Torrefaction of Durian peel and bagasse for bio-briquette as an alternative solid fuel

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Abstract. Biomass waste of durian (Durio zibethinus) peel and bagasse could be used as solid fuel by a toreffaction process. Durian peel and bagasse were washed and crushed into small sizes then dried in order to remove water content. The treated biomass was burned at varied temperature of 200 – 350 °C and a residence time of 30 min prior to producing torrified charcoal as intermediate product. Torrified charcoal was ground into a powder blended with tapioca glue followed by casting into a cylinder to form a bio-briquette. The bio-briquette was characterized by determining its calorific value via bomb carolimeter analysis. The key parameter of bio-briquette are calorific value and combustion rate. The result that as the burning temperature was increased the calorific value of bio-briquettes also increased. The maximum calorific value was achieved at 350°C whereas the maximum calorific value of durian (6,157 cal/gr) is higher than bagasse (6,109 cal/gr). The minimum combustion rate was attained in durian peel torrefaction at 350 °C with the rate 0.0398 g/s. The result showed that bio-briquette of durian peel and bagasse have calorific values equivalent to that of subbituminus coal in the range of 4,900 - 6,800 cal/gr.

1. Introduction

Energy consumption in Indonesia still dominates with fossil fuel like natural oil and gas or coal as solid fuel. Whilst the fossil fuel is non-renewable energy and the supply decreases all over the time. This condition needs researchers to find out the alternative energy to ensure energy consumption. Biomass waste has the high prosperity to be raw material for alternative energy. Two of them are Durian Peel and Bagasse.

Durian (Durio zibethinus) is the local fruit of Indonesian and it grows well in Indonesia especially in South Sumatera. Durian peel is a waste that can rise environment problems but it is high prospect as bio-briquette raw material for improving its added value.

Bagasse is the by-product (waste) in sugar industry which 35% - 40% of sugarcane weight generate bagasse. Biomass waste from bagasse (with 37% cellulose content) and durian peel (with 60% cellulose content) potentially proceed as solid fuel (bio-briquette) with high calorific value and environment benign without emmision of combustion via torrefaction process [1], [2].

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Torrefaction is a thermochemical treatment of biomass at 200 to 300 °C. It is carried out under atmospheric conditions and in the absence of oxygen. In addition, the process is characterised [3]. After passing through torrefaction, the moisture contained in the biomass is substantially reduced and the components of low weight organic volatile are liberated. As a result, hydrophobic bio-briquette with higher content of fixed carbon are produced [4]. Torrefied biomass has advantageous properties (such as low moisture, lower emission of smoke and increased heating values) that improve fuel quality [5]. Torrefaction also makes biomass hydrophobic, that is, it practically does not reabsorb moisture during storage [6].

Several researches have been also established for producing briquette from various biomass. Nugraha [7] informed that bagasse charcoal briquettes production via carbonization process with adhesive material Lapindo Mud generate calorific value of 3,564 cal/g and combustion rate of 0.142 g/min. Production of briquette from empty fruit bunches torefaction has been reported by Irawan et al [8] with temperature and holding variation. The result showed the higher temperature had higher calorific value 4,469 cal/g. Ridhuan and Suranto [9] compared carbonization and pyrolysis process in producing biobriquette from durian peel. It showed that carbonization has lower calorific value (3,418 cal/g) than pyrolysis (5,609 cal/g).

In this present work, biomass waste of durian peel and bagasse was torrefied in the purpose of comparing calorific value and combustion rate of durian peel and bagasse bio-briquette. Furthermore, this work aims to find out the influence of temperature and residence time in calorific value and combustion rate.

2. Methodology/Experimental

2.1. Samples
Durian peel samples which grow in Medan were collected directly from Kuto Fruit Market, Palembang, Indonesia. Bagasse samples were collected from sugar industry PT. Pemuka Sakti Manis Indah (PT.PSMI), Lampung, Indonesia. All samples were cut into 5 cm then dried in sunny side for a week until attain constant weight.

2.2. Torrefaction Process
250 g dried material enters the reactor then burnt on 8.5 A with varied temperature of 200- 350 °C and residence time of 30 min. After the recidence time, the product is in a form of charcoal. Figure 1 shows the experiment equipment scheme for torrefaction. This equipment includes reactor that completed with heating element in a whole reactor wall. This reactor is connected with thermocouple in order to control temperature during torrefaction process.

![Figure 1. Experimental equipment scheme.](image-url)
2.3. Bio briquette Casting
The torified charcoal of biomass durian peel and bagasse were ground into powder. The charcoal powder samples blended with tapioca glue which is tapioca flour was mixed with boiled water in ratio of 1 : 10 and followed by casting in pressed cylinder tube to produce bio-briquette with diameter 2.5 in and height 10 cm. The cylinder bio-briquette was dried in an oven for 1 h to ensure the bio-briquette has low water content for improving storage time.

The bio-briquette products were characterized by determining the calorific value with bomb calorimeter analysis. The sample briquette was burnt in atmospheric condition for establishing combustion rate.

2.4. Calorific Value Analysis
All the biobriquette samples were analyzed using a bomb calorimeter (Parr) in Jasa Mutu Mineral Indonesia Laboratory, Inderalaya, South Sumatra, Indonesia. The bomb calorimeter was equipped with an integrating ignition unit (Parr 2901) and oxygen bomb (Parr 1108).

Bomb calorimeters require 0.5 g of sample matter weighed in a crucible. The sample was placed crucible inside the stainless steel container (the bomb vessel) and filled bomb vessel with 30 bar (435psi or 30 atm) of pure oxygen. Once the bomb vessel temperature has stabilized in the bomb well, the sample was then ignited. During the burning of the fuel sample, the crucible could momentarily rise to above 1000 °C with the pressure spiking to 3 x the initial pressure. Once the determination is complete, typically within 4 min, the calorimeter calculated the calorific value of the fuel sample. At this point in time, the bomb vessel was removed from the bomb well to be cooled. The heating value on calorimeter can be calculated as follows [7]:

\[ HHV = \frac{(c \times \Delta T) - (\text{Acid}) - (\text{Fulse})}{\text{Mass of sample}} \]  (1)

where HHV is Highest Heating Value (cal/g), Acid is ash residue (cal/g), Fulse is length of burnt wire (1 cm = 1 cal/g), \( \Delta T \) is temperature differences (°C), \( c \) is constanta (2,401.46 cal/g).

2.5. Combustion Rate Calculation
Briquette combustion rate was determined by equation (2). Briquette sample was put on the analytic scale to know the weight. Briquette sample of known weight was placed on bucket completed with the burner ignited. The mass balance was monitored to record measurements of the weight loss throughout the combustion process using stopwatch, until the briquettes were completely burnt. The weight loss at specific time was calculated from this expression [7]:

\[ M = \frac{M_o}{\Delta t} \]  (2)

Where \( M \) is Briquette combustion rate (g/s), \( M_o \) is mass of briquette sample (g), \( \Delta t \) is time of combustion (s).

3. Result and Discussion

3.1. Calorific Value Analysis with different biomass waste
Figure 2 shows the calorific value of biobriquette with two different biomass waste (durian peel and bagasse). Based on Figure 2, it can be seen that calorific value of biobriquette is significantly influenced by temperature differences and raw material. The calorific value of durian peel samples with more cellulose content is higher than bagasse that of smaller one. It could be explained that the greater cellulose content, the greater fixed carbon and the greater calorific value. The maximum calorific value was attained at 350°C, as the burning temperature increased, the calorific value of bio-briquettes also increased. This phenomenon occurs due to accomplished decomposition of cellulose to carbon content at 350°C. Generally, the thermal decomposition of hemicellulose occurs at
temperatures ranging from 150 to 350 °C; cellulose is decomposed for the temperatures in the range of 275-350°C, and lignin is featured by gradual decomposition for the temperatures between 250 and 500°C [10], [11]. The high fixed carbon carried out high calorific value as indicator of bio-briquette quality.

![Calorific Value vs Temperature Graph]

**Figure 2.** The influence of temperature variations with calorific value of bagasse vs durian peel.

Compare to previous research [7], [8], [9], this present study indicates that torrefaction process in ranges temperature of 200 - 350 °C is better than carbonization process (high temperature, with oxygen presence). This is because of the vacuum condition in torrefaction process lead high calorific value of 6,157 cal/g than others only 3,000 - 5,000 cal/g.

### 3.2. Combustion Rate Analysis

Figure 3 indicated combustion rate of durian peel bio-briquette and bagasse bio-briquette. This figure shows the rising temperature which conduct the increased combustion rate. It is caused by the increasing of fixed carbon and the decreasing of bio-briquette volatile mater. The combustion rate of bagasse bio-briquette is higher than durian peel bio-briquette with the value of 0.0509 g/s and 0.0398 g/s, respectively. Low combustion rate leads the briquette burning in longer time consistent with Nugraha's statement [7].
4. Conclusion
The comparison of durian peel and bagasse bio-briquette indicates that durian peel is better than bagasse as torrefaction material. The calorific value and combustion rate is highly influenced by a variety of temperature. The calorific value increased with rising of temperature that achieved the maximum value to 6,157 cal/g at 350 °C over durian peel bio-briquette and 6,109 cal/g over bagasse. This result shows both biomass waste potentially as an alternative energy to substitute coal (fossil fuel) due to the calorific value of durian peel and bagasse bio-briquette equals to subbituminous coal in the range 4,900-6,800 cal/gr according to International standard.

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