Effect of Combustion Temperature on Thermal Stability of Paddy Leaves Char Produced in Northern Malaysia

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Abstract. Paddy leaves is good biomass that can be converted as renewable energy sources especially in Northern Malaysia. Dry paddy leaves can be burned into char which contains a high amount of carbon that useful in the production of charcoal. This paper reports the effect of the combustion temperature of paddy leaves in Northern Malaysia during the combustion process by using a universal oven on its thermal stability. The char was subjected to Thermogravimetric (TG) analysis in the investigation of its thermal stability at the range of combustion temperature 220-260°C for 4 hours. The average moisture content of paddy leaves before combustion was 9.23%. The investigation showed that 260°C was the best combustion temperature that can be used in the production of paddy leaves char.

1. Introduction

Northern Malaysia is blessed with huge amount of biomass residue that can potentially be used as a source of renewable energy alternatives. Biomass is clean, renewable and environmentally friendly energy. It has very much less sulfur and ash as compared to fossil fuels. Biomass can generate biomass energy. Biomass energy is obtained from the release of heat during decomposition of the material to its elementary molecules, which represents a faster and renewable imitation of the natural processes. There are lots of biomass energy sources that vary throughout the world. As an energy source, biomass can be used directly by burning it to produce hear or indirectly by converting it to various biomass fuels [1].

It is inefficient to burn biomass waste directly in domestic and industrial applications. The common practice is to burn these residues or they are left to decompose [2]. This burning will consequently lead to environmental pollution but more than that, the burning or decomposition is a waste of available energy. Recycling of this biomass helps to improve the accumulation of greenhouse gases [3]. In order to avoid this problem, biomass is a highly promising option as sources of renewable energy.

One of them is paddy residues. Perlis and Kedah top the rank among the most important states in Malaysia in the production of paddy plants up to 3.660 metric tonnes per hectare. So, both Perlis and Kedah stand out as two states with great potential for the use of paddy biomass waste as a renewable energy source.

After harvesting session in the paddy planting industry, the paddy leaves will be removed from the field in order to prepare the land for the next plantation cycle. Field burning is the major practice for removing paddy leaves and it will increase air pollution as an environmental issue [4]. Because of the
preceding scenario, there is need to introduce alternative and improved bio-energy such as charcoal produced from agricultural biomass residues. Therefore, the paddy leaves are useful biomass that can be converted as renewable energy sources because it is an organic material that possesses energy available for burning [5].

A research reported that based on the composition data (hemicellulose 22.3%, lignin 13.3%, Cellulose 31.1%, Ash and other 33.3%), this waste is suitable to be used as a new renewable energy alternative [6]. This implementation will lead to reducing deforestation activity and environmental pollutions. Usually, lignocellulosic agricultural crops waste has huge unutilized energy generation potential [7]. An alternative would be the application of combustion technique; this technique would convert the paddy leaves into char, expanding its uses and facilitating transportation, storage, handling and cost [8]. Char is useful for the production of charcoal briquettes. Charcoal briquettes are used as good material in creating renewable energy to improve the quality and economic value of paddy leaves waste [9,10].

From the previous research, most of the researchers used furnace with very high combustion temperatures up to 850°C for the combustion process of biomass [11-13]. This method caused high energy consumption. So, the aims of this study are to determine the moisture content of paddy leaves and to investigate the best combustion temperature to produce char for the production of charcoal briquettes. Therefore, in this paper, we present a simple method to produce paddy leaves char to reduce energy consumption during combustion process. The combustion process was conducted by using a universal oven with combustion temperature below 300°C to minimise the energy consumption.

2. Materials and Methods

2.1. Sample Collection

The paddy leaves used in this research study were obtained from the Muda Agricultural Development Authority (MADA) Kodiang, Kedah. Paddy leaves used in this research are from MR297 rice seeds. Dried paddy leaves were taken from paddy field after harvesting session.

2.2. Sample Preparation

Paddy leaves feedstock was carefully sorted manually to remove impurities such as wood, sand and any other unwanted material. Next, the paddy leaves were cut into 10 cm long and post dried in an oven for 24 hours at 80°C in order to reduce the moisture content. Then, the paddy leaves were reduced in size by cutting until they reached uniform size (5 mm).

After that, a universal oven was used to obtain the paddy leaves char during the combustion process. The temperatures used were range between 220-260 °C in normal atmosphere. About 100g of paddy leaves were packed closely in the covered aluminum container before combustion process. The combustion process was held for 4 h to obtain the char. Lastly, the size of char obtained after combustion process has been reduced by grinding and sieving. The maximum size of char dust was 63 μm.

2.3. Moisture Content

Weight of paddy leaves, before and after post dried had been taken in order to gain the information on moisture characteristic of raw dried paddy leaves. Moisture content percentage was determined as used by [13]. It was measured by the oven-dry method. The paddy leaves with the known weight was kept in the oven for 24 h at 80°C. Then, the oven-dried paddy leaves were weighed. The moisture content percentage was calculated using the formula:

\[
\text{Moisture content percentage} (\%) = \frac{w_2 - w_4}{w_2 - w_1} \times 100 \%
\]

Where,

\(w_1\) = weight of container (g)
w2 = weight of container + sample (g)

w3 = weight of container + sample after drying process (g)

2.4. Thermal Gravimetric Analysis

Thermal Gravimetric (TG) analysis was used to analyze the weight change (%) as a function of the temperature in a controlled argon atmosphere. These measurements are used to determine the thermal stability of the paddy leaves char dust as well as the compositional properties.

The sample weight used for the test was about 3 mg. The measured test samples were put in an alumina pan and then placed into the heating chamber. The thermal stability of the paddy leaves was analyzed in the temperature range of 30-400°C under an inert argon atmosphere to prevent unwanted oxidation. The heating rate temperature and flow rate of gas was set at 20°C/min and 80 ml/min respectively.

3. Results and Discussions

3.1 Moisture Content Percentage on Dried Paddy Leaves

Moisture content is a very important factor that can greatly affect the burning characteristic of paddy leaves. Based on the equation (1), the calculated mean value of moisture content percentage of paddy leaves is 9.23%.

A research reported that the recommended biomass materials moisture before briquetting is between 0% and 18%, but it is better to use material of the lower moisture content; up to about 12% [11,12]. Based on calculated moisture content in this study, the dried paddy leaves were significantly useful for the production of char, which is below 12%.

3.2 Thermal Stability of Paddy Leaves Char

Thermogravimetric analyses of the chars at different combustion temperatures are given in Fig. 1. There is a clear differentiation in the thermograms of the chars at different combustion temperatures during the combustion process in a universal oven. In general, the thermograms of the chars can be divided into two stages. First stage mostly due to the elimination of moisture content in the chars. While the second stage referred to the decomposition of lignin and hemicellulose in the paddy leaves. The thermograms are shown in figure 1 has similar pattern to the previous research done using banana tree waste [13]. They reported that the first stage corresponded to the amount of required energy during heating process while the next stage could be explained by the degradation of hemicellulose and some lignin part contained inside the banana wastes.
Another previous research also stated that the first stage (<120°C) was involved in moisture removal due to initial heating. Afterward, the removal of lighter volatile started. This stage was characterized by the release of volatiles and the lignin decomposition [14].

Figure 1 shows that the moisture removal occurred less than 10% until temperature <120°C for the chars. This is due to the moisture in biomass just at the top of the surface and loosely bounded. From the figure, the release of loosely bonded adsorbed moisture involved in every combustion temperature. But, the thermogram of chars for stage II in Fig. 1 was significantly different for every combustion temperature. Start from 250°C, the thermogram of 220°C char showing the greatest decrease in weight %. It was mainly due to more unburnt lignin and hemicellulose inside paddy leaves during the combustion process.

The high yield of char at lowest combustion temperature (220°C) demonstrated that the material has been only partially combusted. The yield of char could be associated with either primary or secondary decomposition of raw paddy leaves during combustion process which consequently influenced the conversion processes to become char [15].

However, for the highest combustion temperature (260°C), the decrease in weight % at the second stage was the lowest. Higher combustion temperature caused more lignin and hemicellulose parts contained in the paddy leaves decomposed after the combustion process. It can be seen from the figure that char yield decreases gradually as the combustion temperature increases.

Thus, from this result, it is evident that the thermal stability of chars were increase by increasing the combustion temperature during combustion process. Increase in combustion temperature decreases char yield; however, it improves char quality. Highest combustion temperature (260°C) was better and char also can be obtained from a simple method of combustion process only by using a universal oven.

4. Conclusions

Paddy leaves (MR297) are suitable to be used for the production of charcoal briquettes. This is due to low moisture content of paddy leaves which is 9.23% only. Moreover, paddy leaves waste in Northern Malaysia is seen to be useful for producing char. The investigation showed that 260°C was the best combustion temperature that can be used in the production of paddy leaves char. The char can be produced using a universal oven and at very minimized combustion temperature.
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References
[1] Chewa Thassana W. N. 2017 *AIP Conf. Proceed.* **1868**
[2] Falemara B. C., Joshua V. I., Aina O. O. and Nuhu R. D. 2019 *Recycling* **3** 1–13
[3] D. A. Aslam and Zulkifli M.M 2013 *J. Energy* **3** 1–5
[4] P. Binod 2010 *Bioresour. Technol.* **101** 4767–4774
[5] P. Jittabut 2015 *Energy Procedia* **79** 2-9
[6] S. M. Shafie 2015 *J. Eng. Appl. Sci. (Asian Res. Publ. Netw.)* **10** 6643-6648
[7] Sari F. P. and Budiyono B. 2014 *Waste Technol.* **2** 17-25
[8] Zanella K., Gonçalves J. L. and Taranto O. P. 2016 *Chem. Eng. Trans* **49** 313-318
[9] A R Irfan, M R Farizuan, Z Shayfull, M A H Mohammad, A Azlida, 2019 *AIP Conference Proceedings* **2129** 020179
[10] Brenda M. G., Innocent E. E., Daniel O. and Y. A. Abdu 2017 *Int. J. Scient. Eng. Sci.* **1** 55–60
[11] M G Normah, A R Irfan, K S Koh, A Manet, A M Zaki 2013 *Procedia Engineering* **56** 829-834
[12] Do C., Babaçu C. and Napoli A. 2019 *Cerne* **23** 1–10,
[13] Onukak I. E., Mohammed-Dabo I. A., Ameh A. O., Id S. I. R. O. and Fasanya O. O. 2017 *Recycling* **2** 4-10
[14] Ahmad K. Ku, Sazali K. and Kamarolzaman A. A. 2018 *Mater. Today Proc.* **5**, 21744–21752
[15] S. Gangil 2014 *Environ. Eng. Sci.* **31** 183–192
[16] Aliyu A. and N. Abdullah 2018 *AIP Conf. Proceed.* **1774**