

SOLID FUEL FROM EMPTY FRUIT BUNCH FIBER AND WASTE PAPERS PART 1: HEAT RELEASED FROM CUMBUSTION TEST

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ABSTRACT

This research discussed on the results obtained for each sample that have been conducted to the solid fuel briquettes made of empty fruit bunch fiber and waste papers from view of heat released during combustion test. The results shows tremendous amount of energy can be generated from these biomass compositions. The energy can easily harness to generate heat and electricity for many productive operations. Hence, the possibility result in this research is the development of solid fuel briquette by mixing the empty fruit bunch with a waste paper can be one sources of fuel energy. From the combustion analysis shows sample briquette with ratio 60:40 has given a highest value of heat released which is 162.77 kJ, whereas sample with ratio 40:60 has good burning time.

Keywords: Empty Fruit Bunch Fiber, Waste Papers, Heat, Burning Time.

1.0 INTRODUCTION

Producing energy from renewable biomass is only one of the various ways of responding to the challenges of the energy crisis. Since the oil crisis in 1970's the use of biomass as a source of energy is a topic of growing interest and debate as agreed by Ana (2012), Tong and Li (2012), Arias (2011), Vaclav (2010), Fernando (2009), Kaygusuz and Keles (2008).

Corley and Tinker (2008) in their book discuss in detail about oil palm in Malaysia. In 2004, Malaysia had about 3.87 million hectares of land under oil palm cultivation. Currently, more than 80 percent of the oil palm produced is used for food applications like cooking oil, frying oil and many others. Oil palm is a perennial crop. It has an economic life span of about 25 years. Traditionally, oil palm is grown for its oil example like palm oil, palm kernel oil, and palm kernel cake as the community products. Besides palm oil and palm kernel, oil palm industry generates large quantity of biomass residue which is side products as stated before like fronds, trunks, EFB, palm oil mill effluent, palm fibre and shell that have not been fully commercially exploited.

Through concerted research and development efforts by many research organizations including Malaysian Oil Palm Board, this co - products from palm oil industry have been found to be good resources for many application such as palm oil fuel ash a biomass residue (Brown *et al.*, 2011), oil palm as a viable concrete pozzalanic material (Foo and Hameed, 2009), Oil palm ash as partial replacement of cement for solidification/stabilization of nickel hydroxide sludge (Chun Yang Yin *et al.*, 2008), oil palm ash in concrete (Tangchirapat *et al.*, 2007). There are many competitive uses of these materials. One of them is to utilize them as a fuel for energy production but in term of biodiesel fuel. In fact, Malaysian government has identified biomass as fifth fuel resource to compliment the petroleum, gas, coal, and hydro as energy resources, while palm biomass has been identified as a single most important energy source as stated by Sumiani (2006). On the other hands,

the main sources of biomass in Malaysia are domestic wastes, agricultural wastes, effluent sludge and wood chips (Mohd Yuhazri *et al.*, 2011) and (Mohd Yuhazri *et al.*, 2010).

Biomass energy systems can be based on a wide range of feedstock like food and garden wastes (Romeela and Ackmez, 2012), solid wastes and sewage sludge (Despina *et al.*, 2012), cellulosic ethanol (Gonzalez, 2011), coal and cattle biomass (Carlin *et al.*, 2011) and many more. They use many different conversion technologies to produce solid, liquid, and gaseous fuels. These can then be used to provide heat, electricity and fuels to power vehicles; using burners, boilers, generators, internal combustion engines, turbine or fuel cells. Power can be generated by co – firing a small portion of biomass on existing power plant, burning biomass in conventional steam boilers, biomass gasification and anaerobic digestion.

Converting palm biomass into a uniform and solid fuel through briquetting process appears to be an attractive solution in upgrading its properties and add value as reported by (Sławomir Obidziński, 2012), (De Yu Tu *et al.*, 2012), (Nasrin, *et al.*, 2011), (Chuen-Shii Chou, 2009). Biomass briquette is the process of converting low bulk density biomass into high density and energy concentrated fuel briquettes. Biomass briquette plant is of various sizes which converts biomass into a solid fuel. Briquettes are ready substitute of coal or wood in industrial boiler and brick kiln for thermal application. Biomass briquettes are non conventional source of energy, renewable in nature, eco – friendly, non polluting and economical. Process of converting biomass into solid fuel is non polluting process. It involves drying, cutting, grinding, and pressing with or without the aid of a binder.

Malaysia has involved in palm oil industry over the last four decades and since then it has generated vast quantities of palm biomass, mainly from milling and crushing palm kernel. Empty fruit bunch is the main solid waste from oil palm obtained from milling process. This biomass can be used as an alternative energy for combustion purposes especially in industry. Unfortunately, due to its poor physical properties EFB is not normally utilized as fuel. However, it can be use in optimise by upgrading and treating its properties. The method that can be used is the briquetting technique. Briquetting is the alternative method in upgrading biomass into a useful solid fuel that can be done through various technologies. In this research, EFB material will be mixed up with the recycled papers and it will be turned into solid briquette through the briquetting process. The used of recycle papers in this research is to utilized the abundant papers into something useful, thus helps in reducing the number of municipal wastes generated every year. Papers are selected as a material to be used compared to the other types of recycled wastes such as glass and plastic because it is known to be a good material for a combustion ignition. As for plastics, it may be compatible to papers to be used as ignition material in combustion, but it will spread a toxic gas while it is burn.

The scope of this research is mainly focusing on the mixing of the empty fruit bunch, EFB and the recycled papers. All these palm oil mills is to be obtained, mixed up and to be develop as a fuel briquette at a certain ratio or percentage with the EFB as the major element. This fuel briquette is to be carried out with the performance tests and comparison tests in terms of its calorific values, stability, and durability, proximate, ultimate, immerse and crack, but in this paper (part 1) only discuss on heat released after combustion test.

2.0 MATERIALS AND METHODS

Empty Fruit Bunch (EFB) supplied by Malaysian Palm Oil Board (MPOB) from one of plantation in Malaysia was used as reinforced material in this green composites fabrication. The EFB used in the composites was in a chopped strand form. The EFB type used was shown in the Figure 1(a) and the Table 1 is the basic properties of EFB used for the fabrication of the composites based on study done by (Nasrin, *et al.*, 2008).

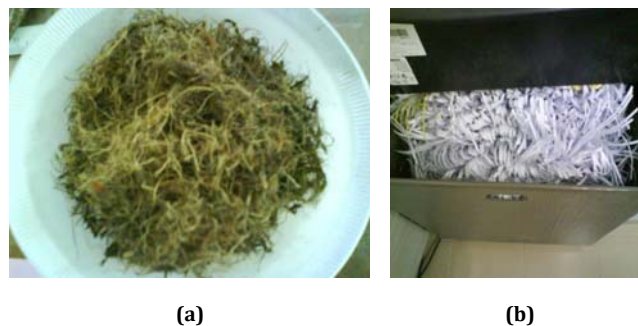


Figure 1: (a) EFB in fibrous form, (b) Shredded paper in shredder machine.

Recycled papers are use as a matrix material in the solid fuel briquette fabrication. The reason to choose papers as recycled waste in this research is because due to the properties of papers which can provide good properties for combustion. Furthermore, it can act as a binder during the blending of papers and EFB during fabrication stage. The papers are obtained from waste papers of the paper shredder machine. This is because the

crushing papers have a standard size and dimension after is shredded inside the crushing machine. The standard size and dimension helps to ensure that the blending of papers and EFB is uniform.

Table 1: Properties of EFB as raw materials. (Nasrin, *et al.*, 2008)

Raw Material	Average size of Materials	Calorific Value kJ/kg	Moisture Content %	Ash Content %
Pulverized EFB	<212 μ m	17000	12.0	2.41
EFB Fibre	3 cm	16641	16.0	4.70
EFB Fibre	2.5 mm	16641	14.0	4.60

The dimension of sample briquette produced during sample preparation is 40 mm in diameter and 73 mm in length with average weight about 67.64 grams. The ratio of briquette produced is presented in Table 2 and Figure 2 is actual specimens.

Table 2: Sample ratio and its serial number

Ratio of EFB to Paper	Serial Number
90:10	S/N 1
80:20	S/N 2
70:30	S/N 3
60:40	S/N 4
50:50	S/N 5
40:60	S/N 6

There are several steps involved in producing a single briquette according to its ratio. Firstly, the waste papers need to be immersed in water for 24 hours and then it is blended using a blender to mash up the waste papers. Then, the blended papers it weighed again to get the weight of mashed papers with water. After dividing the EFB and shredded papers according to their ratios, the EFB fiber is mixed up with the shredded paper. Then, the compacting step takes place by compacting the mixing of EFB and waste paper into a solid briquette by using hydraulic press machine and cylinder mold. The size of the mold is 100 mm in length and 40 mm in diameter. The mixing is compressed into the mold until it gets to the desired length which is 73 mm. The amount of pressure applied during compacting process is 3 bars. Finally, the solid briquette is placed inside a drying oven at temperature 100 °C for 24 hours to remove the water obtained during the compacting process.

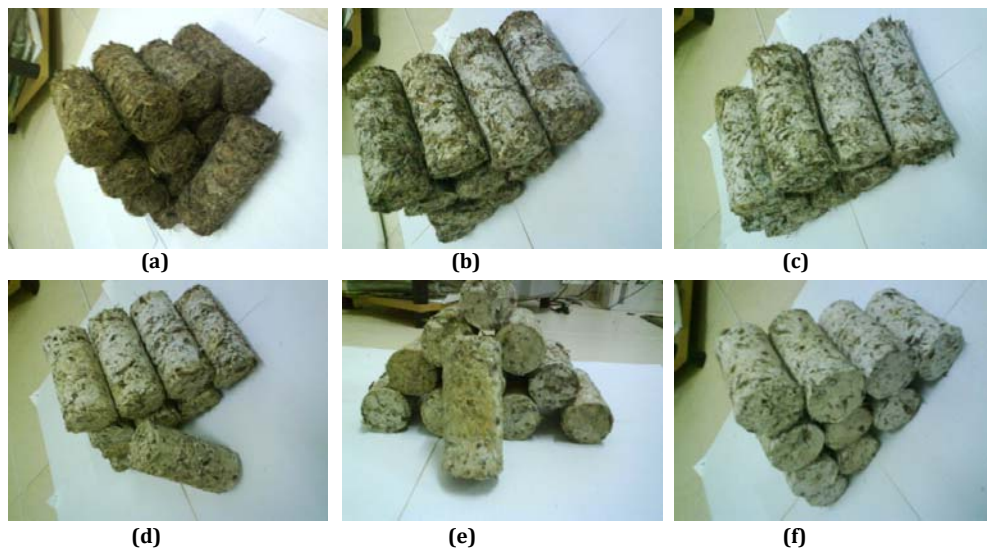


Figure 2: Samples of solid briquettes in different ratios; (a) S/N 1, (b) S/N 2, (c) S/N 3 (d) S/N 4, (e) S/N 5 and (f) S/N 6.

3.0 RESULTS AND DISCUSSION

A combustion test is conducted using equipment called gasifier to observe and measure the combustion efficiency of each ratio of briquettes in terms of its flammability and the amount of heat that will be generated by each sample ratios during the combustion. During the test, one sample of briquette is burnt inside the gasifier and the time and temperatures taken for the briquette to burn completely are recorded inside a Picolog

software. From the gasifier, there are six channel that recording the temperature inside the gasifier for every two seconds. The channel that located closely to the chamber where the briquette is being burn is a channel six. From this data, a graph of temperature and time can be generated by taking the channel 6 as the referent temperature because it is the closer channel located to the chamber. This step is done for all ratios and it is repeated for three times to get an accurate data. A comparison of time taken for each briquette to finish burning and the temperature recorded is represented in the Figure 3.

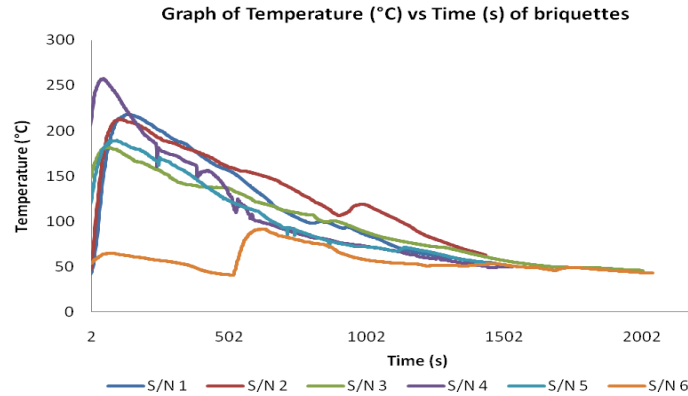


Figure 3: Graph of comparison on overall briquettes.

From the graphs in Figure 3, it can be interpreted that sample briquette S/N 6 sustained the longest time during the combustion process. It is explained by the time recorded for the briquette to finish burning completely which is the longest time compared to other samples. Even though it record the longest time to burn one sample briquette, but the heat produced from the starting of combustion process is relatively lower than the other briquettes. This is followed by briquette S/N 3 which took about 2004 seconds to burn completely. Sample S/N 4 recorded the highest starting temperature during combustion in which it gives the highest heat value during the starting of the combustion process. Sample briquette S/N 1 finished burning the fastest compared to others with a time recorded 1414 seconds. From the combustion analysis, the amount of heat transferred of the fuel briquettes can also be calculated from the combustion test conducted on the briquettes. Heat transfer is that science which seeks to predict the energy transfer which may take place between material bodies as a result of temperature difference. From the data in Table 4, the value of heat released per sample briquette can be calculated by using the equation 1.

$$Q_{out} = [(N\bar{h}_{of})_o + (N\bar{h}_{of})_M] - \left[(N_{CO} (h_{of} + h - h^o)_{CO}) + (N_{CO2} (h_{of} + h - h^o)_{CO2}) + (N_{O2} (h_{of} + h - h^o)_{O2}) \right] \tag{1}$$

From the equation 1, it shows that the fuels have unburned elements which are CO₂, CO and O₂. By referring to the enthalpy of formation and some interpolating the \bar{h}_{of} and \bar{h}^o values of various elements at core temperature of 720 K and standard temperature of 298 K are shown in Table 3.

Table 3: Enthalpy of various elements

Elements	\bar{h}_{of} kJ/kmol	$\bar{h}_{720\text{K}}$ kJ/kmol	$\bar{h}^o_{298\text{K}}$ kJ/kmol
O	+249190	-	-
N	+472650	-	-
CO ₂	-393520	+28121	+9634
CO	-110530	+21315	+8669
O ₂	-	+21845	+8682

Substitute the value into equation 1 and yields, therefore Q_{out} is 84696.202 kJ/kmol. The heat released per briquette after 74 minutes at temperature 720 K is 84696.202/44 and will obtained 1.9249 MJ per kilogram briquette of palm fiber. By obtaining the Q_{out} value, the value of constant, C in the equation 2.

$$Q = mC\Delta T \tag{2}$$

By substituting the value of Q into the equation, the value of constant, C yield is 2.673. By obtaining the constant, C value the amount of heat released for each sample briquettes can be calculated by substituting all the value into the equation 2 and the results is presented in Figure 4.

Figure 4 shows the value of heat released from sample briquettes during combustion process. The figure shows that S/N 4 released the highest amount of heat during its combustion with a value of 162.77 kJ. This is followed by S/N 3 with a value of 150.62 kJ. S/N 6 released the least amount of heat during the combustion with a value of 104.26 kJ.

Referring to Figure 4, it can be seen that the different gap in the value of heat released from each briquette is not too big in which each briquette given almost compatible amount of heat released with each other. The average value of heat released is 144 kJ. From the Figure, S/N 6 recorded the lowest amount of heat released compared to others. S/N 4 is chosen as the best ratio for which is provide the largest value of heat released followed by S/N 3, S/N 1, S/N 5 and lastly is S/N 6.

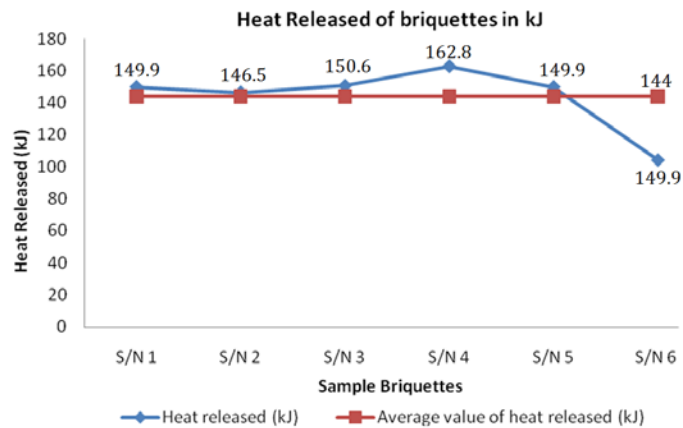


Figure 4: Comparison in the value of heat released of sample briquettes

The combustion characteristics of the palm briquettes were studied by using gasifier and conducted in an open air as an attempt to stimulate the actual combustion situation for domestic heating or cooking. From the analysis, it was found out that the palm briquettes were not easy to ignite. This is due to the condition of palm briquette which highly compacted. The ignition of the palm briquettes is helped with the aid of a fire starter medium such as kerosene to instant the process. This characteristic is highly supported by Nasrin *et al.*, (2008) in his study of palm briquette which also stated that a firestarter medium is needed to help the ignition of the palm briquette due to the highly compacted briquette. Once the briquette is ignited, it will take quite sometimes to finish burning completely due to the presence of EFB in cellulose that caused the burning of the briquette longer. This is suitable for the end application of the palm briquette which used to generate energy in a long time. It can be deduced that the longer it took for the briquette to finish burning, the better the briquette will be in terms of its combustion efficiency. The time taken to keep the briquette to keep burning is not the only factor that leads to a good and quality briquette, other factor that must be taken into account is the amount of heat generated or amount of heat transfer from each briquette during the combustion process. Demirbas *et al.*, (1997) stated that a combustible material should be easy to ignite particularly for household, but low porosity, low volatile content, and high ash content are likely to reduce the ignitability of the material. Qualitative observations have shown that as the densities of the briquettes increased, their ignitability will decreased. It is very difficult to obtain parameters for acceptable ignitability of briquettes. Briquetted waste paper is likely to be more difficult to ignite because of the low porosity and higher density. As a result, as the density of briquettes increased, its ignitability decreased. This is proven by the research that carried out which shown that the briquettes are difficult to ignite during combustion process due to the presence of waste paper in the ratio. The higher the percentage of waste paper in the ratio, the harder the ignition of the briquette will be. Meanwhile, the higher the percentage of EFB in the ratio, the longer the briquette will keep its burning due to the fibrous condition of the EFB. Nonetheless, from the experiment, it is observed that S/N 1 took less time to completely burn even though it contained the highest percentage of EFB compared to other briquettes. From the combustion efficiency analysis, it can be summarize that S/N 6 burnt the longest time compared to other briquettes, but releasing the lowest amount of heat to its surrounding. Meanwhile S/N 1 burnt the most quickly from the other briquettes, but the amount of heat released during the combustion is higher compared to S/N 6, S/N 3 and S/N 2. Briquette that released the highest amount of heat during combustion is S/N 4 and the time taken to finish burning is also quite long.

The main objective from the combustion process conducted is to measure and observe the amount of heat released from the combustion of the briquettes to the surrounding during the combustion process. This will determine whether the objective of the research is achieved or not. This is because the main objective is to study on the best ratio of the fuel briquettes that could gives the highest amount of energy to be utilized as an alternative energy in industry. The higher the heat transferred from the briquettes to its surrounding is

desirable rather than a briquette that released lower heat transfer into its surrounding. From the result in Figure 4, it can be deduced that sample briquette S/N 4 is the best ratio as it released the highest amount of heat during its combustion. Briquettes with the lowest amount of heat released it S/N 6. The highest amount of heat released is 162.77 kJ and the lowest amount of heat released is 104.26 kJ. Comparing to the study on briquetting of waste paper and wheat straw mixtures conducted by Demirbas *et al.*, (1997) the highest heating value of straw and waste paper were found to be 17.3 and 16.4 MJ kg⁻¹. The value is higher compared to the study conducted due to the mass of the briquettes and the density of the briquettes which relatively higher. The amount of heat released from the briquettes depend on the density of the briquettes, this is supported by Didar Singh and Kashyap (1997), in their study of mechanical and combustion characteristic of paddy husk briquettes which stated that the density of the briquette will affect the amount of heat released. From their study, the heat value of briquettes prepared with molasses was higher than those of briquettes with smaller amount of molasses. The average heat value of briquettes is from 3568 kcal kg⁻¹ to 3110 kcal kg⁻¹.

4.0 CONCLUSION

From the experiment carried out, it was generally found out that the characteristics of palm biomass briquettes produced from compaction of EFB and waste paper were satisfactory and compatible with the other researches that involved the palm briquettes. Nevertheless, the results obtained have met the objectives set at the early stage of the research. The objective to develop a solid fuel from the mixing of an empty fruit bunch (EFB) and waste paper at different ratios has been achieved successfully by producing sample briquettes in six different ratios. From combustion (heat released) analysis, it can be concluded that S/N 6 gives the best properties in terms of burning time of the briquette. This is because S/N 6 took the longest burning time before the briquette completely burnt, but in terms of heat released value, sample S/N 4 is the best ratio as it released the highest value of heat released from the combustion process with a value of 162.77 kJ. In the nutshell it can be summarized that all samples briquettes have their own strength and weakness when they were subjected to different types of testing, but still all the briquettes were compatible with each others and it is suitable to be commercialized as a new solid fuel sources that can be utilized in many application such as camping, barbeque and for residence utilization energy. The blending of EFB fiber with waste paper can improve its physical, mechanical, and combustion properties.

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