# Physical and Combustion Characteristics of Biomass Residues from Palm Oil Mills

H. M. Faizal, Z. A. Latiff, Mazlan A. Wahid, Darus A. N.

***Abstract*—** The quantities of biomass residues produced from palm oil mills increased significantly from year to year. As reported by Malaysia Palm Oil Board (MPOB, 2006), the production of shell, mesocarp fibre and empty fruit bunch (EFB) in Malaysia for year 2006 are $5.20\times10^6$ tonne/year, $9.66\times10^6$ tonne/year, and $17.08\times10^6$ tonne/year respectively. Therefore, the briquetting technology promises the solution to prevent waste and dump areas adjacent to the mills. In this paper, the physical and combustion characteristics of densified palm biomass contains mesocarp fibre and EFB fibre for different compaction pressure are presented. Beside the increasing of energy content per unit volume, due to its fibrous structure,the combustion rate and heat release of the proposed briquette is very competitive with current local briquette which contains mesocarp fibre and shell.

***Keywords*—**Briquette, palm biomass, combustion rate, heat release

## I. Introduction

There are several alternative energy which are expected can substitute fossil fuel in the future, i.e. hydro, solar, wind, biomass and ocean thermal energy. Among these energy sources, biomass is the only carbon-based sustainable energy and the wide variety of biomass enables it to be utilized by most people around the world. In Malaysia, currently the utilization of renewable energy has several advantages including enhancing profit margins and eliminating the cost burden for managing waste disposal.

Cattaneo (2003) mentioned that briquetting is compressing the materials into small logs with a diameter of between 30mm and 100mm and of any length depending on the technology used, either screw or piston compression.

For producing high quality briquette, several characteristics such as strength and durability must be considered. Kaliyan and Morey (2008) mentioned the parameters that show the strength of certain briquettes are compressive strength, impact resistance, shear strength water resistance and several others. Meanwhile, the durability of the briquette depends on abrasion resistance. Besides, the combustion characteristics of briquette such as values of proximate analysis, gross calorific values, combustion rate, and heat release are also need to be considered.

Chin and Siddiqui (2000) have conducted an experiment to study the effect of compaction pressure on combustion rate of briquettes contain different biomass materials such as rice husks, sawdust, peanut shells and coconut fibres. The compaction pressure was within the range of 1 to 7 MPa. It was found that the burning rate increased as the binder content increased. The binding agents used in their experiment were molasses and starch.

An experiment carried out by Husain et al. (2002) explains the combustion characteristics of briquettes contain fibre and shell residues in the ratio of 60:40. They used starch as binding agent (10% of the weight of residues) with addition of water (50% of the weight of residues). The combustion characteristics were studied by using locally made stove. They found that the combustion of heap of briquettes in the stove releases about 0.5kW, air-fuel ratio was about 10.2 and ash content was 5.8%. Besides, the average compressive strength of about 2.56 MPa is considered as a value for good resistance for disintegration.

Li (2003) has conducted an experiment to investigate the ignition temperature of coal briquette with plastic (polyethylene) addition. It was found that the ignition temperature decreased from 413 to 373$^o$C when plastic was added.

Faizal et al. (2009) has done the experiment to study the physical characteristics of briquette contains different mixing ratio of EFB fibre and mesocarp fibre. They found that the briquette with ratio 60:40 (EFB fibre:mesocarp fibre) is competitive with local practiced briquette. The compressive strength of this type of briquette is within the range of 2.83 to 2.92 MPa, which is already exceeded the minimum value of good resistance to mechanical disintegration (2.56 MPa). Thus, in this paper, further study has been done for determining the combustion characteristics of briquette contains EFB fibre and mesocarp fibre with weight ratio of 60:40. By using this constant weight ratio (60:40), combustion

H. M. Faizal is with Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, MALAYSIA. (Phone: +6017-7537301; e-mail: mfaizal@fkm.utm.my).

Z. A. Latiff is with Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, MALAYSIA. (e-mail: zkarnain@fkm.utm.my).

Mazlan A. Wahid is with High Speed Reacting Flow Research Laboratory (HiREF), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, MALAYSIA. (e-mail: mazlan@fkm.utm.my).

Darus A. N. is with Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, MALAYSIA. (e-mail: amer@fkm.utm.my).

performance of briquette was investigated under various compaction pressures. The comparison with local practiced briquette which contains mesocarp fibre and shell (weight ratio 60:40) also has been made.

## II. METHODOLOGY

### *A. Preparation of Briquette*

The palm biomass residues (EFB, mesocarp fibre and shell) have been collected from local fibre industry and palm oil mill. The result of proximate analysis is shown in Table 1 below.

TABLE I
PROXIMATE ANALYSIS FOR RAW MATERIALS

| Item | EFB | Shell | Mesocarp Fibre |
|---|---|---|---|
| Fixed Carbon (%) | 15.083 | 15.685 | 14.889 |
| Moisture Content (%) | 7.331 | 8.528 | 5.200 |
| Volatile Matter (%) | 72.962 | 73.208 | 75.111 |
| Ash Content (%) | 4.624 | 2.579 | 4.800 |

For making briquette, EFB fibre powder and mesocarp fibre powder are mixed in weight ratio 60:40. As binding agent, starch (20% of weight of residues) and water (80% of weight of residues) are used. After these materials have been mixed homogeneously by using mixer, it is dried under ambient temperature for about 6 hours before pressing process. This procedure also has been practiced during preparation of local practiced briquette which contains mesocarp fibre and shell (also in weight ratio of 60:40).

Then, the mould is pressed with high pressure (within the range of 3 to 11MPa) by using YASUI hydraulic hand press. It is pressed by using die set which consisted of plunger, die and base made of mild steel. The dwell time during this briquetting is 10 to 15 minutes until there is no change on load reading during compression process. As information, this dwell time is very important in order to prevent the deformation of compressed briquettes.

After briquetting, the briquette produced is removed from the die set and it is dried at room temperature for about 1 week to obtain stability and rigidity.

### *B. Investigation on Combustion Characteristics*

The combustion characteristics such as burning rate, heat release, ash content and emission are determined. The logs with diameter approximately 10 mm are used in this combustion study to represent the briquette characteristics. Figure 1 shows the holder that is used to hold the log of briquette during the experiment.

The combustion study is held under "natural draft" condition without using blower. This is as an attempt to simulate the actual cooking or heating condition.

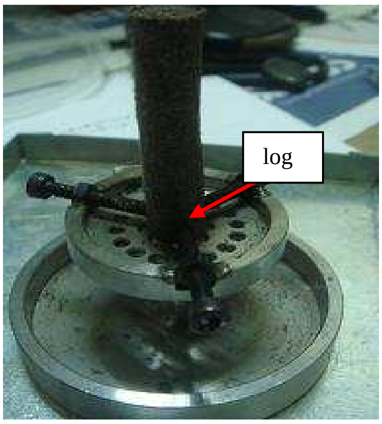


Fig. 1 Holder with Log or Briquette for Combustion Study

Burning time is obtained by observing the mass changes recorded on mechanical balance and also by using stop watch. It is time for the biomass combustion is complete. With known amount of total burnt briquette and burning time, average combustion rate can be calculated by using following formula.

$$\text{Combustion Rate} = \frac{\text{Total Mass of Burnt Briquette}}{\text{Burning Time}} \quad (1)$$

In order to obtain the heat release of briquette during combustion, the calorific value needs to be determined first. The calorific value is determined by using bomb calorimeter as shown in Figure 2 below.

By knowing the calorific value and burning rate of briquette, the heat release can be calculated.

$$\text{Heat Release} = \text{Calorific Value} \times \text{Combustion Rate} \quad (2)$$

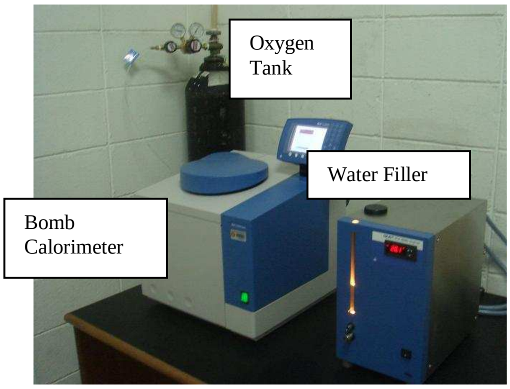


Fig. 2 Calorimeter System at UTM, Skudai

Ash content is measured by using mechanical balance. This content represents the total weight of the ash accumulated on the base of briquette holder.

## III. RESULTS AND DISCUSSIONS

### A. *Physical Characteristics*

Relaxed density is determined by using geometric formulae. The density of briquette contains EFB fibre and mesocarp fibre (weight ratio 60:40) is increased from 950 to 1010 kg/m$^3$ when compaction pressure changes from 3MPa to 11MPa.

Meanwhile, high density of shell itself compared to other two palm biomass residues causes the briquette contains shell has higher density. Thus, the relaxed density of briquette contains mesocarp fibre and shell (60:40) is higher than density of proposed briquette contains EBF fibre and mesocarp fibre (60:40) as illustrated in figure below.

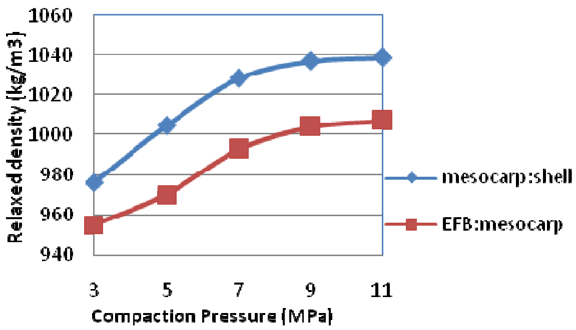


Fig. 3 Relaxed Density versus Compaction Pressure

The figure shows that after compaction pressure of 9 MPa, the density of both types of briquette tends to be constant. This characteristic is very important in order to save energy during briquetting process. As shown in figure above, the compaction pressure of 9MPa or higher is unnecessary. This is mainly due to the only small changes of relaxed density produced even though there are significant changes in compaction pressure.

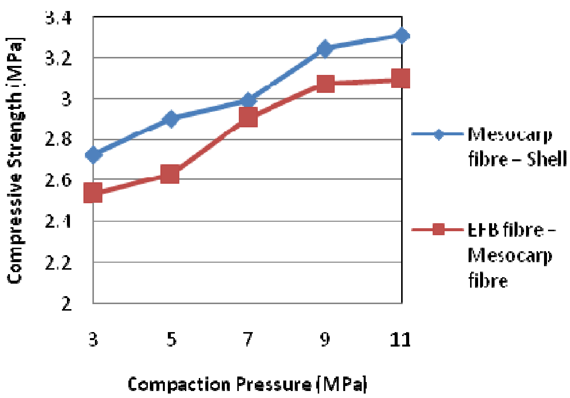


Fig. 4 Compressive Strength versus Compaction Pressure

As shown in Figure 4 above, the compressive strength of both types of briquette increased when compaction pressure increased. It is found that compressive strength of briquette contains mixture of mesocarp fibre and shell is higher if compared with the compressive strength belongs to briquette contains mixture of EFB fibre and mesocarp fibre. However, all the values are higher than minimum limit for mechanical disintegration, which is 2.56 MPa as stated by Nor Azmmi, M. et al (2006). Therefore, the result shows that the physical characteristics of briquette contains proposed mixture (EFB fibre and mesocarp fibre) are competitive with local practiced briquette (contains mesocarp fibre and shell).

### B. *Combustion Characteristics*

Based on the figure below, it is found that most of the briquettes fulfill the minimum requirement of calorific value for making commercial briquette (>17500 J/g), as stated by DIN 51731. Besides, there is no significant difference when the briquette with same mixture undergoes different compaction pressure. This is mainly due to no heat applied during briquetting process.

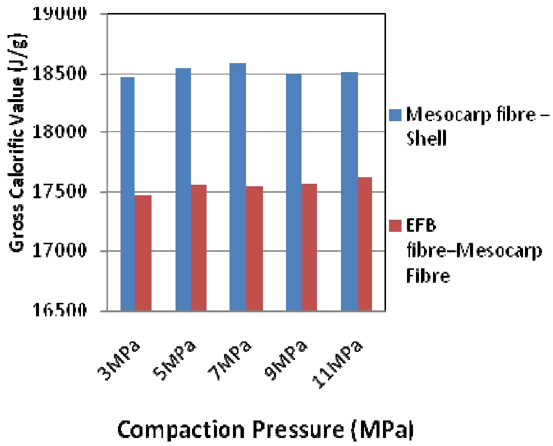


Fig. 5 Gross Calorific Value versus Compaction Pressure

For all compaction pressure, it is found that briquette contains mixture of mesocarp fibre and shell has higher gross calorific value than the value belong to briquette contain mixture of EFB fibre and mesocarp fibre. This proved that the gross calorific value is most influenced by the composition of briquette rather than compaction pressure.

The briquettes produced under different compaction pressure will have different combustion rate as shown in figure below.

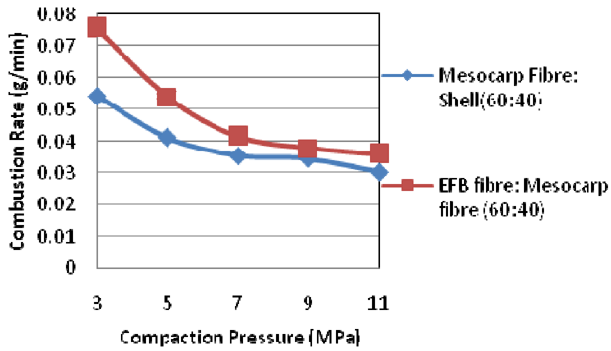


Fig. 6 Combustion Rate versus Compaction Pressure

As shown in figure above, combustion rate for both types of briquette decreased as the compaction pressure increased. This is because when compaction pressure increased, the reduction of air gap between particles of briquette also increased.

Due to better air circulation through the air gap of briquette, the briquette contains mixture of EFB fibre and mesocarp fibre has higher combustion rate if compared with the other one.

Based on Figure 6 above, it is also found that for each type of briquette, the changes of combustion rate become less as compaction pressure increased. This is obvious especially when the compaction pressure becomes more than 9MPa. This trend is similar with the graph which explains the relationship between relaxed density and compaction pressure. This shows that combustion rate relates closely with the density of briquette.

The heat release from both types of briquette decreased as the compaction pressure increased. This is because the combustion rate of briquettes also decreased when the compaction pressure increased even though the gross calorific value seems to be constant. From the Figure 7 below, it is also found that heat release of briquette contains mixture of EFB fibre and mesocarp fibre is higher than heat release of briquette contains mesocarp fibre and shell.

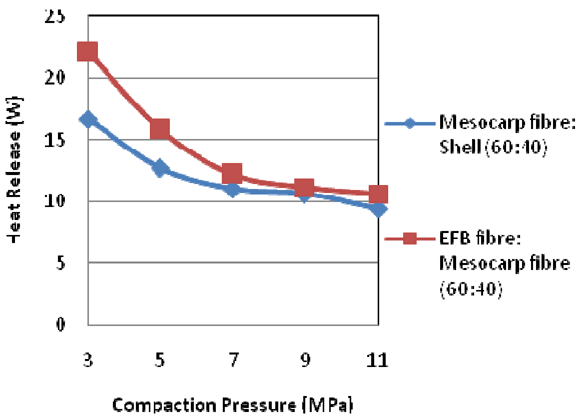


Fig. 7 Heat Release versus Compaction Pressure

Even though gross calorific value of briquette contains EFB fibre and mesocarp fibre is lower than the gross calorific value belongs to another one, the higher combustion rate has made it possible to release more heat.

Then, after the combustion of briquette is complete, the ash accumulated in the briquette holder is measured. Figure 8 and 9 below show the ash content for both types of briquette in term of theoretical and experimental value. As information, the theoretical value is obtained from proximate analysis.

Based on Figure 8 and 9, it is found that for both types of briquette, the ash content obtained from the experiment is higher than theoretical ash content. This is because to the existence of unburned carbon left after combustion during experiment. It means that combustion efficiency for experimental case is lower than the theoretical case.

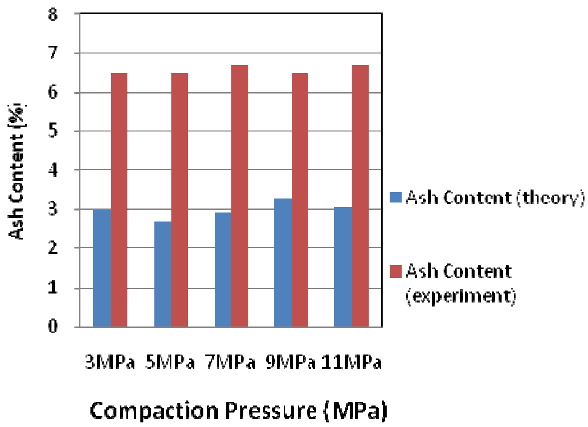


Fig. 8 Ash Content versus Compaction Pressure for Local Practiced Briquette

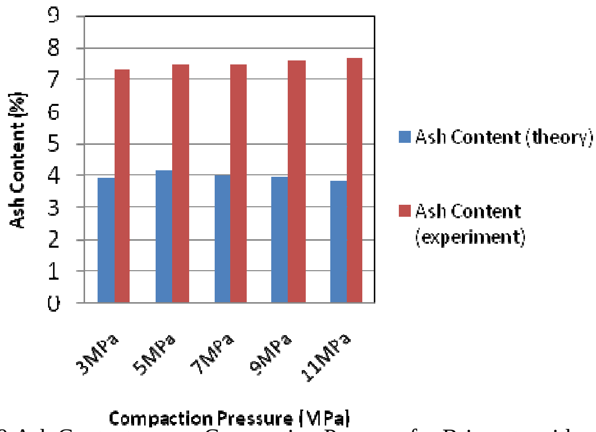


Fig. 9 Ash Content versus Compaction Pressure for Briquette with Proposed Mixture

## IV. Conclusion

From the study, it is found that the compressive strength of proposed briquette with weight ratio of 60:40 (EFB fibre: mesocarp fibre) is sufficient enough to prevent briquette disintegration. Due to fibrous structure of proposed briquette, it has higher combustion rate and heat release compared with local practiced briquette which contains mesocarp fibre and shell (60:40). However, due to lower relaxed density but higher combustion rate, it is expected that transportation cost for proposed briquette is slightly higher. Based on result of all tests, it is expected that the proposed new briquette has the potential to be developed as commercial briquette.

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