C = weight of ash analysis sample, g

The fixed carbon was a calculated value. The percentage of fixed carbon was performed according to ASTM D5681-98a (2004) [7] by subtracting moisture, volatile matter and ash content from the total percentage of 100%. The percentage fixed carbon was computed by using the equation below:

Fixed carbon, % = (100 - moisture, % + ash, % + volatile matter, %)

D. Ultimate Analysis

Ultimate analysis includes the measurement of the carbon, hydrogen, nitrogen, oxygen and sulphur composition in dry leaves sample. The elemental compositions were detected by CHNS analyser, model FlashEA 1112 (Thermo Finnigan, US).

III. RESULTS AND DISCUSSION

A. Heating Value

The heating value of dry leaves obtained from calorimetric analysis of this study were shown in Figure 2.

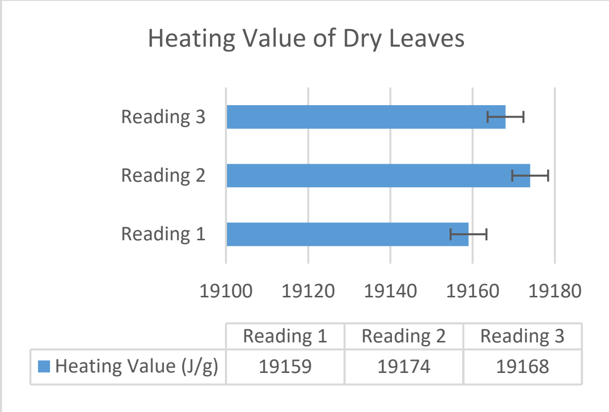

Fig.2: Heating Value of Dry Leaves Samples.

The average heating value obtained from the three readings was 19167 J/g with 4.3% standard deviation. This values does not much differ with the heating value of other dry leaves obtained from previous literature studies conducted in Malaysia as shown in Table 1.

Table 1: Comparison of the Heating Value of Dry Leaves.

Reference	Heating Value (J/g)
This study	19167
[8]	20400
[9]	18134

As the types of species are different among each studies, the heating values might slightly varies since it has strongly influenced by the composition of the dry leaves. However, the value obtained in this study was correspond with the heating value for forestry residues biomass, which generally lies between the ranges of 15-19 MJ/kg. With this greater amount of heating value, dry leaves could become source of biofuel that burns more cleanly and producing less pollutants.

B. Proximate Analysis

The proximate analysis of gives the value of moisture content, volatile matter, ash and fixed carbon in dry leaves sample. The proximate analysis data of this study were shown in Table 2.

Table 2: Proximate Analysis of Dry Leaves.

Properties	Values, wt.%
Moisture	9.33
Volatile Matter	62.67
Ash	3.67
Fixed Carbon	24.33

In order to make a comparison, the properties of dry leaves data collected from previous literature were presented in Table 3.

Table 3: Comparison of Proximate Analysis of Dry Leaves.

	Proximate analysis, wt.%		
Properties	**This study**	**[10]**	**[11]**
Moisture	9.33	6.00	7.70
Volatile Matter	62.67	74.33	68.70
Ash	3.67	4.67	12.30
Fixed Carbon	24.33	15.00	11.30

Compared to both literature studies, dry leaves in this study gives the highest moisture content. This could occur due to the various amounts of volatile compounds in untreated dry leaves which may influence the evaporation process during oven drying. However, the value was still in the acceptable range of 7 to 13% moisture for biomass [8]. The lower moisture value of 9.33% contributes to higher thermal efficiencies and higher heating values.

Volatile matter of dry leaves sample in this study was included in the range of common volatile matter of biomass, which typically lies between 60% to 90% [12]. A good biofuels were supposed to have volatile matter content within that range to avoid any problems towards the internal combustion engine and provide a stable flame for a mixed fuel.

Compared to previous studies, this study gives the lowest ash content of 3.67%. The lower value of non-combustible minerals in dry leaves make it more desirable as a fuel because it was positively contribute to the heating value, reduce the dust emissions and ease the conversion process of biomass feedstock into energy.

For the fixed carbon content, there was 24.33% of carbon left from the sample of dry leaves after the volatiles have been driven off. This study gives the highest value of fixed carbon compared to both previous published literature. The high value of fixed carbon in dry leaves indicates the good quality of fuel materials as it acts as the main heat generator during burning and have direct relationship with the heating value.

C. Ultimate Analysis

Results obtained from the elemental analyser were tabulated in the Table 4 and for comparison, the elemental composition of dry leaves from other literature were shown in Table 5.

Table 4: Ultimate Analysis of Dry Leaves.

Elemental composition	Values, wt.%
C	75.94
H	9.81
N	0.22
O	14.02
S	0.00
H/C	1.55
O/C	0.16

Table 5: Comparison of Ultimate Analysis of Dry Leaves.

Reference	Elemental composition (wt.%)				
	C	H	N	O	S
This study	75.95	9.81	0.22	14.02	0.00
[13]	45.80	6.24	0.09	47.20	0.67
[14]	41.61	5.44	2.38	50.57	0.00

In this study, carbon have the highest content among all the elements, followed by oxygen, hydrogen and nitrogen. Carbon content for the dry leaves in this study was quite high compared to the previous studies. The high carbon content in dry leaves make it suitable to become the substituent for fossil fuels because carbon represent the major contribution to the overall heating value. Fuel efficiency are also depends on the atomic ratio H:C and O:C. Dry leaves have relatively low H:C and O:C ratio, which are 1.55 and 0.16 respectively. Lower ratio indicates that it contain higher energy density and greater amount of heating value. This happen because C-H and C-O has lower chemical energy than C-C bonds [16]. The formation of C-C bonds contribute to the largest possible amount of carbon in the fuel range.

Hydrogen is also responsible for the energy content in biofuels. The higher the hydrogen, the higher the energy content in biofuel because it involves in the exothermal reactions that take place with O_2 during combustion, generating H_2O. The high hydrogen content of dry leaves (9.81%) was beneficial in increasing the volatility and enhancing the highly reactive nature of the fuel.

Results from ultimate analysis in this study showed that nitrogen content in dry leaves was 0.22%. This value is below the upper limit for N (0.6% dry basis) that is considered to be acceptable for nitrogen dioxide emissions [17]. The small percentage of nitrogen provide an advantage in combustion process, as it can reduce the emissions of NOx (NO,NO_2), N_2O, ammonia (NH_3), ozone pollution, and photochemical smog [18]

As can be seen in Table 5, the oxygen in this research study was the lowest. The lower oxygen content is an advantage because it will increase the energy value, decrease the volatility and prevent soot formation during thermochemical conversion.

The dry leaves in this study does not contain sulfur. The absence of sulfur is a good indicator because it means that the biomass is not contaminated by fertilizers or pesticide. The low sulfur content in biomass lower the SOx emissions, smoke type smog and acid precipitation. The deposit formation, slagging and corrosion were also minimized during thermochemical conversion [19].

IV. CONCLUSION

Heating value determination, proximate analysis and ultimate analysis are an important analysis used for the quality characterization of dry leaves as a fuel materials. The higher heating value of 19167 J/g obtained for the dry leaves indicates that they have an excellent fuel properties. The dry leaves are considered to have heating values about the same values of some well-known biofuels and fall within the limit for the production of steam in electricity generation. From the proximate analysis and ultimate analysis that has been carried out, it is also concluded that dry leaves has the potential to replace fossil fuels as a source of energy. Low moisture, ash and fixed carbon as well as high volatile content of dry leaves make it has potential for producing a better quality fuels and friendly environment.

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