Characterization of *Leucaena leucocephala (Petai Belalang)* as an Energy Crop for Power Generation Application

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Abstract. Currently, empty fruit bunch (EFB) is the main biomass source to fuel biomass power plant and as co-firing fuel with coal at the existing coal-fired power plants in Malaysia. However, these power plants frequently face insufficient EFB supply, which may contribute to load losses. Energy crops a new source of biomass, are introduced to replace or substitute the shortage of biomass supply. Planting energy crops worldwide ensures a sufficient and cleaner fuel supply for power generation. Positive characteristics of the energy crop are including calorific value, carbon contents and density. Higher value of these parameters indicating the good quality of the energy crop. While, the negative characteristics of energy crop are including moisture content and ash content. Higher value of these two parameters indicating lower quality of energy crop. One of the studied energy crops was *Leucaena leucocephala (Petai Belalang)*, which showed better quality than EFB, based on calorific value, moisture content, ash content and density. It is naturally grown, typically near rivers in Peninsular Malaysia. Furthermore, it can be easily planted and matures in about six months for harvesting.

1 Introduction

Currently, empty fruit bunch (EFB), a waste from palm oil plantation is the main source of biomass for power generation in Malaysia. To ensure sufficient biomass supply, TNB should be utilising energy crops as fuel.

In European countries, energy crops such as switchgrass, miscanthus, bluestem, elephant grass and wheatgrass are used as fuel to power biomass power plants. While, energy crops such as eucalyptus, *Leucaena leucocephala (Petai Belalang)* and napier grass (*Pennisetum purpureum*) are mainly used as biomass to power biomass power plants in South East Asia Countries such as Philippines, Thailand and Cambodia. It is expected that Malaysia can adopt this similar approach by utilising suitable energy crops for biomass sources.

There are various energy crops available in Peninsular Malaysia, such as 'petai belalang' and 'gamal' (*Gliricidia sepium*). Currently, they are spotted at different locations either they are planted by Majlis Perbandaran, Stesen Penyelidikan Forest Research Institute Malaysia (FRIM) or naturally grown. Centralised plantation of suitable energy crops is necessary to ensure sufficient biomass supply for biomass power plant.
Leucaena leucocephala (Petai Belalang) was selected as the studied energy crop due to its energy value, short rotation crop and high yield. Fuel characterisation and Fuel Value Index (FVI) of this energy crop as fuel for the biomass power plant were analysed and compared with EFB data.

2 Methodology

This study involved sampling of the energy crop *Leucaena leucocephala (Petai Belalang)* and characterisation of the energy crop using calorific value determination, proximate analysis (moisture, volatile matter, fixed carbon, ash), ultimate analysis (carbon, hydrogen, nitrogen, sulphur) and density

2.1 Sampling and characterisation of *Leucaena leucocephala* as energy crop

Leucaena leucocephala was selected as an energy crop based on its high growth rate and calorific value/energy value range. A photo of this energy crop is shown in Figure 1.

Samples of different diameters of *Leucaena leucocephala* were characterised for calorific value determination, proximate analysis (moisture, volatile matter, fixed carbon and ash), ultimate analysis (carbon,hydrogen, nitrogen and sulphur) and density at the Analytical Laboratory, FRIM.

Fig. 1. Example of *Leucaena leucocephala* tree during sampling activities.

2.2 Data Analysis

The data gathered in section 2.1 were used for comparison with previous biomass and EFB published data.

3 Results and Discussion

3.1 Comparison of *Leucaena leucocephala* with EFB

Generally, biomass fuels behave similarly to low-rank coal [1]. In this study, positive and negative characteristics of the *Leucaena leucocephala* were studied. Positive characteristics include calorific value, carbon content and density. Higher values of these parameters indicate a good quality of the fuel. On the other hand, negative characteristics include moisture content and ash content. The higher value of these two parameters indicates a lower quality of the energy crop.

Vassilev et. al, [2] reviewed previous research on the chemical compositions of biomass and provided a range of chemical compositions for all varieties of biomass (e.g. energy crops, forest residue, willow, giant grass). Chemical composition ranges such as moisture content, ash content and carbon content are listed in Table 2 for comparison with other biomass and EFB characteristics. Additionally, Saidur et. al, [3] studied the physical, chemical and fuel properties of biomass, including fuel density and heating value.

Table 1 shows the comparison of the positive and negative characteristics of *Leucaena leucocephala* with the biomass range as fuel [2]-[3] and empty bruit bunch (EFB). It indicated that *Leucaena leucocephala* has a higher calorific value than EFB and lower moisture content than EFB. The moisture content in EFB is about 64%, which exceeds the biomass range [2].

Leucaena leucocephala has carbon, ash contents and density within the biomass range. The carbon content of *Leucaena leucocephala* is lower than EFB. However, the carbon content in *Leucaena leucocephala* is still within the accepted biomass range. *Leucaena leucocephala* has a lower ash content of 3.84% compared to EFB. The density of EFB is 680 kg/m^3, while *Leucaena leucocephala* has a higher density than EFB at 836 kg/m^3.

It is expected that *Leucaena leucocephala* is easier to handle during the pre-treatment process and has fewer ash slagging and fouling problems (due to lower ash content) during the combustion process in the boiler compared to EFB.

Table 1. Comparison of five main characteristics of the *Leucaena leucocephala* with EFB.

Fuel Name	**Calorific Value (kcal/kg)**	**Moisture Content (%)**	**Ash Content (%)**	**Carbon (%)**	**Density (kg/m^3)**
Biomass range (Vassilev et al, 2010; Saidur et al, 2011)	3346-5019	2.5-62.9	0.1-43.3	42.2-70.9	500
EFB	4230	64	5.36	49.07	680

Leucaena leucocephala	4380	48	3.84	43.64	836

3.2 Ranking of solid fuel using Fuel Value Index (FVI) Approach

There are also several approaches to rank solid fuel/biomass using Fuel Value Index (FVI) equations [4]-[6]. For example, the Fuel Value Index equation used by Ojelel et al, [6] (2015) is shown below:

Fuel Value Index = Gross Calorific Value (kJ/g) x Density (g/cm) / Moisture Content (%) (1)

This equation shows that the effective calorific value depends on the moisture content and density of the solid fuel. The higher the moisture content, the less efficient the solid fuel is and vice versa.
The data from Table 1 were used to test Equation (1). It was found that, *Leucaena leucocephala* showed a higher FVI than EFB (Table 2), indicating better quality of solid fuel. However, this approach only considered a few parameters such as calorific value, moisture and density.

Table 2. Fuel Value Index for different solid fuels.

Local Name	Fuel Value Index ($x10^3$)
EFB	188
Petai Belalang	319

4 Conclusion

Leucaena leucocephala (Petai Belalang) showed better quality than EFB based on calorific value, moisture content, ash content and density. The Fuel Value Index (FVI) of this energy crop is also higher than EFB, indicating better quality of solid fuel. Therefore, it is expected that it can be used in the future as an alternative fuel instead of EFB for co-firing with coal at the existing coal-fired power plant in Peninsular Malaysia.

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