Production of high-calorie energy briquettes from bark waste, plastic and oil

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Abstract. Bark is the waste generated from the utilization of plantation timber, while plastics and oil waste are produced from daily human activity. These waste has the potential to be used as energy briquettes raw materials, especially for fuel in power plants. It would be worth very strategic for the environment and the welfare of society, considering that at this time we are not yet fully capable of well managing all three waste types. On the other hands most of the power plants that operate today still use diesel and coal as fuel. Therefore, the best composition of mixing bark, plastic and oil will be studied as well as its influence on the physical and chemical quality of the briquettes produced. The results show that the addition of the oil waste (70%) and used plastic (30%) as additive give effect to the performance of the briquette formation with the highest calorific value of 33.56 MJ/kg.

1. Introduction
Since fossil fuel sources across the globe are fast depleting, renewable and non-conventional energy sources are urgent to be explored to ensure the world is not threatened by a vacuum of energy. Due to the erratic change of energy prices and unfavourable forecast of world economy, considerable efforts have been devoted to substitute raw fossil fuels with various other sources for the production of energy. The various factors, such as ever increasing diesel consumption, large outflow of foreign exchange, and concern for environment, contribute to the search for a suitable environmental friendly alternative to fossil fuel [1, 2].

Biomass is one of the renewable and potentially sustainable energy sources and has many possible applications varying from heat generation to the production of advanced secondary energy carriers. It has almost zero or very low net CO₂ emission since carbon and energy are fixed during the biomass growth. There are different types of technologies for converting biomass to electricity or to a secondary fuel such as thermal conversion, chemical conversion and bio-chemical conversion [3, 4]. Biomass is generally defined as any hydrocarbon material, mainly consists of carbon, hydrogen, oxygen, and nitrogen. It has been recognized as a major world renewable energy source to supplement declining fossil fuel resources. However, the use of first generation biofuels, which have been mostly taken from food and oil crops, such as rapeseed oil, sugar cane, sugar beet, maize, vegetable oils, and
animal fats, has generated a lot of controversies, primarily because of their impact on global food markets and food security. Hence, it drives the need to base non-food biomass resource biofuels [5, 6].

As one of the countries with abundant biomass reserves and also experiencing energy and fuel crises, the Government of Indonesia has set a target of diversifying energy sources to replace coal, gas and petroleum with renewable energy sources, including those with developing biofuels and bioenergy derived from the use of various types of biomass, which can be obtained from agriculture, plantation, forestry and others [7]. Plantation forest were developed as part of efforts to provide sufficient raw materials for the existence of the pulp and paper industries that are currently expanding rapidly in Indonesia. The development of the pulp and paper industry that generally uses wood raw materials, in practice, many also leave environmental problems, especially those derived from bark as a disturbing waste and usually only burned or used as an artificial soil matrix.

On the other hand, the plastics have become one of the most important and indispensable materials in our contemporary world. These plastics are not presently biodegradable and are extremely troublesome components for land filling. The waste plastics are known for creating a very serious environmental challenge because of their huge quantities and the disposal problems caused by them. To avoid the impact of the plastic in the environment, the recycling of plastics constitutes a valid alternative [2].

Another waste material that also needs to be taken seriously and observed is the vehicle oil waste. The amount of oil waste from motor vehicles, industrial machinery and power plants from time to time increases as the number of vehicles grows in the midst of society. Generally, used oil is only collected in order to facilitate the transportation and recycling, although there are many people who immediately throw it into the environment. Therefore, serious attention needs to be given to prevent the recurrence of this incident, especially by seeking alternative use of this waste oil into raw materials or additives from derivative products that we may produce from the processing.

Responding to this waste problem, a strategic thought was needed to process and exploit the potential of these three waste types into an energy product that can be utilized as fuel for power generation, since to date most of the area in Kalimantan is also facing the lack of electricity supply. This study aims to know the potential utilization of mixture of acacia bark waste, plastics and oil as raw materials in the production of energy briquette; the optimum composition of these mixture that can be applied to obtain energy briquette products with high calorific value (high quality); and the quality of energy briquette that can be produced from the composition of this mixture.

2. Material and Methods

2.1. Material

*Acacia mangium* bark waste was collected from chip mill industry of PT. Sarana Bina Semesta Alam (SBSA), located in the Village of Tanjung Karas, Muara Kaman, Kutai Kertanegara and also PT. Kutai Chip Mill (KCM) in Balikpapan, East Kalimantan. Prior to use, the ingredients have been previously dried under the sun for several days to reach a water content of 12 ~ 14%, before further made into chips and converted into powder.

2.2. Methods

Energy briquettes are made from a mixture of acacia bark waste, plastics and used oil. All ingredients based on each ratio are mixed in the mixer at low speed, heated and then printed into briquette using briquette press, to obtain energy briquettes with final dimensions: length ± 20 cm, width ± 10 cm and thickness ± 5 cm. In this study, the ratio of ingredients has been developed by placing the use of acacia bark waste as the main factor of the constituents (50 ~ 60%), while the plastics and additives of used oils are minor factors, each of which will be attempted to be developed by varying amounts of mixing
in the range of 5-20% for plastics and 30-40% for used oil, where the respective portion of the material will be calculated from the weight of the waste bark waste used (w/w). The mixed compositions that will be developed in this study can be seen in Table 1.

**Table 1. The composition of a mixture of bark, plastic and oil**

| Sample Number | Plastic (g) | Oil (g) | Bark (g) |
|---------------|-------------|---------|----------|
| 1             | 40          | 60      | 100      |
| 2             | 25          | 70      | 100      |
| 3             | 30          | 70      | 100      |
| 4             | 35          | 70      | 100      |
| 5             | 40          | 70      | 100      |
| 6             | 20          | 80      | 100      |
| 7             | 20          | 60      | 120      |
| 8             | 10          | 70      | 120      |

Acacia bark waste, due to its abundant amount, is expected to become the main component of the forming and filling of this biomass energy briquette product. While plastic waste is used as an adhesive substitute to strengthen the structure and increase the calorific value. Used waste oil is deliberately added to increase the calorific value of this super briquette product, since waste oil has a high enough calorific value of ± 10,000 Kcal/kg and also to facilitate the initiation process of combustion of energy briquette product [8-11].

To know the characteristic and quality of raw material and energy briquette product, especially to evaluate the best composition that can be developed further, there will be a series of test which includes the analysis of physical properties and also the chemical content of the product. The complete series of tests is carried out with reference to the methods contained in Table 2.

**Table 2. Parameters and methods of briquette testing [12]**

| Number | Parameter       | Methods          |
|--------|----------------|------------------|
| 1      | Density        | ASTM D 4784      |
| 2      | Moisture       | ASTM D 3173-11   |
| 3      | Ash Content    | ASTM D 3174-12   |
| 4      | Volatile Matter| ASTM D 3175-11   |
| 5      | Fixed Carbon   | ASTM D 3172-07a  |
| 6      | Total Sulphur  | ASTM D 4239-12   |
| 7      | Calorific Value| ASTM D 5865-12   |

3. Results and Discussion
The result showed that increasing the addition of plastics in the mixed briquette can increase the density value and lower water content as seen in Table 3. This may occur because the function of adding plastic to this mixture can increase the adhesiveness and compactness of this briquette texture. These results are also in line with the results of research which states that the materials are pressed under the different pressure caused the material amount transported into do compacting matrix. If the
matrix capacity is large and thus also the material amount is larger, then the pressing machine produces a higher pressure, the final briquettes are longer and therefore their density and strength are also higher [13, 14].

**Table 3.** The physical properties of briquettes

| Mixture Composition (plastic:oil:bark) | Density (kg/m³) | Moisture Content (%) |
|---------------------------------------|-----------------|----------------------|
| 40:60:100                             | 0.79            | 3.58                 |
| 25:70:100                             | 0.68            | 5.45                 |
| 30:70:100                             | 0.70            | 3.43                 |
| 35:70:100                             | 0.70            | 3.12                 |
| 40:70:100                             | 0.79            | 3.66                 |
| 20:80:100                             | 0.67            | 4.93                 |
| 20:60:120                             | 0.64            | 6.49                 |
| 10:70:120                             | 0.56            | 6.05                 |

The ash content, volatile matter and fixed carbon contained in the briquette samples were also determined and the results as presented in table 4. The mixture of briquettes with large amount of bark waste has higher ash content and fixed carbon than a small one, while the volatile matter is lower than other briquettes. The results of this study are also in line with previous research that convey the characteristics of briquettes produced from several types of biomass [15, 16].

**Table 4.** The chemical properties of briquettes

| Mixture Composition (plastic:oil:bark) | Ash (%)  | Volatile Matter (%) | Fixed Carbon (%) | Sulphur content (%) |
|---------------------------------------|----------|---------------------|------------------|---------------------|
| 40:60:100                             | 2.41     | 85.15               | 8.86             | 0.13               |
| 25:70:100                             | 2.80     | 80.37               | 11.38            | 0.17               |
| 30:70:100                             | 2.19     | 86.26               | 8.12             | 0.16               |
| 35:70:100                             | 2.85     | 84.62               | 9.41             | 0.16               |
| 40:70:100                             | 2.57     | 85.04               | 8.73             | 0.20               |
| 20:80:100                             | 2.51     | 82.32               | 10.24            | 0.18               |
| 20:60:120                             | 4.06     | 75.69               | 13.76            | 0.13               |
| 10:70:120                             | 3.42     | 77.25               | 13.28            | 0.17               |

Table 4 also shows that the higher the addition of oil, the higher the sulphur content. On the other hand, adding plastics to the mixture does not seem to affect the quality of the briquettes due to their very small amounts and plastic functions only as adhesives.

Figure 1 presents the calorific value generated by the briquettes mixture. The highest calorific value of 33.56 MJ/kg was obtained by a mixture of 30:70:100 (plastics: oil: bark). These results indicate that the optimal mixture is not always produced by the amount of ingredients most widely added but the best mixed combinations that can produce the high quality of briquette. Compared to calorific value obtained in the other study of different acacia species [14], these results indicate a higher calorific value. It can be caused by the addition of plastic and oil on the production of this briquette.
Figure 1. The calorific value of briquettes

The relationship among ash content, fixed carbon and volatile matter with the calorific value is depicted in figures 2-3.

Figure 2. The relationship among ash, fixed carbon and calorific value
The relationship between ash content and calorific value is indicated by a smaller R value compared to the relationship between fixed carbon and calorific value of 0.61401 and 0.84473, respectively, whereas the relationship between volatile material and calorific value gives a higher R value of 0.85382.

The highest calorific value of briquette obtained in this study shows that it can exceed the calorific value of coal used as conventional fuel during this time and wood (dry) [16] as shown in table 5. According to European standard EN 14961-3 (ENplus A2) for wood briquette, the calorific value of the briquettes produced in this study may be stated to meet this standard whose calorific value is ≥ 15.3.

| Mixture Composition | Calorific value (MJ/kg) | Sample | Coal<sup>a</sup> | Wood (dry)<sup>a</sup> | EN 14961-3 (ENplus A2)<sup>b</sup> |
|---------------------|-------------------------|--------|-------------------|-------------------|----------------------------------|
| 40 60 100           | 30.46                   |        |                   |                   |                                  |
| 25 70 100           | 30.11                   |        |                   |                   |                                  |
| 30 70 100           | 33.56                   |        |                   |                   |                                  |
| 35 70 100           | 33.26                   |        |                   |                   |                                  |
| 40 70 100           | 32.76                   | 15.0-27.0 | 14.4-17.4     | ≥ 15.3          |
| 20 80 100           | 30.00                   |        |                   |                   |                                  |
| 20 60 120           | 27.00                   |        |                   |                   |                                  |
| 10 70 120           | 27.11                   |        |                   |                   |                                  |

<sup>a</sup>[17]  
<sup>b</sup>[18]

Although the testing of briquette quality in this study has shown good results, the most optimum briquette research study still needs to be continued to reduce the oil addition so that the sulfur released can still be below the standard determined threshold.
4. Conclusions
Bark waste, plastic and oil very potential to be used as raw material for energy briquette production. The mixture of these three waste types produced a high-calorie energy briquettes. The highest calorific value of 33.56 MJ/kg is obtained by briquette mixture of 30:70:100 (plastics:oil:bark). Overall, the calorific value of the briquettes produced in this study may be stated to meet the standard.

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