Biomass Utilization of Some Agricultural Wastes as Alternative Fuel in Indonesia

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Abstract. The world's energy consumption continues to increase from year to year. On the other side, the reserve of energy source, especially energy from fossil fuels are diminishing. To anticipate energy shortage or even energy crisis, a study to find an alternative of energy sources needs to be done. Agricultural wastes biomass is very interesting to study because of abundantly available but not fully utilized yet.

Agricultural waste biomass can be made more useful as fuel by of carbonizing and briquetting process. Agricultural wastes that were used in this study i.e. corn cob (CC), corn stalk (CS), soybean shell and stalk (SSS), peanut shell (PS), rice husk (RH) and rice straw (RS).

The results of this study showed that many kinds of agricultural waste had different heating value. Carbonizing could increase the heating value of six agricultural wastes. Raw material and charcoal of corn cob have the highest heating value, while raw material and charcoal of rice husk has the lowest. From combustion testing, it was found that the briquette of soybean shell and stalk charcoal has the highest flue gas temperature, while rice husks charcoal briquette had the lowest. Combustion of cord cob charcoal briquette produced less of ash residue than others, while combustion of rice husk charcoal produces the most ash.

1. Introduction
Indonesia, as one of the developing countries, requires sufficient and sustained energy supply. Until now, the fossil fuels that consist of coal, oil, and gas is still become the main energy source in Indonesia. In the near future, the provision of national energy can not continuously rely on fossil energy resources particularly oil fuel, because their reserve continues to diminish. Based on the reserve to production ratio of fossil energy, coal has the biggest potential with the lifetime of 75 years, while gas potential will finish in the next 33 years. Oil is the smallest potential of fossil energy resources with potential available only until the next 12 years if no new reserves are found (1).

Indonesia government has regulated energy management issues to anticipate the problem that includes the provision, utilization, exploitation, and conservation of energy, including encourage developing new and renewable energy sources by the issuance of the Energy Law No. 30 of 2007. In addition, to reduce dependence on oil fuel, the government issued a National Energy Policy through Presidential Regulation of the Republic of Indonesia no. 5 of 2006 with the target of National Energy Mix 2025 which reduces the use of oil fuel to 20% (from 51.66% in 2006) and increases the utilization of new and renewable energy sources up to 17%.

Indonesia has great potential with some renewable energy sources such as hydro energy, geothermal energy, biomass energy, solar energy and wind energy (2). Biomass energy is a renewable energy source that is very interesting to study its utilization because Indonesia as an agricultural country located in the
tropics has abundant sources of biomass energy. There are various kinds of potential biomass energy sources in Indonesia. The biomass energy sources include waste forest products such as sawdust, small twigs, branches and stems, farm wastes such as palm shells and fiber, coconut shells and fiber, agricultural wastes such as rice husk, straw, bagasse, corn cob, and stalk.

Biomass energy reserves of various agricultural wastes have considerable potential. Various agricultural wastes have not yet fully utilized as fuel. Most of the agricultural wastes are only burned in the fields or just piled on the fields after harvest whereas they can be processed and utilized as a fuel with a high heating value.

One method of biomass processing to fuel that can be applied to agricultural wastes is carbonizing then continued by briquetting. By carbonizing, the elements that form smoke and soot can be minimized, so the exhaust gas is cleaner. By briquetting, storage is smaller, combustion quality is better and the application is more practical.

Biomass consists of several components, namely moisture, volatile matter, fixed carbon, and ash. Biomass combustion mechanism consists of three stages, namely drying, devolatilization, and char combustion. The drying process will eliminate moisture, devolatilization which is a stage of pyrolysis will release volatile, and char combustion will release heat. The residue of combustion is ash.

For small-sized particles, drying time is the time required to heat the particles to reach the point of evaporation and water that was in it all released. Equilibrium energy at small particle states that the rate of change in the particle energy is equal to the rate of heat to evaporate the water plus the rate of convection and radiation heat transfer to the particles (3). For the fuel particles that relatively large, moisture develops from the inside due to the temperature gradient in the particle while volatile apart near the outer particles.

The rate of solid fuel devolatilization does not depend on the particle size during constant temperature. If the temperature during devolatilization constant, the rate of mass reduction as a function of time depends on the mass of volatile matter, the mass of the fuel particles, the mass of char and the mass of ash. Pyrolysis process for larger particles occurs gradually from the outside to the inside of the particles. Charcoal burning rate depends on the concentration of oxygen, the gas temperature, Reynolds Numbers, charcoal size, and porosity.

Basically, various types of biomass can be burned without briquetted and carbonized first. However, uncarbonized biomass has some weaknesses among other its properties of ignition and combustion is not good, its combustion produces a lot of smoke, and it is unstable in humid conditions (4). Raw biomass has also some unfavorable properties such as high moisture and oxygen contents, low density, and heating values (5)(6).

During the carbonization process, gases that can be burned as CO, CH₄, H₂, Formaldehyde, Methane, Formic and Acetic acid and gases cannot be burned as CO₂, H₂O and tar released. Released gases in this process have a heating value that can be used to fulfill the heat need in the carbonization process.

Zanderson (7) studied the effect of carbonization temperature on the content of fixed carbon in charcoal produced from bagasse. The results showed that increasing carbonization temperature from 320 °C to 600 °C could increase carbon content. The same results were shown by Debdoubi (8) who conducted research to briquetting of esparto plant material. It was also known that the higher the carbonization temperature will increase the heating value of charcoal produced.

Biomass generally has a fairly low density, so it will difficult to handling. Densification of biomass is able to increase the density and decrease the handling problems such as storage and transport. Generally, densification of biomass has several advantages, among others, it can raise the heating value per unit volume, it is stored and transported easily and it has uniform size and quality (9). Briquetting technology can be divided into three: high pressure briquetting, medium pressure briquetting by heating, low pressure briquetting by binder. Starch, molasses, and asphalt are several types of materials that can be used as a binder (10).

The objectives of this study were to investigate the effect of carbonizing to increase the heating value and the results of the proximate analysis of various agricultural wastes, to know the rate of combustion and flue gas temperature of various charcoal briquettes from agricultural wastes. The results of this study
are expected to publicize using agricultural waste biomass energy to the community and motivate to utilize this energy source as an alternative energy source.

2. Methods
The feedstocks used in this research consist of agricultural waste i.e. rice husk and straw, corn stalk and corncob, soybean shell and stalk, and peanut shell. Starch was used as a binder. The agriculture wastes were obtained from around Yogyakarta province, Indonesia.

The reactor for carbonization process, bomb calorimeter to determine heating value, ovens, furnaces, desiccator, and scales for proximate are needed to prepare the materials and to collect the data in this study. Combustion characteristics of charcoal briquettes of agricultural wastes were investigated by burners equipped with microscale and thermocouple.

![Figure 1. Raw and carbonized biomass.](image)

2.1. Experimental procedure
Agricultural wastes were dried first. A part of feed stacks was carbonized at 400 °C for 30 minutes. Charcoal produced from the carbonization process was ground then sieved. Furthermore, charcoal powder and starch were mixed and made to briquettes by molding.

![Figure 2. Carbonized biomass briquette.](image)

2.1.1. Proximate analysis and heating value. Proximate analysis is used to determine the moisture content, volatile content, bound carbon content, and ash content in the fuel. It was done by drying two grams of samples in an oven at temperature of 103 ± 2 °C for approximately two hours. The Weight of the samples was measured before and after drying. Volatile content in the sample was investigated by placing 2 grams of sample in the crucible, wrapped by aluminum foil and heated in a furnace until the temperature reached 950 °C for 6 minutes. Then the samples were cool in desiccator for 1 hour and weigh. The ash content of the sample was tested by heating 2 grams of the sample in a furnace at a
temperature of 750 °C for 6 hours. The weight of the samples was measured before and after heating. Fixed carbon content was determined after three others component are known.

Adiabatic bomb calorimeter was used to determine heating value of biomass and charcoal by entering one gram of sample into the ignition cup and touched the fuse ware made of wire Nikelin. Then into the bomb was filled with oxygen gas pressure of 25-30 atm. Enter the bomb into the pan that has been filled with water. Cable terminal on the cap bomb connected to the AC mains voltage 23 volts. The stirrer was run for five minutes. After the electric circuit closed, the temperature should be recorded every minute until three times temperature reading similar.

2.1.2. Combustion test. Apparatus for combustion performance was prepared and arranged as shown in Figure 3. The steps of the test were started by recorded initial mass briquette, then enter the briquette to the burner. The initial burning of briquette was done by burn cotton moistened with kerosene on the top of the briquette. After the briquette started on fire, the mass reduction and flue gas temperature were recorded every five minutes until no significant mass reduction briquette that means combustion has been completed.

![Figure 3. A schematic diagram of combustion testing apparatus.](image)

3. Result and Discussion

3.1. Physical appearance
The effect of carbonization on biomass is decreasing mass by vapourization and devolatilization, while carbon still keep in the biomass.

The physical appearance of raw and carbonized agricultural wastes can be seen in figure 1. The first row is a raw material and the second row is carbonized one. From the figure, it can see that the colour becomes dark after carbonization process. The solid yield of carbonization about one third of initial feed stock mass.

3.2. Effect of carbonization on proximate analysis and the heating value
The proximate analysis of all agricultural wastes in this experiment are shown in figure 4 – figure 7. From the proximate analysis in figure 4 and figure 5, it can be seen that volatile content reduced while the fixed carbon content increased after the carbonization process. Similar results were obtained by Liu (11), (12) and (13). This phenomenon was due to release a part of volatile during the carbonization process. While the fixed carbon would remain in the fuel. Volatile content of all charcoals was almost similar to each other. Among others, corncob charcoal had the highest fixed carbon content, whereas rice husk had the lowest fixed carbon content. After carbonized, fixed carbon content in corn cobs rose by 28.4%, in corn stalks rose by 5.0%, in soybean bark and shell rose by 23.9%, in peanut shell rose
28.1 %, in rice husk rose 15.5%. While rice straw result the highest increasing of fixed carbon content, it increased by 42.4%. These results show that the type of biomass has influence to charcoal carbonization process.

Figure 4. Volatile content in raw material and charcoal.

Figure 5. Fixed carbon content in raw material and charcoal.

Figure 6. Moisture content in raw material and charcoal.

Figure 7. Ash content in raw material and charcoal.

Figure 6 and figure 7 showed the moisture content and ash content in raw material and charcoal, respectively. The moisture content in all charcoal was lower than in the raw material because the moisture was released when carbonization process. Actually, the amount of ash in fuel does not change. Changing of ash content was caused by changing of moisture, volatile matter and fixed carbon content in fuel. Among the six agricultural wastes, rice husk charcoal has the highest ash content.

Figure 8. Heating value raw material and charcoal.
The heating value of the test results in figure 8 revealed that the heating value increased for all agricultural wastes after the carbonization process. Syamsiro, et al. (14) and Correia et al. (15) get a similar result that carbonization can increase the heating value of biomass. The increase of heating value of each material was corn cob by 40.1%, corn stalk by 29.5%, soybeans stalk and shell by 35.5%, peanut shell by 42.3%, rice husk by 29.0% and rice straw by 28.6%. The heating value of corn cob charcoal was 7091.35 cal/gr. It was the highest heating value. While the rice husk had the lowest heating value, i.e. 4266.77 cal/gr. The heating value of the material in Figure 8 has a correlation with fixed carbon content in Figure 5.

3.3. Combustion
Combustion performance of all agricultural wastes was illustrated in figure 9 and figure 10. From figure 9, it is known that in the early minutes of the mass loss was rapid, then slow down and eventually no longer mass reduction when the carbon content in the fuel has been burned. Ash was left at the end of the combustion. In figure 9 it can be seen that the sixth charcoal agricultural wastes have different combustion characteristics. Briquettes from corn cob charcoal produced the least ash as burning residual, while the rice husk briquettes charcoal produced the most ash when was burning. The least mass of residual combustion, the fuel was getting better, because most of the mass is converted into energy. Amount of ash as residual combustion suitable with ash content in figure 7.

From figure 10 it can be seen all the charcoal from agricultural waste had similar characteristic flue gas temperature. The temperature of the flue gas initially rose until reach a maximum value, then down. Increasing flue gas temperature indicated an occurrence of charcoal combustion. After most of the carbon burned, the flue gas temperature began to decrease along with shrinkage of the amount of charcoal burning. Among six briquette charcoal, charcoal of soybean shell and stalk produced the highest flue gas temperature, while charcoal of rice straw produced the lowest flue gas temperature. The average flue gas temperature on peanut shells charcoal combustion was the highest. It showed that the peanut shell charcoal had the most stable flame.

4. Conclusion
Carbonization process can increase the carbon content and heating value of agricultural waste biomass. Among the other six agricultural wastes, corn cob charcoal has the highest carbon content and heating value, while the rice husk has the lowest carbon content and heating value. Combustion of corn cobs charcoal briquette produces the least residual in the form of ash, while rice husk charcoal briquette produces the most ash. Combustion of soybeans shell and stalk charcoal produces the highest flue gas temperature, while the rice straw charcoal produces the lowest flue gas temperature.

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