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Characterization study on oil palm empty fruit bunches as bioenergy feedstock

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Abstract
There is a lot of scope for fuel production from the unexploited potential of wastes generated from agro processing industries. In the case of palm oil processing industries, four different wastes are produced from various unit operations of palm oil production *viz.*, empty fruit bunches, palm fiber, palm kernel and decanted cake. Among these oil palm empty fruit bunches (OPEFB) was found to be abundantly available. In order to recover energy from this waste, preliminary studies like proximate analysis and thermo-gravimetric analysis were conducted to analyze its characteristics to use it as a bioenergy feedstock. The proximate analysis reveals that the moisture content of OPEFB is relatively higher. The thermal behavior was analyzed in TG Analyzer (TGA) at different heating rates of 20, 30, 40, and 50˚C/min. There were three peaks appeared in all the thermo-grams and temperature ranges for maximum weight loss of the selected biomass sample was also reported. From the study, OPEFB was found to be well suitable for fuel production through thermochemical conversion route.

Keywords: Bioenergy feedstock, oil palm empty fruit bunches, proximate analysis, thermo-gravimetric analysis

1. Introduction

Increasing concern of energy security and environmental issues such as emission of greenhouse gases has raised the interest towards the development of renewable bio-energy as an alternative energy to fossil based fuel. Bioenergy is the renewable energy contained in the materials derived from biological sources known as biomass. As one of the most productive biomass source, oil palm offers great potential as bio- energy feedstock. Palm oil which is a major product from oil palm industry, is gaining widespread acceptance across the world as a source for bio-diesel [1]. Its utilization as bio-energy feedstock also brings other environmental benefits such as reduced levels of CO_2, black smoke of carbon particulates, carbon monoxide, and sulphur dioxide as it is a cleaner energy. Also the oil palm industry is found to be one of the largest producers of biomass mostly in the form of wastes.

Currently, the palm oil industry in the world generates over 190 million tons of wastes in the form of solid and liquid residues. Out of this only about 10% are utilized commercially for value-added bio-products like bio-fertilizers [2]. The wastes produced by the palm oil industry are oil palm empty fruit bunches, palm pressed fiber, palm kernel shells and palm kernel cake. Oil palm empty fruit bunches (OPEFB) are a non-wood lignocellulosic biomass which are regularly collected and discharged at palm oil mills. It is left after removal of the fruits. An empty fruit bunch is made up of a main stalk about 20-25% of the total weight of OPEFB and numerous spikelet of about 75-80% of the total weight of the OPEFB with sharp spines at their tips. It is partially utilized for mulching and as raw material for fertilizers. Many of them are returned to plantation sites as composts [3]. It is the large amount of solid waste generated from the palm oil mill, during the stripping process of the fresh palm fruits from the fresh fruit bunches (FFB). The production of 1 ton of crude palm oil (CPO) generates nearly 1.3 tons of OPEFB. By considering these points, a study was conducted with following objectives to recovery the energy from the OPEFB wastes.

- To study the physico-chemical characteristics of oil palm empty fruit bunches
- To study the thermo gravimetric behaviour of oil palm empty fruit bunches

2. Methodology

Based on the characteristics of biomass, suitable conversion technologies can be adopted for efficient energy production from the available sources. Density plays an important role in this conversion process. Higher density biomass are suitable for combustion and gasification. The OPEFB wastes were collected from a local palm oil industry and the physico-chemical characteristics and the thermal behaviour of the selected biomass OPEFB were analyzed. The following Fig 2.1. shows the OPEFB wastes collected.

Fig 2.1: Oil palm empty fruit bunches (OPEFB)

2.1 Physical properties of biomass

2.1.1 Bulk density

Bulk density one of the major physical properties was determined by weighing the sample filled in a vessel of known volume and calculating the ratio of the weight of the biomass sample to the volume of the vessel [4].

$$\text{Bulk density } (\rho),\ kg/m^3 = \frac{W}{V}$$

2.1.2 True density

True density is defined as mass per unit volume. It does not include pore space between the biomass samples.

$$\text{True density, } kg/m^3 = \frac{M}{V}$$

2.1.3 Proximate analysis

Proximate composition such as moisture, volatile matter, ash content and fixed carbon content of the biomass was calculated by American Society for Testing and Materials [5].

2.1.3.1 Moisture content

Using hot air oven, moisture content of the sample was determined. By oven method [5] (ASTM, E-871), about 5 g of powdered sample was taken in a petridish and kept inside the oven at a temperature of 103±5˚C for 24 hrs. The moisture content was calculated by measuring weight of moisture evaporated from the sample (W_2) and the original sample weight (W_1)

$$\text{Moisture Content,\%} = \frac{W_1 - W_2}{W_1} \times 100$$

2.1.3.2 Volatile matter

The volatile matter was determined using muffle furnace [5] (ASTM, E-872), (M/S. Sequent, India). To measure the volatile matter, known content of dried sample was taken in a closed crucible and kept inside the muffle furnace at 650˚C for six minutes and again at 750˚C for another six minutes. The loss in weight of the sample was found out and the percent of volatile matter was calculated as,

$$\text{Volatile matter,\%} = \frac{\text{Loss in weight of the sample}}{\text{Weight of moisture free sample}} \times 100$$

2.1.3.3 Ash content

The ash content was found out [5] (ASTM, E-830) by taking a known quantity of dried biomass sample in an open crucible and keeping it in a muffle furnace (M/S. Sequent, India) at about 750 ˚C up to reaching a standard weight. The ratio between the remaining weight of biomass in the crucible and the sample taken was the fraction of ash content of tested material.

$$\text{Ash content, \%} = \frac{\text{Weight of ash formed}}{\text{Weight of dried sample}} \times 100$$

2.1.3.4 Fixed carbon

The fixed carbon was calculated by subtracting the sum of ash content (%) and volatile matter (%) from 100. The fixed carbon is the residue left after removing the volatile matter and the ash from the substance

2.2 Thermal properties

2.2.1 Calorific value

The calorific value (CV) which is the amount of heat liberated, when a unit mass of a fuel is burnt completely was determined by using the Bomb calorimeter [5] (ASTM D-5865). The efficiency of a fuel can be understood by its calorific value. Calorific value was calculated by,

$$CV = \frac{(W * T)}{M}$$

Where, CV– calorific value, cal / g
W – water equivalent of calorimeter assembly, cal / °C
T – rise in temperature, °C
M – mass of sample burnt, g

2.2.2 Thermo gravimetric Analysis (TGA)

Thermo Gravimetric Analysis is used to determine changes in weight of the sample in relation to change in temperature. It relies on a high degree of precision in measuring weight, temperature and temperature change. Thermal behavior of the sample is analyzed from the derivative weight loss curve which can be used to predict the point at which actual weight loss occurs.

3. Results and Discussion

OPEFB were collected and dried in solar tunnel dryer for a period of one week. After drying, the feedstock was shredded to a powdered form and is used for characterization.

3.1. Physical properties

Bulk density of OPEFB = 278 kg/m³
True density of OPEFB = 371 kg/m³
The values of proximate analysis for the sample OPEFB is given in the Table 3.1. The volatile matter and fixed carbon values are found to be greater than 70% and 15% respectively, which shows that the samples can burn very effectively in the presence of an ignition source. The moisture and ash are less of the order of 6% and 3% respectively which indicates the sample can thermally degrade very easily.

Table 3.1: Proximate analysis

Parameters	(wt.%)
Moisture	6.4
Volatile matter	72.5
Fixed carbon	17.8
Ash content	3.3

3.2 Thermal Properties

3.2.1 Calorific value

The calorific value of empty fruit bunches was calculated and is found to be 3912 kcal/kg, which is almost equal to the calorific value of wood (4000 kcal/kg) [6].

3.2.2 Thermo gravimetric analysis

It is observed from the TG graph that the thermal decomposition of the selected biomass sample shows three different stages. The range of temperatures was found to be ambient to 150 ºC, 151 to 400 ºC and 401 to 900 ºC for the zone I, II and III respectively. The first and second peaks appeared in TG plot is indicating zone I and II respectively. The weight loss for the biomass was very slow at zone I. The loss in weight in this zone was mainly due to release of moisture and light volatile matter present in the sample. During the second stage of thermal decomposition zone, the biomass sample release volatile matter due to rapid pyrolysis reaction and reaction rate increases quickly to a maximum level, then the reaction rate quickly dropped. The third stage is from the end of the second stage to 900ºC, where carbonaceous residue is decomposed slowly. However, the thermal decomposition proceeds at a relatively low reaction rate until the terminated temperature of experiment, without any clear demarcation.

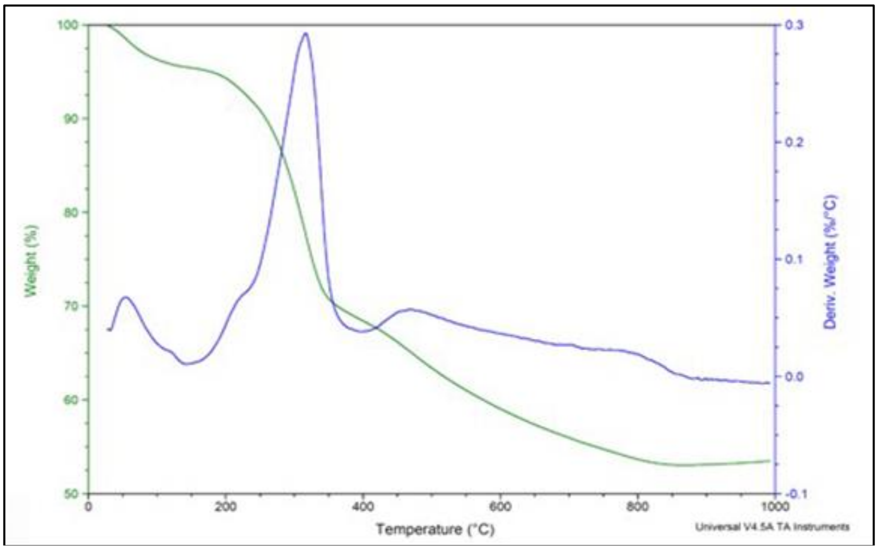

Fig 3.1: TGA graph for OPEFB at 20ºC/min heating rate

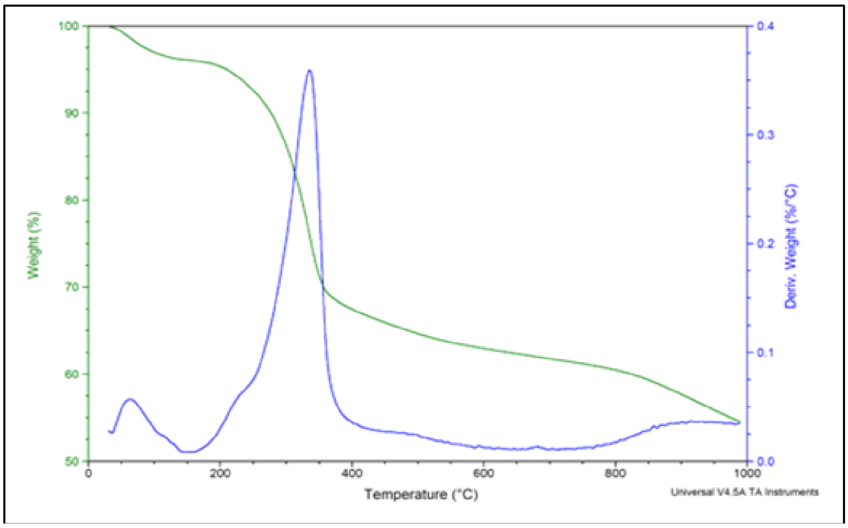

Fig 3.2: TGA graph for OPEFB at 30ºC/min heating rate

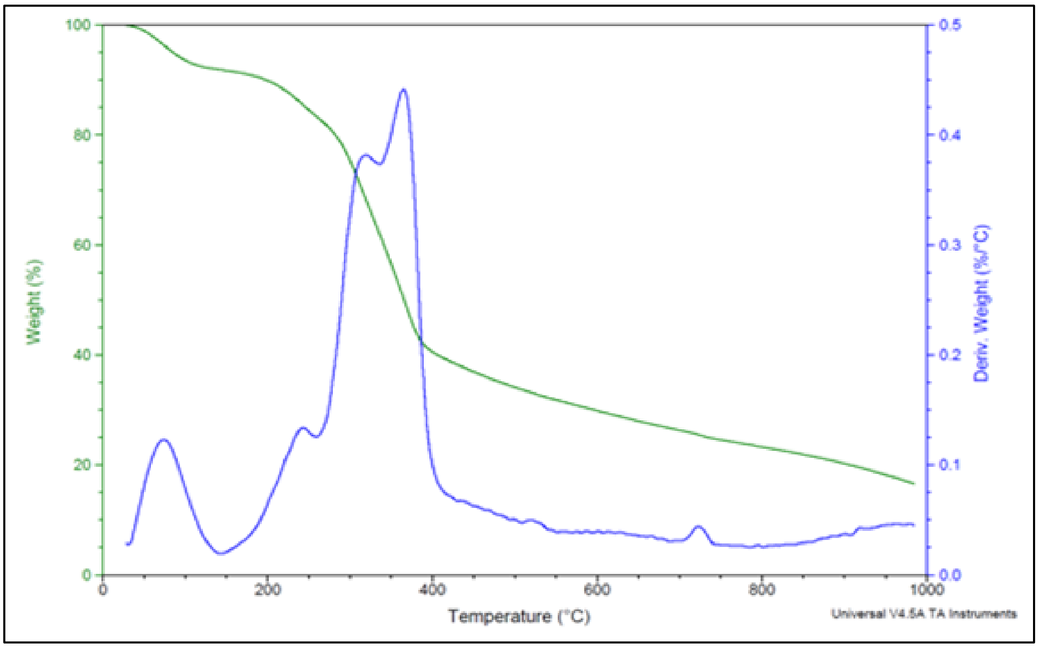

Fig 3.3: TGA graph for OPEFB at 40ºC/min heating rate

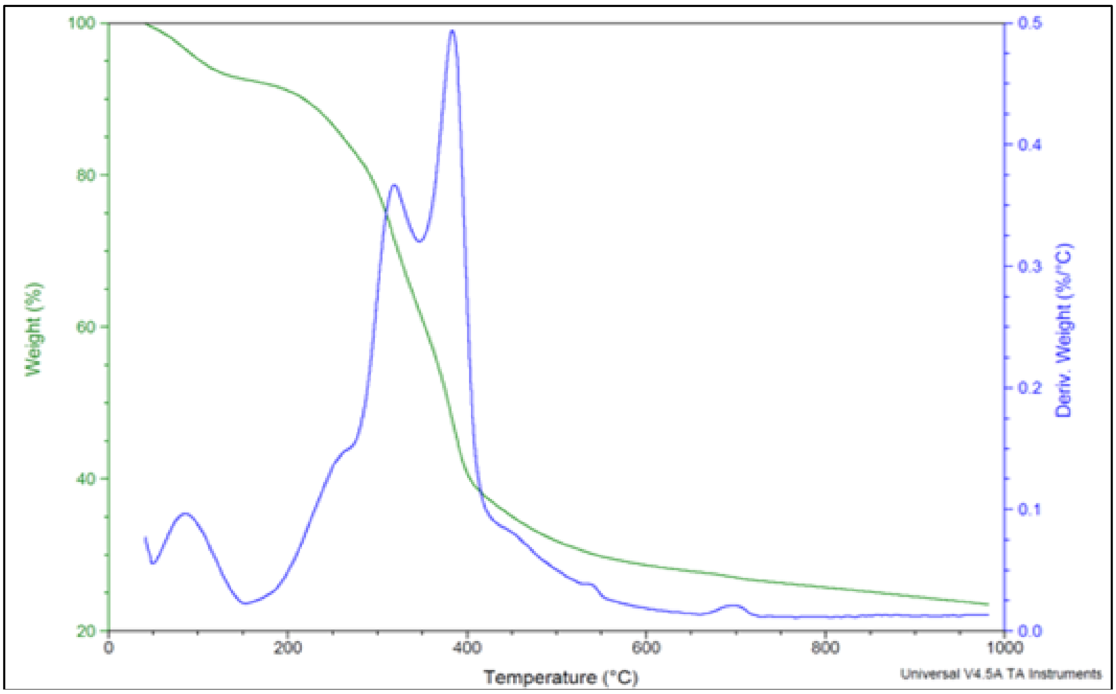

Fig 3.4: TGA graph for OPEFB at 50 ºC/min heating rate

The results of the loss in weight of the OPEFB sample at different heating rate experiments conducted in TGA are presented in Table 3.2.

Table 3.2: Loss in weight of OPEFB at different heating rate

Temperature, ºC	Loss in weight of the samples,%			
	20ºC/min	30ºC/min	40ºC/min	50ºC/min
100	3.7	3.0	5	2.7
200	5.7	4.6	8.4	5.4
300	17.7	13.7	25.3	15
400	31.6	32.5	62.4	39.1
500	36.6	35	67.72	44
600	41.1	37	70.9	47.8
700	44	38.2	72.9	50.7
800	46.3	39.5	75.1	53.4
900	46.9	42.3	79	57.8

From the Table 3.2, it is clearly observed that loss in weight of the sample follows a similar trend i.e. increasing weight loss with increasing in temperature. The weight loss recorded for 100 ºC for all selected heating rates was in the range of 2.7 to 5.0%. The percentage of the residue left after at 900 ºC for the selected heating rates was in the range of 21 to 57.7%. The sharp rise in the weight loss was observed at the temperature (200-300 ºC) and the weight loss up to 200 ºC may be due to the release of bound moisture and volatile matter present in the sample. The loss of the weight within this zone was ranging from 2.7 to 8.4%.

4. Conclusion

From the study it is clearly found that Oil palm empty fruit bunches (OPEFB) which is an abundant waste produced from oil palm industries can be used as an effective feedstock in thermochemical conversion route ie., combustion, gasification and pyrolysis. In these, it can be more effectively used in gasification as the feedstock shows more volatile content and less ash content.

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