Microwave Torrefaction Briquettes from Mixture of Sugarcane Bagasse and Dried Leaves

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Abstract: Biomass waste and waste can be an alternative energy sources. Utilization of biomass-derived from waste products of forestry and plantation activities as briquettes. Bagasse biomass waste and dry leaves contain cellulose and lignin, affecting the calorific value. This study aimed to determine the effect of time and power of microwave torrefaction on calorific value, moisture content, and ash content. The method used to make briquettes is the microwave torrefaction method. The research flow consists of drying raw materials, size reduction, and the microwave torrefaction process. The torrefaction process is carried out with natural materials, namely bagasse and dry leaves, put in a microwave at a temperature of 230°C to 280°C in a state without air. The research variable used was Microwave power; 80, 400, and 800 W and torrefaction time; 5, 15, and 25 minutes. According to the result, torrefaction time and microwave power affect briquettes' heating value and characteristics.

Keywords: Briquettes, Sugarcane Bagasse, leaves, microwave torrefaction

1. Introduction

The volume of biomass waste increases day by day, and its utilization is not optimal.
One way to utilize biomass waste can be as raw material for alternative energy sources to increase the economic value [1]. Actual examples of biomass-derived use from forestry waste products and plantation activities that have been implemented are briquettes and charcoal [2]. Agricultural waste, biomass, is an abundant alternative energy source with relatively large energy content. If the farm waste is processed, it will become an artificial solid fuel that is more widely used as an alternative fuel [3].

The conversion of biomass waste into briquettes has been widely carried out and produces briquettes whose characteristics, especially the calorific value, are higher than coal[4], [5]. Efforts to increase biomass's calorific value of bio briquettes are added with plastics[6], [7]. Generally, making bio briquettes using biomass waste uses a pyrolysis process, which is a carbonization process, where this process uses high energy because it uses a temperature of around 400 – 500OC. In addition, the briquettes produced by the pyrolysis process still contain relatively high water[8], [9]. Therefore, it is necessary to do technology to increase its economic potential in converting biomass waste into energy.

One of the technological developments carried out to reduce the water content and increase the heating value of briquettes is torrefaction[10]. Torrefaction of biomass using the microwave as renewable energy replaces dwindling coal and reduces high carbon energy. Wood biomass, plants, forest waste are renewable energy sources that can be used [11]. The Pre Treatment torrefaction process with a mild reaction was previously shown until the final destination. Relatively low reaction temperature with a range of 200-300 oC in a free oxygen environment and a heating rate of less than 50oC minimum[12]. The torrefaction reaction can be improved by substantive heating value, energy density, C/O ratio and biomass moisture. Torrefaction reactions can occur between 200-250oC or 250-300oC. Normally, hemicellulose, cellulose and lignin decomposition occurs at the reaction temperature and with the reaction time and the resulting volatile gas[13].

The selection of biomass as raw material for briquettes is based on cellulose and lignin content. Cellulose and lignin affect the calorific value of the briquettes produced. Sugarcane bagasse because the general public can use sugarcane bagasse and be used in burning sugar factory steam boilers so that people can be self-sufficient in energy. The choice of dry leaves is because leaves from trees are often found around the neighbourhood and are a mixing material to produce more briquettes. The comparison between bagasse and dry leaves is 50: 50; the comparison selection is based on the cellulose content in bagasse and dry leaves, almost the same. Bagasse contains 52.7% cellulose, 20.0% hemicellulose, and 24.2% lignin[14]. Leaf fibre contains 65% -cellulose, 12% hemicellulose, and 9.9% lignin. From these two journals, it can be concluded that the cellulose content in bagasse and dry leaves is almost the same, so we decided to make a 50:50 comparison between bagasse and dry leaves [15],

[16]. The purpose of this study was to determine the effect of time and power of microwave torrefaction on the calorific value, moisture content and ash content and to determine the maximum conditions for the selected variables.

2. Literature Review

Briquettes

Briquettes are solid fuels made from the organic, factory, and urban waste [17]. This solid fuel is an alternative fuel or the cheapest substitute for fuel oil. It is possible to develop it en masse relatively quickly, considering the technology and equipment used are relatively simple (State Ministry of Research and Technology). Quality standards for briquettes can be seen in Table 1 below [18]:

Tabel 1. Briquettes quality standard

Characteristics	**Karakteristik Briket**			
	Japan	**United Kingdom**	**Unite d States**	**Indonesia**
Water content (%)	-8	3-4	6	7.75
Ash Content (%)	3-6	8-10	18	5.51
Evaporated Substance Level (%)	5-30	16	19	16.14
Bonded Carbon Content (%)	60-80	5	58	78.35
Density (g/cm2)	1-2	0.84	1	0.44007
Compressive Firmness (kg/cm2)	60	12.7	62	0.4
Calorific Value (cal/g)	0-7000	6500	7000	6814.11

Briquette Characteristics

Solid fuels have parameters that will be discussed, among others, as follows:

1. Calorific value (Heating value/calorific value)
2. Water content (Moisture)
3. Ash content
4. Volatile matter (substances that quickly evaporate)
5. Fixed Carbon (FC)

Torrefaction

Torrefaction is the thermal treatment of biomass at a temperature of 230 to 280°C in the absence of air and in a short time of about two hours [19]. In this process, hemicellulose is degraded while the lignin and cellulose content remains [20]. Biomass that has undergone a torrefaction process will provide several advantages, including lower water content, less smoke, and increased heat value [21].

Biomass torrefaction uses microwave as renewable energy to replace the dwindling use of coal to reduce high carbon energy. Wood biomass, plants, forest waste are renewable energy sources that can be used. The Pre Treatment torrefaction process with a mild reaction was previously shown until the final destination. It is known for a relatively low reaction temperature with a 200-300^{o}C range in a free oxygen environment and a minimum heating rate of less than 50^{o}C. Interestingly, the torrefaction reaction can be improved by substantive heating value, energy density, C/O ratio and biomass moisture. Torrefaction reactions can occur between 200-250^{o}C or 250-300^{o}C. Normally, the decomposition of hemicellulose, cellulose and lignin occurs at the reaction temperature and with the reaction time and results in the formation of volatile gases.[22].

The lignocellulosic material will undergo chemical decomposition to change the polymer structure in the torrefaction process. Various factors influence changes in the lignocellulose material during the torrefaction process. The influencing factors during the torrefaction process are as follows:

1. Temperature
   The torrefaction process is at a temperature of 200-300°C. Torrefaction temperature considerably influences the torrefaction process because biomass thermal degradation rate depends on temperature [23].
2. Dwelling Time
   The residence time is another parameter that affects the product resulting from the torrefaction process. The residence time is related to the time the biomass material remains in the reactor. This

parameter affects the decomposition and carbonization processes during the torrefaction process [21].

3. Particle Size
   Particle size also affects torrefaction reaction, but lesser than temperature and residence time. Particle size affects the contact surface area of heat transfer between the biomass material and the heat source during the thermal decomposition process [24].
4. Biomass type is another important parameter that can affect the torrefaction process. This is because most hemicellulose content is degraded during the torrefaction process. As a result, it will lose more mass in biomass containing many hemicelluloses [25].

Method

Tools and materials used

The tools have used a set of microwave torrefaction and a specimen mount press. The materials used are bagasse, dry leaves and tapioca flour.

Independent Variable

In this study, the independent variables were two parameters, namely microwave power: 80, 400, and 800 W and torrefaction time: 5, 15, and 25 minutes.

Pre-Treatment

The total mass mixture of raw materials in the form of milled sugarcane pulp and dry leaves was weighed to determine the wet weight before drying. The milled sugarcane pulp and dry leaves are dried in the sun for one whole day. The total mass of the raw material mixture after drying was weighed to determine the dry weight. Sugarcane pulp and dried leaves are cut into small pieces (size reduction).

Torrefaction Process

The bagasse was dried until the moisture content reached 10%. We prepared a microwave that is connected to electricity and a nitrogen gas hose. The nitrogen tube valve is opened by 25% of the valve opening. Make sure there is no oxygen gas left in the gas flow by looking at the water indicator on the Erlenmeyer tube that is not bubbling. The sample was put in a 1000 ml measuring cup covered with aluminium foil and connected to a nitrogen gas hose in the microwave. The microwave was closed and the power is turned on. Power and time are set according to variables. The bagasse and dried leaves are burned into charcoal in the microwave. The torrefaction process was carried out according to the microwave power variables of 80, 400, and 800 W. The torrefaction process was performed based on the predetermined time variables, namely 5, 15, and 25 minutes.

Adhesive Preparation

Tapioca starch adhesive was weighed as much as 10% of the total sample mass mixture. Tapioca flour adhesive is dissolved with aqua dest in a ratio of 2:5, then mixed well.

Briquette Making

After going through the torrefaction process, the bagasse and dried leaves were weighed 60 g of the whole sample. For example, 60 grams of bagasse charcoal and dried leaves were mixed with tapioca flour adhesive in a ratio of 45:45:10. After the bagasse dough, dry leaves and tapioca flour were mixed. The printing was carried out on the briquette printing press machine with the same pressure.

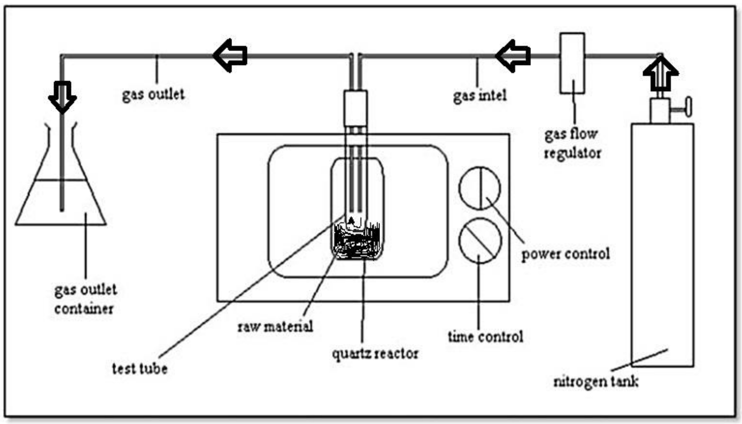

Figure 3.1. Microwave Torrefaction Apparatus Schematic

Results And Discussion

The relationship between time and microwave voltage on moisture content

Figure 1 can be seen the value of water content at time variables 5, 15 and 25 minutes with three kinds of microwave power variables, namely 80, 400 and 800 watts.

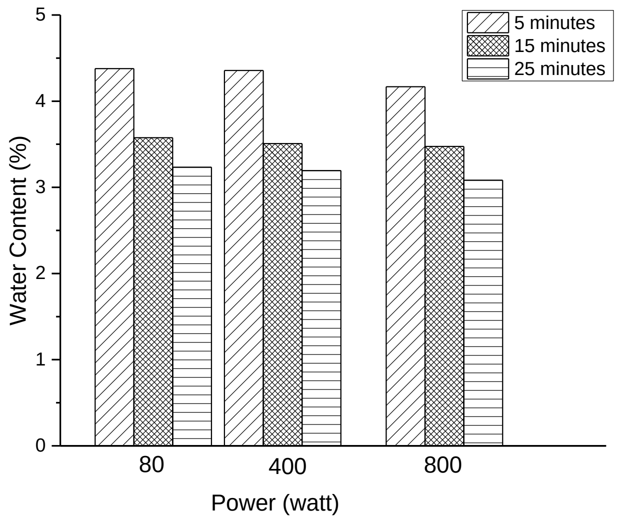

Figure 1. The relationship between time and microwave voltage on Moisture Content

Based on Figure 1, the results of the analysis of the water content of the briquette sample for the temperature variable 5 minutes, 15 minutes and 25 minutes following SNI, namely a maximum of 7.75%. Then, it can also be seen that the relationship between microwave power and water content. The increase in temperature and microwave power also affects the amount of volatile content and the percentage of fixed carbon where it is clear that the increase in temperature and power reduces the percentage of volatile content and increases the percentage of fixed carbon [26].

The relationship between time and microwave voltage on the Calorific Value

Figure 2. shows the calorific value for time variables 5, 15 and 25 minutes with 3 kinds of microwave power variables, namely 80, 400 and 800 watts.

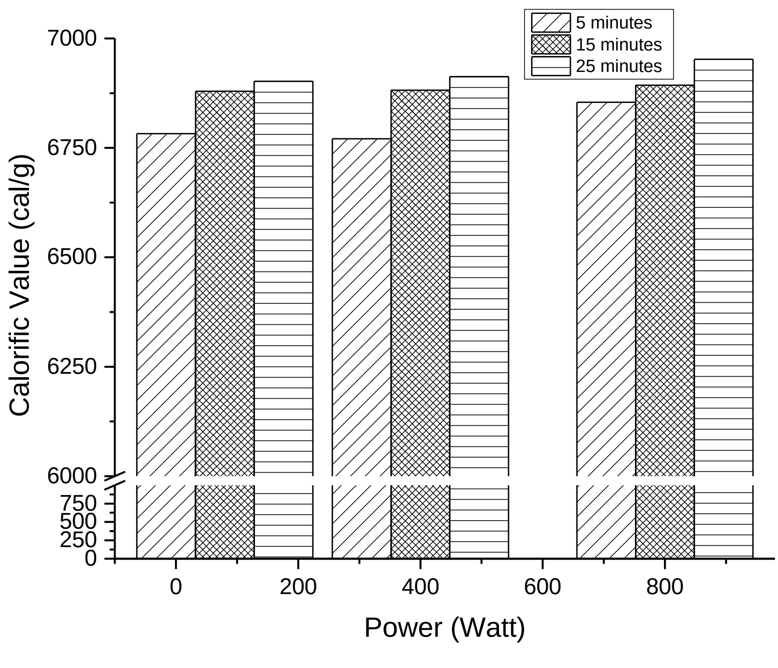

Figure 2. The relationship between microwave time and voltage on the Calorific Value

Based on Figure 2, it can be seen that the 25 minute time variable has the largest calorific value compared to the 15 minute time variable and the 5 minute time variable, then the sequence of calorific values is followed by the 15 minute time variable and ends with the 5 minute time variable which has the smallest calorific value. Variable time of 25 minutes there are three kinds of microwave power variables in a row, namely 80 watts; 400 watts; 800 watts with a calorific value in the succession of 6902.03 cal/gram; 6912.74 cal/gram; 6952.45 cal/gram. Variable time of 15 minutes there are three kinds of microwave power variables in a row, namely 80 watts; 400 watts; 800 watts with a calorific value in the sequence of 6879.41 cal/gram; 6881.76 cal/gram; 6893.19 cal/gram. Variable time of 15 minutes there are three kinds of microwave power variables in a row, namely 80 watts; 400 watts; 800 watts with a calorific value in the sequence of 6782.57 cal/gram; 6770.68 cal/gram; 6854.12 cal/gram.

The results of the analysis of the calorific value of the briquette samples for the 15 minutes and 25 minutes temperature variables are following SNI, namely 6814.11 calories/gram, while for the 5 minute time variable with 80 and 400 watts of microwave voltage it does not meet the SNI standard for calorific value. This is due to several factors, namely the leakage of nitrogen gas during the process that causes the torrefaction process to be perfectly defective and the temperature during the torrefaction process that cannot be stable. Meanwhile, when compared from previous studies with the variable length of torrefaction time of 20 minutes, the results obtained that the calorific value of the briquette sample was 5565 (cal/g).

The calorific value analysis results for the 15 minutes and 25 minutes time variables follow the literature where one way to increase the calorific value is the torrefaction method. Torrefaction is the thermal treatment of biomass at a temperature of 230°C to 280°C in the absence of air and in a short time. In this process, hemicellulose is degraded while the lignin and cellulose content remains. Biomass that has undergone a torrefaction process will provide several advantages, including lower water content, less smoke, and increased heat value. Torrefaction can increase the competitiveness of biomass as renewable energy through a thermal process using inert gas or nitrogen. Other advantages obtained from this process are high heating value, low Oxygen and Hydrogen atoms to Carbon atoms, and water resistance [27].

The relationship between time and microwave voltage on the value of ash content

The value of ash content in the time variables 5, 15 and 25 minutes can be seen with three kinds of microwave power variables, namely 80, 400 and 800 watts.

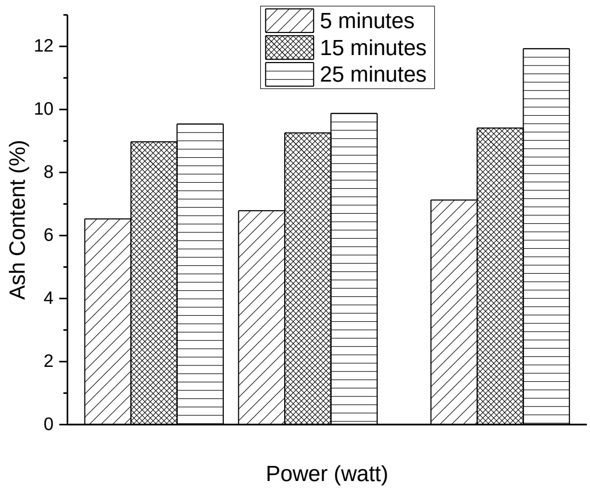

Figure 3. The relationship between microwave time and voltage on Ash Content

Based on Figure 3, the results of the analysis of the calorific value of the briquette samples for the temperature variable 5 minutes, 15 minutes, and 25 minutes according to SNI, which is at least 5.51%. Meanwhile, compared to previous studies with the variable torrefaction time of 20 minutes, the ash content value was 13.996 %.

The results of the analysis of the ash content are also following the literature where the higher the heating value of the briquettes, the better the quality of the briquettes. Where the briquettes' water content influences the calorific value and ash content, the higher the ash content and water content, the lower the calorific value of the briquettes [2].

Conclusion

The 25 minute time variable obtained the most optimal results with a calorific value of 6952.45 calories/gram, the water content value is 3.0831 %W/W, and the ash content value is 11.9314%W/W. In the 800-watt microwave power variable, the most optimal results were obtained with a calorific value of 6952.45 calories/gram, a water content value of 3.0831 %W/W, and an ash content value of

11.9314%W/W. The most optimal variable from the results of our research is 25 minutes with 800 watts of power.

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