Investigation of mango (*Mangifera odorate*) sap and starch as organic adhesive of bio-briquette

S Rodiah, J L Al Jabbar, A Ramadhan, E Hastati

Chemistry Study Program, Faculty of Science and Technology, State Islamic University of Raden Fatah Palembang, Palembang, South Sumatera, 30126, Indonesia

Corresponding author: siti.rodiah_uin@radenfatah.ac.id

Abstract. Rice husk and coconut shell waste is potential biomass found in Palembang that has not been utilized properly. Besides being used for primary purposes, biomass can be used for energy sources like renewable energy. Biomass residues can be obtained from the pyrolysis process with thermal cracking units (UTC) and used as bio-briquettes. Bio-briquette is prepared from a mixture of pyrolysis residues of coconut shell and rice husk with a mass ratio of 2:1 using a combination of adhesive mucilage (mango sap) and paste (starch). The adhesive is prepared by dissolving the starch in water, then mixing it into melted mango sap. The mass ratio of the sap and starch is 1:1 (w/w), while the ratio of the mixture of adhesive and water is 1:10. Based on the ATR-FTIR characterization, it showed that the C = C strain group and the C-H bending group appeared at 2800 cm⁻¹, which was confirmed by its appearance at 800 cm⁻¹ in the fingerprint area. Then, appears peak in the area of 1300 cm⁻¹, indicating the presence of a nitro group, which is assumed to have come from mango sap. Measurements of the briquette physicochemical properties such as moisture content, ash content volatile matter, and fixed carbon were measured using the proximate analysis method. Furthermore, the addition of coconut shells in producing bio briquettes from rice husks increased the calorific value by 7.305 MJ kg⁻¹. So that, bio-briquette is an effective as an alternative energy source to replace fossil fuel for household purposes.

1. Introduction

Rice husk and coconut shell biomass waste is potential waste in Palembang City, South Sumatra, which has not been fully utilized. Besides being used for primary purposes, biomass can be used as an energy source. Biomass is a renewable sustainably energy resources [1] and can be converted into thermal energy, liquid, solid or gas fuels and other chemical products through conversion processes including direct heating, gasification, pyrolysis, decomposition, and fermentation [2]. Pyrolysis is the common method to convert biomass become an energy resource using a thermal cracking unit (UTC). The main product of the pyrolysis is liquid smoke, while the by-product is biomass residue which has potential as raw material for bio-briquettes.

In this research, coconut shell was added with rice husk to produce high efficiency bio-briquettes. Bio-briquettes combustion is clean. Therefore bio-briquettes are environmentally friendly energy [3]. Most of the research objective of bio briquette is to determine the efficiency of boiling that can be compared to coal or firewood [4]. Two important factors in producing bio-briquettes are the raw material and the adhesive material. Bio-briquette adhesive also affects the quality of briquettes. The adhesive commonly used is the adhesive from starch. Based on Ifa’s research [5] shows that producing bio-briquettes from agro-waste requires starch, alcohol, and warm water with a calorie value of 29.49 MJ
kg\(^{-1}\). The adhesive activity of the starch was higher than the mixing jackfruit and flour adhesive on the biomass of palm shell charcoal [6]. Currently, research related to the use of sap as an adhesive has not been done. Therefore, mango tree sap (Mangifera Odorate) was used as an adhesive to produce bio-briquettes from coconut shell and rice husk biochar in this study.

2. Experiments

2.1. Materials
Coconut shells and rice husks were collected from an area of South Sumatra. Mango sap was collected from mango plantations in South Sumatera, Indonesia. Starch was purchased from Merck (99.9%). The bio-briquette mold and press device were designed and made by researchers as needed.

2.2. Procedures

2.2.1. Preparation of coconut shell and rice husk residues. The coconut shell and rice husk were pyrolyzed separately using Unit Thermal Cracking at temperature of 250 – 300 °C. The pyrolysis produced liquid smoke and a by-product in the form of biomass residue. The biomass residue, which were coconut shell and rice husks, was used as a raw material for making bio-briquettes. The rice husk and coconut shell charcoal were mashed and sieved with a 100 mesh sieve to obtain powdered rice husk and coconut shell charcoal.

2.2.2. Preparation of bio-briquette. The preparation of bio-briquettes has two important stages, namely dough making and molding. The bio-briquette dough preparation began with melted the mango sap (2.5 g) in a hotplate at a temperature of 60-70°C, then added a starch solution (2.5 g of starch in 25 mL distilled water) and stirred until homogeneous. The adhesive mixture was added with 30 g of powdered rice husk charcoal, stirred until the dough was well blended. The dough was printed with the bio-briquette mold that had been provided. The mold filled with dough was pressed to obtain the bio-briquette. The same procedure was also applied for the preparation of bio-briquettes from coconut shells and from a mix of rice husks and coconut shells with a ratio of 1: 2 (w/w). The composition of bio-briquettes in this study is presented in Table 1.

Table 1. Composition of bio-briquettes

| Sample name                           | composition of biochar (g) | composition of adhesive (g) |
|---------------------------------------|---------------------------|-----------------------------|
|                                       | coconut shell | rice husk | mango sap | starch |
| Bio-briquette (rice husk residue)     | -            | 30        | 2,5       | 2,5    |
| Bio-briquette (coconut shell residue) | 60           | -         | 2,5       | 2,5    |
| Bio-briquette (rice husk and coconut shell residue) | 40           | 20        | 2,5       | 2,5    |

2.2.3. Characteristics analysis of bio-briquettes. Bio-briquette characteristics were analyzed by Fourier Transform Infrared (FTIR). Measurements of the briquette physicochemical properties such as moisture content, ash content volatile matter, and fixed carbon were measured using the proximate analysis method. Furthermore, the bomb calorimeter was used to investigate the calorific value of bio-Briquette. To find out the value of emissions, testing the levels of CO and NO from the combustion of bio-briquettes has been investigated.
3. Result and Discussion

3.1. Proximate Analysis

The results of the bio-briquette proximate analysis in this study were shown in Table 2.

| Sample name | Proximate analysis results |
|-------------|-----------------------------|
|             | % moisture  | % fixed carbon | % volatile | % ash |
| Bio-briquette (rice husk residue) | 5,14 | 58,36 | 31,80 | 4,71 |
| Bio-briquette (coconut shell residue) | 4,49 | 67,02 | 22,58 | 5,91 |
| Bio-briquette (rice husk and coconut shell residue) | 3,55 | 44,05 | 48,99 | 3,41 |

Table 2 shows that bio-briquette made from coconut shell residue has the highest fixed carbon and ash content, in addition, the highest volatility is shown by bio-briquette made from rice husk and coconut shell residue. The moisture of bio-briquettes from rice husks is higher (5,14%) than bio-briquettes from coconut shells (4,49%). This could be due to the fact that rice husks contain higher water content than coconut shells, thus affecting the moisture of the bio-briquettes produced. When bio-briquettes were made from a mixture of rice husks and coconut shells with a ratio of 1:2 (w/w), it has lower moisture (3,55%) because it was influenced by more coconut shell composition.

3.2. FTIR analysis

FTIR spectra of bio-briquettes made from rice husk residue using an adhesive mixture of starch and mango sap were shown in Figure 1. In the wavenumber area, 2800-3010 cm\(^{-1}\) indicates the presence of an aliphatic CH group. The mango sap spectrum shows the aliphatic CH functional group of the aldehyde group. However, the vibrational intensity of the aliphatic CH groups of this aldehyde group was reduced in the bio-briquette spectrum. This can be influenced by the process of the oxidation reaction that occurs in the aldehyde group to its derivative aliphatic compounds.

Stretching of the carboxyl group (C=O) appeared in the area of 1700 to 1740 cm\(^{-1}\) and the C=C molecular bonds of the aromatic compounds appeared in the area of 1600 to 1475 cm\(^{-1}\) [7]. In this study, the appearing peaks in these areas were in low intensity. Then in the area of wave number 857-1270 cm\(^{-1}\), was a vibration of the Si-O functional group [8], which undergoes a shift change due to the carbon carbonyl group, which may be derived from the primary alcohol compound or aliphatic ether group [7].

3.3. Calorific and emission value analysis

The potential energy of material can be described from a calorific value which is one of the most important thermophysical properties. Calorific value is related to moisture and strongly dependent on the chemical composition of the fuel. These properties constitute a basis for evaluating the quality of energy sources.

Table 3 shows that the calorific value of the bio-briquette from blend of rice husk and coconut shell residue represents an increase in the calorific value of the bio-briquette from the rice husk residue. In addition, another advantage of this bio-briquette is the reduction in CO and NO emission levels that are owned by the bio-briquette from coconut shell residue. In this study, bio-briquette made from a blend of rice husk residue and coconut shell has the potential for an energy source compared to other studies [9]–[11].
Figure 1. FTIR spectra of bio-briquettes

Table 3. Calorific value and emission value of bio-briquette

| Sample Name                              | Calorific Value (MJ kg⁻¹) | Emission Value (ppm) | CO | NO       |
|-------------------------------------------|----------------------------|----------------------|----|----------|
| Bio-briquette (rice husk residue)         | 18.8722                    | 347                  | 1  | current study |
| Bio-briquette (coconut shell residue)     | 28.3750                    | 551                  | 3  | current study |
| Bio-briquette (rice husk and coconut shell residue) | 26.1772 | 416                  | 2  | current study |
| Biochar (miscanthus straw)                | 26.59                      | -                    | -  | -        |
| Charcoal                                  | 23.4                       | -                    | -  | -        |
| Bio-briquette (pine sawdust)              | 19.7                       | -                    | -  | -        |

4. Conclusions

The characteristics of bio-briquette made from rice husk and coconut shell pyrolysis residue were examined. The addition of coconut shells in producing bio briquettes from rice husks increased the calorific value by 7.305 MJ kg⁻¹ and had the lowest moisture and ash content. Therefore, the bio-briquette is a promising alternative renewable energy source.

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