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Investigation on the Mass Loss of Bamboo Biochar by Thermogravimetric Analysis

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Abstract: In present era, biomasses materials like bamboo biochar were becoming more popular for construction materials applications in certain country in the world. On the other side, the choice of bamboo biochar as an additive material may have a substantial influence on the global climate, such as the greenhouse effect. Bamboo is one of the biomasses that can store carbon for a long time to prevent excessive greenhouse gas emissions to the environment. The purpose of this study was to use Thermogravimetric Analysis (TGA) to analyze the mass loss of bamboo biochar. The ungrounded bamboo biochar material was selected in this research. Firstly, the bamboo biochar has been burned in a furnace at various temperature of 500°C, 600°C and 700°C for 5 hours continuously. Thermogravimetric analysis testing is one of the methods that can characterize the material characterization through analysis of their decomposition pattern. The result of the TGA analysis indicates that 700°C biochar type was the highest mass loss during the testing. The study indicates that the bamboo biochar consists of a variety of chemical composition. The findings of this study were highly significant and useful in developing initiatives to use a bamboo biochar as a benefit material to the environment.

Keywords: Thermogravimetric Analysis, Bamboo Biochar, Greenhouse Effect

1. Introduction

Malaysia is a heavily forested country, and the forest products such as bamboo provide massive income to our economy. Most Malaysia's bamboo grows in clumps alongside riverbanks, in disturbed lowland forests, and on hillsides and ridge tops. A bamboo has gained popularity in the built environment in recent years, owing mostly to its cheap cost, great mechanical strength, attractive aesthetics, flexibility, and very minimal, or even positive and environmental impact. Bamboo is an attractive alternative for the industry because of the low energy consumption necessary for its extraction and processing, as well as its potential to sequester large amounts of Carbon Dioxide (CO_2). Goh *et al*, reported that, when

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compared to other natural building materials, bamboo is among the highest renewable rates in the world [1]. However, a bamboo has been identified as a potential alternative of wood because of its short growth and renewal cycles and high mechanical strength.

Bamboo's mechanical characteristics, as well as its availability in underdeveloped countries, have led to its empirical application as reinforcement in concrete structures [2]. The possibility of its widespread use as a sustainable alternative to steel in reinforced concrete structures poses significant challenges for architects, engineers, and researchers regarding structural capacity and compatibility, as well as constructability and sustainability issues. According to Osorio *et al*. (2018) many researchers have studied the anatomical structure of the bamboo internode throughout the years [3]. Aside from that, they discovered that the transverse cross-section of the wall is composed up of numerous vascular bundles that are densely distributed in the outer region and surrounded by parenchyma tissue. One of the advantages of bamboo and wood in construction are both can store carbon for a long period of time. They had a potential for future construction industry as their characteristics of reusable, biodegradable, and made from naturally renewable resources [4].

The research aims are to investigate the mass loss of bamboo biochar using Thermogravimetric Analysis and the chemical content of the biochar. The method of experiment of thermogravimetric analysis (TGA) was used to measure the mass of sample while it was subjected to a controlled temperature in controlled environments. Generally, biochar was come from the process of pyrolysis from the biomass including bamboo. A biochar was a material that contain a carbon-rich material which includes in some plant nutrients [5]. Hence, the yield and chemical characteristics of the pyrolysis product may be affected by the operational conditions such as the temperature, heating rate, holding durations, particle size, environment and also the biochar materials [6]. This study will look further at the effect of different burned temperature of biochar affected their mass loss during the thermogravimetric analysis. The chemical content of the bamboo biochar was tested by X-Ray fluorescence analysis. XRF was a very sensitive method to conduct and the samples must be free of contamination before use [7]. Biochar provides an advantage such as reducing the greenhouse gas emissions, global warming and the most important is become the value-added product for sustaining bioeconomy [8].

2. Materials and Methods

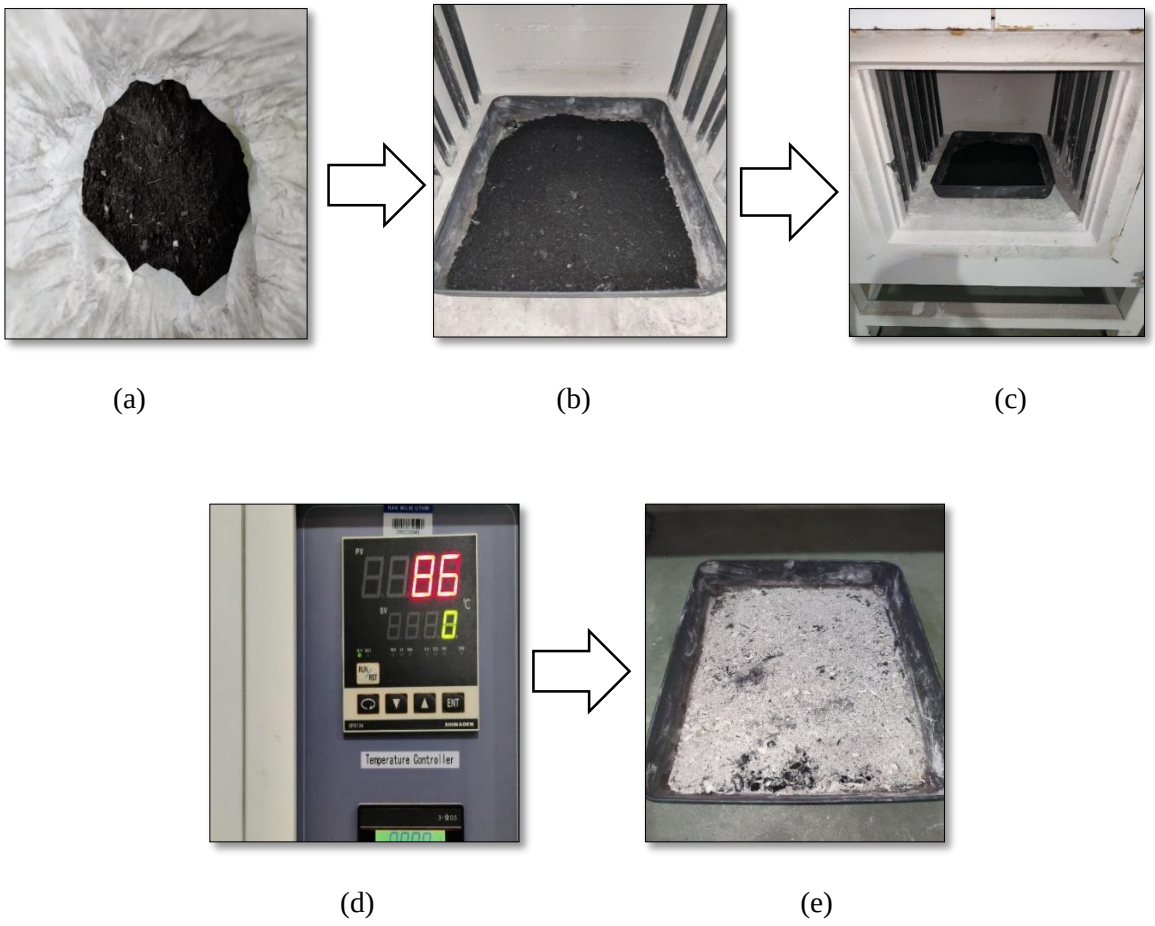
2.1 Materials

Buluh Madu *or Gigantocholoa Albociliata* was used in this research. Biochar samples were taken from bamboo plantation located in Tadom Hill Resort, Selangor. Figure 1 shows the ungrounded sample taken from Tadom Hill Resort. The sample was come in a form of ungrounded biochar sample. The laboratory experiment was performed in two phases in this section; namely the preparation of materials used and the experimental tests conducted in TGA analyzer.

Figure 1: Ungrounded bamboo biochar sample

2.2 Methods

The first phase before testing on the bamboo biochar in thermogravimetric analysis was made a preparation process first. During the preparation process, the bamboo biochar was burned in three different temperatures; 500°C, 600°C and 700°C in a digitally controlled SAFTherm furnace, made by Sante Furnace Tech. Figure 2 below shows the process of sample burning in a furnace for 5 hours. The second phase the bamboo biochar was tested in a digitally controlled STA PT 1600 Platinum Series TA instrument, made by Leinseis Product Inc. The combustion characteristics of the biochar was analyzed to collect the data about their mass loss through thermogravimetric instruments. The test started with weighing the alumina pan + lid. Then, the sample was put into alumina pan with an initial weight of about 5-8 mg [6]. The temperature selected in this research was controlled from a room temperature ($\pm 26°C$) to 700°C with a heating rate of 20°C/min. Nitrogen environment was set as the air flow used through this research with the constant flow of 20ml/min. The testing was performed on four types of bamboo biochar and the result can be obtaining through the TGA analyzer software. Figure 3 shows the thermogravimetric analysis testing procedure from start until finish. The sample weight and alumina pan were weighed, and the result is tabulated in Table 1.



(a) (b) (c)

(d) (e)

Figure 2: Sample burning; (a) Sample preparation, (b) Sample was poured into aluminum tray, (c) Sample was placed into a furnace, (d) The temperature was set, (e) Sample was took out after 24 hours

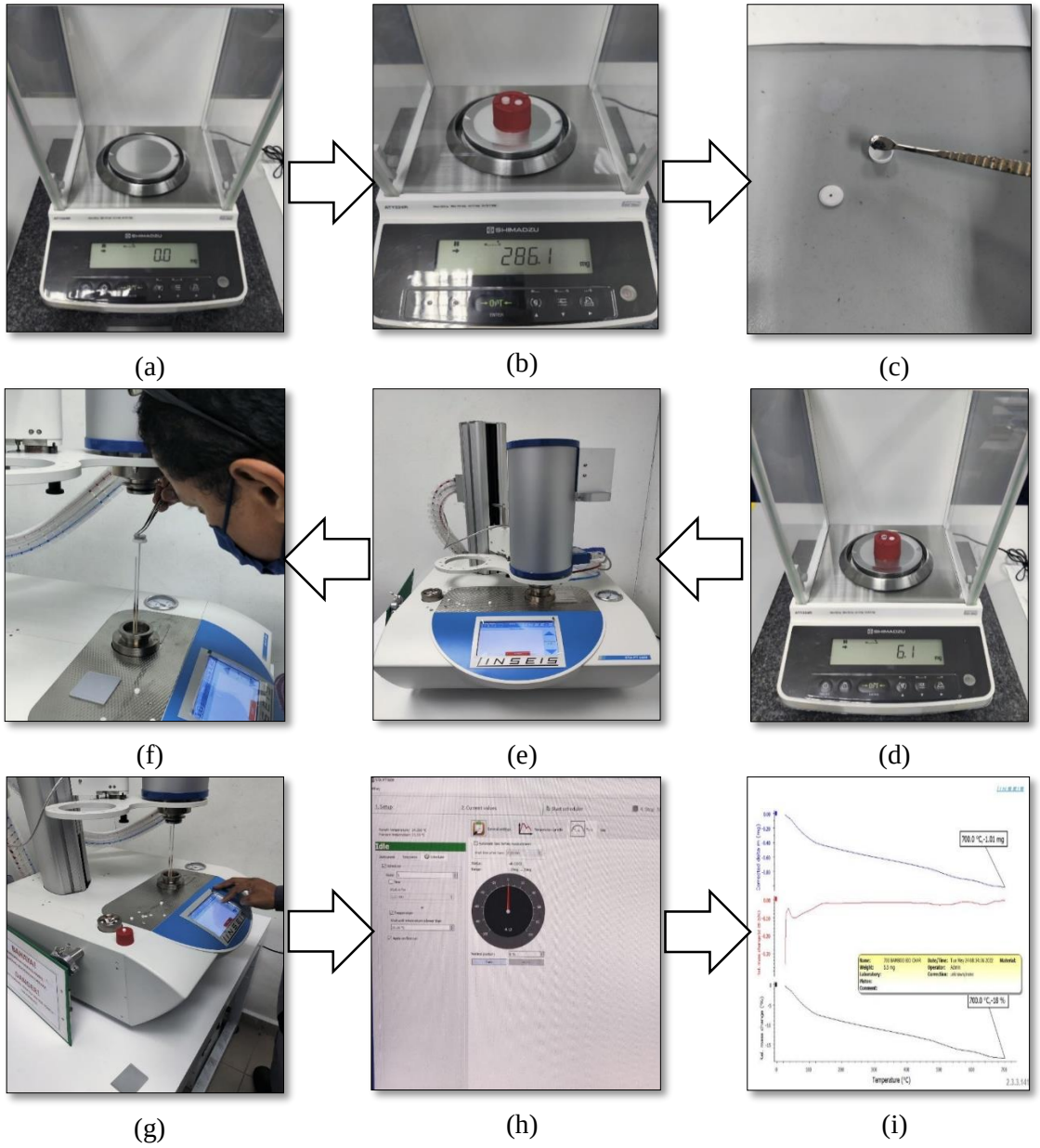


Figure 3: TGA testing procedure; (a)Turn on analytical balance, (b) Weighing the alumina pan + lid, (c) Sample was placed into pan using micro spoon, (d) Weighing the biochar sample, (e) TGA analyzer was prepared before experiment start, (f) Sample was placed into a specimen holder, (g) Lowered the furnace lift, (h) The heating program was set, (i) Result from plot displayed

Table 1: Mass of bamboo biochar sample and alumina pan + lid before TGA testing

Samples	Pan + lid weight (mg)	Sample weight (mg)
Raw	22.97	5.8
500°C	21.96	5.6
600°C	22.37	5.5
700°C	22.57	6.1

3. Results and Discussion

The results of the laboratory test were conducted on the bamboo biochar and analyzed using Microsoft Excel. This data analysis was done to determine the mass loss of the sample after combustion in percentage and derivative mass loss unit either achieving the objective stated on the beginning of the research

3.1 Thermal decomposition of bamboo biochar

Thermogravimetric analysis for all the sample was carried out at the same temperature which is 700°C. The combustion process only take 35 minutes depends on the rate of temperature per minutes started from room temperature. The process of the four condition of bamboo biochar was conducted at the heating rate of 20ºC/min in nitrogen atmosphere (20ml/min). Table 2 below shows mass change for the overall biochar sample after undergoing TGA testing.

Table 2: The weight of bamboo biochar sample after TGA testing

Sample	Sample weight after testing (mg)	Mass loss (%)
Raw	4.60	21
500°C	4.61	17.6
600°C	4.49	18
700°C	4.58	25

3.1.1 Combustion behaviour of raw bamboo biochar

Based on Figure 4, the starting mass of the raw bamboo biochar was 5.8 mg. After going through a heating process for about 35 minutes, the mass was drop to 4.6 mg for about 21%. The distinctive peaks of the relative mass change (E-2/K) in Figure 5 shows at temperature of 28.3ºC indicated that the moisture loss and the thermal decomposition of volatile matters. The distinctive peaks at temperature 686ºC were mostly related to thermal breakdown of bamboo cellulose, whereas the shoulder at 586ºC was related to thermal decomposition of bamboo hemicelluloses.

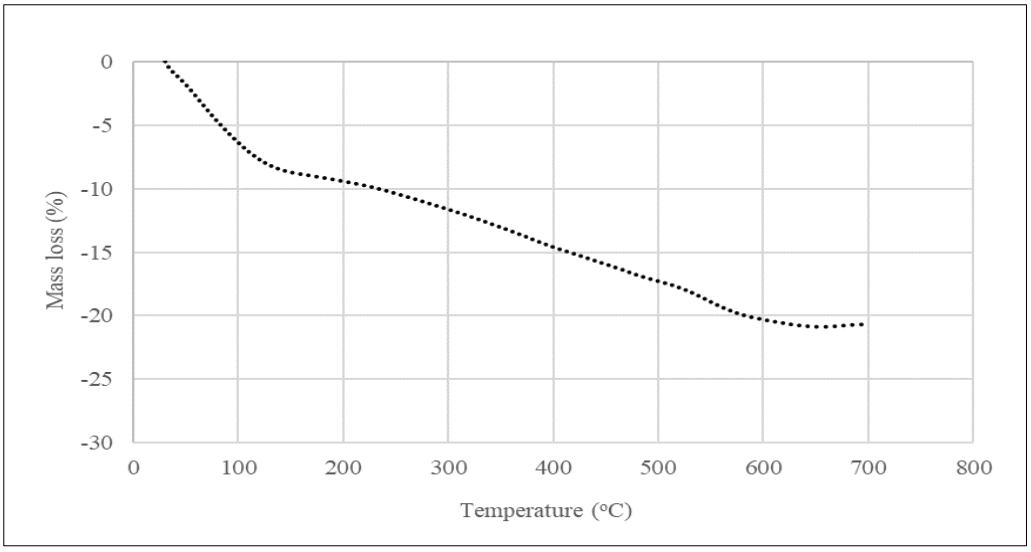


Figure 4: Percentage mass loss of the raw bamboo biochar sample

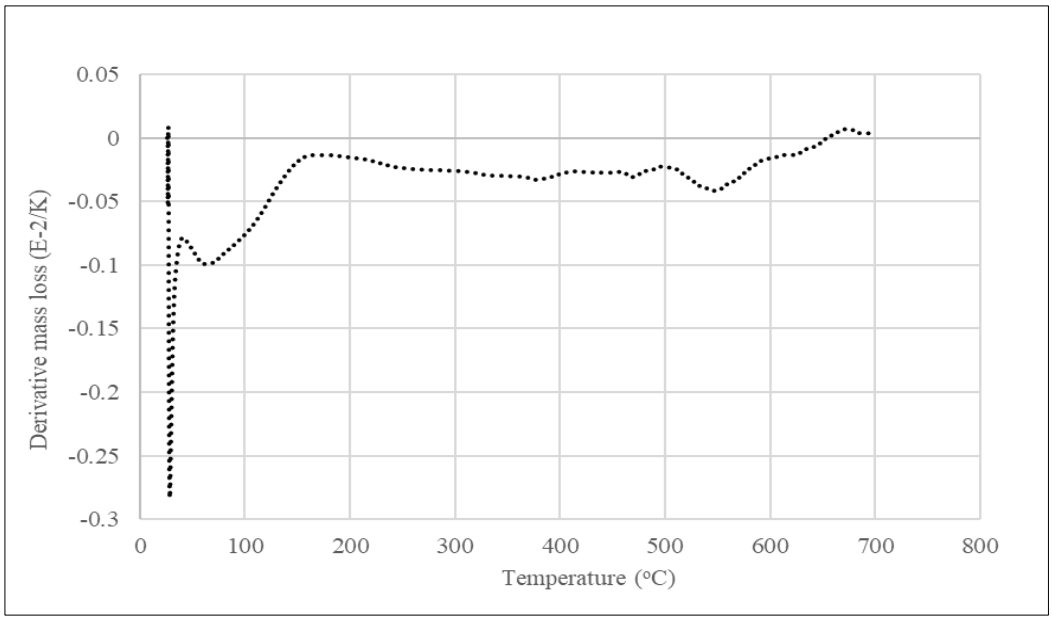


Figure 5: Derivative mass loss of raw bamboo biochar sample

3.1.2 Combustion behaviour of 500°C bamboo biochar

Based on Figure 6, the starting mass of the raw bamboo biochar was 5.6 mg. After going through a combustion process for about 35 minutes, the mass was drop to 4.61 mg for about 17.6%. The distinctive change of the relative mass change (E-3g/K) in Figure 7 shows at temperature of 26.5°C indicated that the moisture loss and the thermal decomposition of volatile matters. The distinctive change at temperature 506°C was mostly related to thermal breakdown of bamboo cellulose, whereas the shoulder at 426°C was related to thermal decomposition of bamboo hemicelluloses.

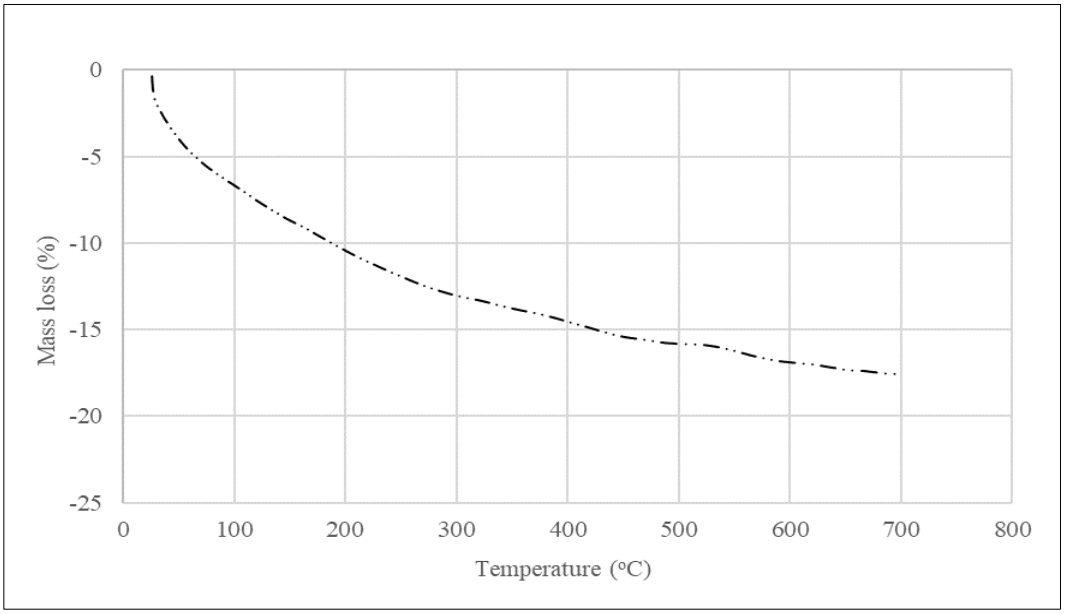


Figure 6: Percentage mass loss of the 500°C bamboo biochar sample

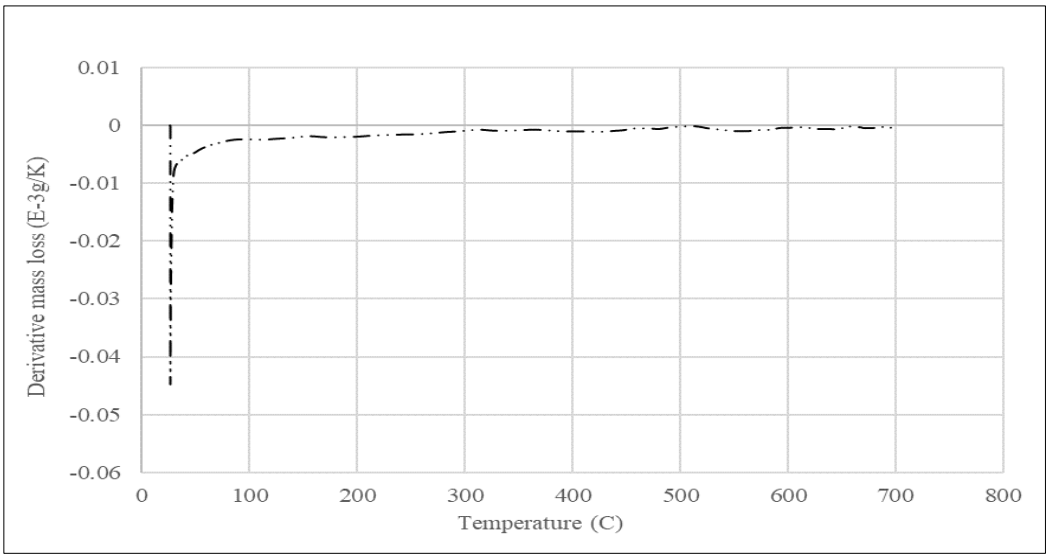


Figure 7: Derivative mass loss of the 500ºC bamboo biochar sample

3.1.3 Combustion behaviour of 600ºC bamboo biochar

Based on Figure 8, the starting mass of the raw bamboo biochar was 5.5 mg. After going through a combustion process for about 35 minutes, the mass was drop to 4.49 mg for about 18%. The distinctive change of the relative mass change (E-2/K) in Figure 9 shows at temperature of 27ºC indicated that the moisture loss and the thermal decomposition of volatile matters. The distinctive change at temperature 147ºC was mostly related to thermal breakdown of bamboo cellulose, whereas the shoulder at 100ºC was related to thermal decomposition of bamboo hemicelluloses.

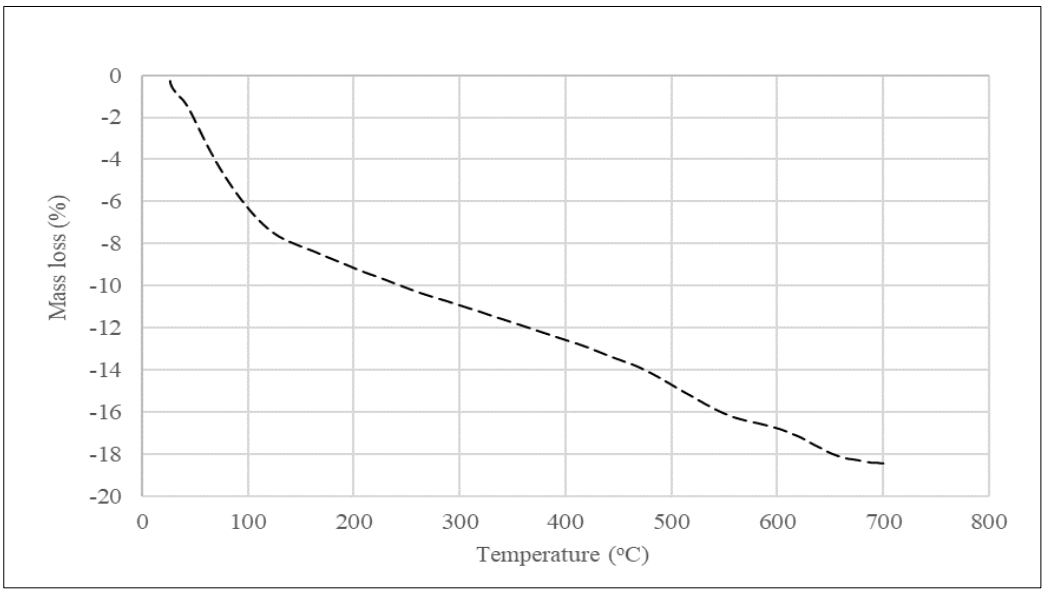


Figure 8: Percentage mass loss of the 600ºC bamboo biochar sample

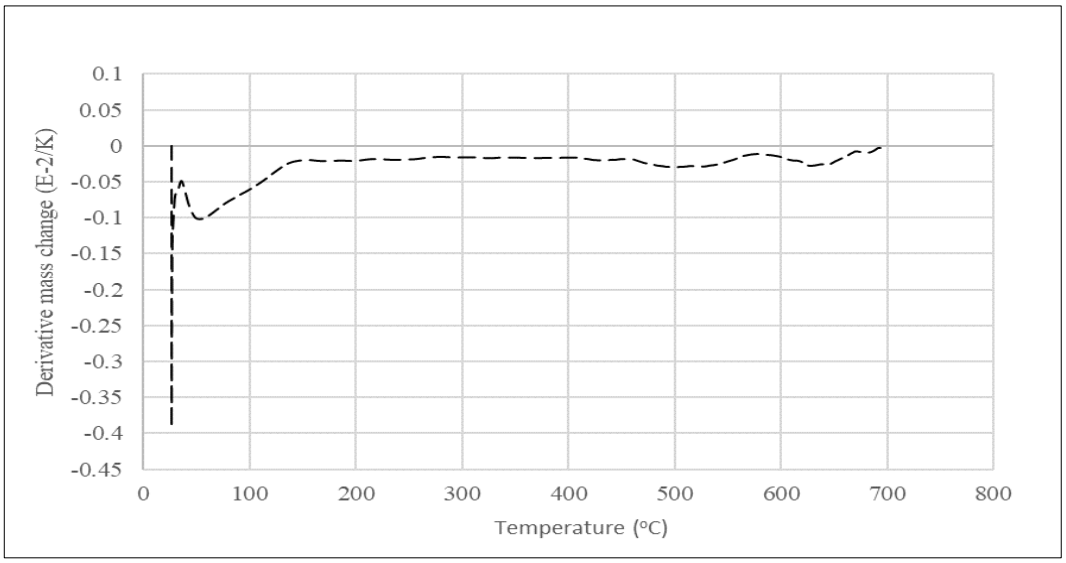


Figure 9: Derivative mass loss of the 600°C bamboo biochar sample

3.1.4 Combustion behaviour of 700°C bamboo biochar

Based on Figure 10, the starting mass of the raw bamboo biochar was 6.1 mg. After going through a combustion process for about 35 minutes, the mass was drop to 4.49 mg for about 25%. The distinctive change of the relative mass change (E-2/K) in Figure 11 shows at temperature of 27°C indicated that the moisture loss and the thermal decomposition of volatile matters. The distinctive change at temperature 286°C was mostly related to thermal breakdown of bamboo cellulose, whereas the shoulder at 148°C was related to thermal decomposition of bamboo hemicelluloses

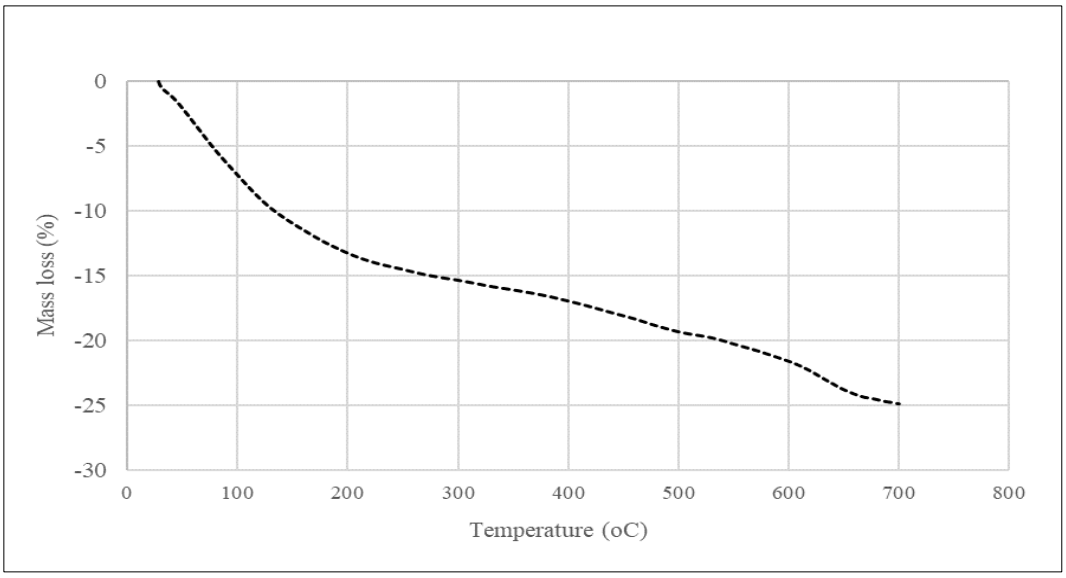


Figure 10: Percentage mass loss of the 700°C bamboo biochar sample

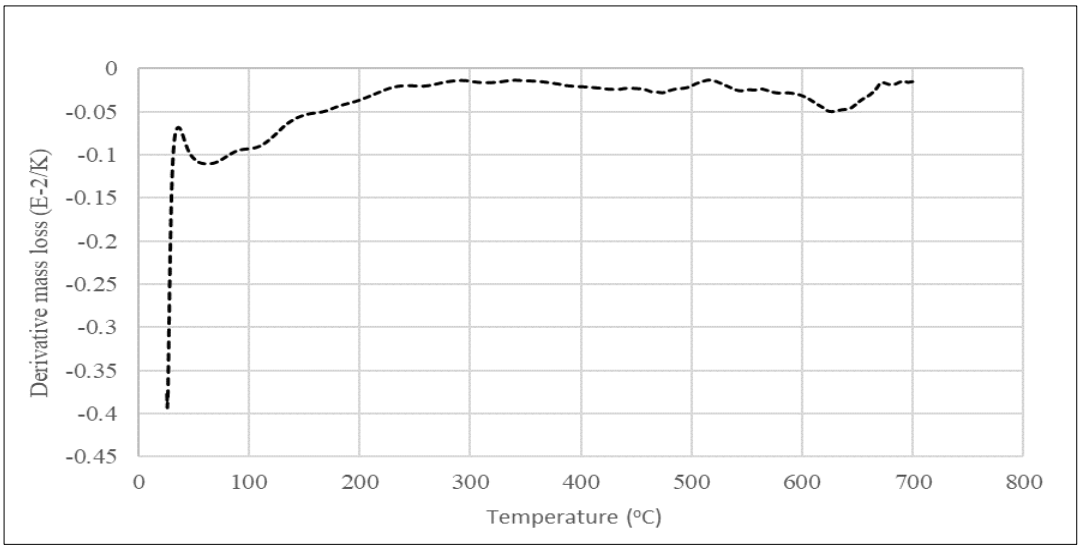


Figure 11: Derivative mass loss of the 700°C bamboo biochar sample

3.1.5 Combustion behaviour of various bamboo biochar

The data in Figure 12 shows the combustion process from various bamboo biochar, which was raw bamboo, 700°C, 600°C and 500°C burn bamboo biochar sample after heating process within 35 minutes. The result shows that the 700°C burn bamboo biochar sample had the highest mass loss than other samples which is 25%.

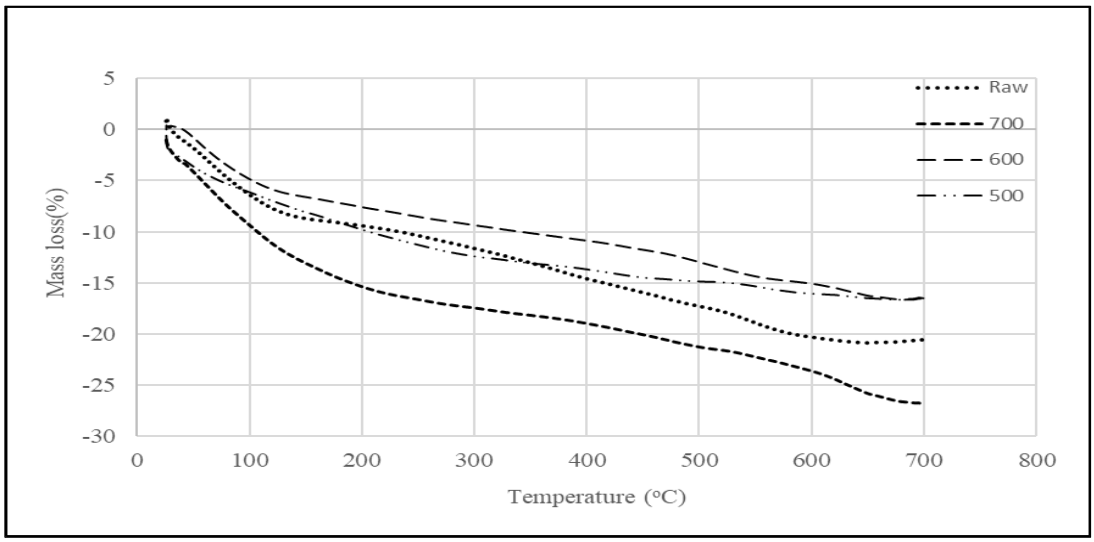


Figure 12: Comparison of percentage mass loss of bamboo biochar sample

Figure 13 shows the derivative mass loss from the four types of bamboo biochar shows that in early temperature between 26°C to 100°C have sudden mass change. This prove that the moisture content starts to loss and the volatile matters start to decompose. According to J. Sun *et al.*, (2017) mainly the volatiles matter comprises of water (H_2O), carbon dioxide (CO_2), hydrogen (H_2), methane (CH_4) and carbon monoxide (CO). Therefore, the volatile matter in the bamboo biochar was affected with the hemicellulose, cellulose and the pyrolysis temperature.

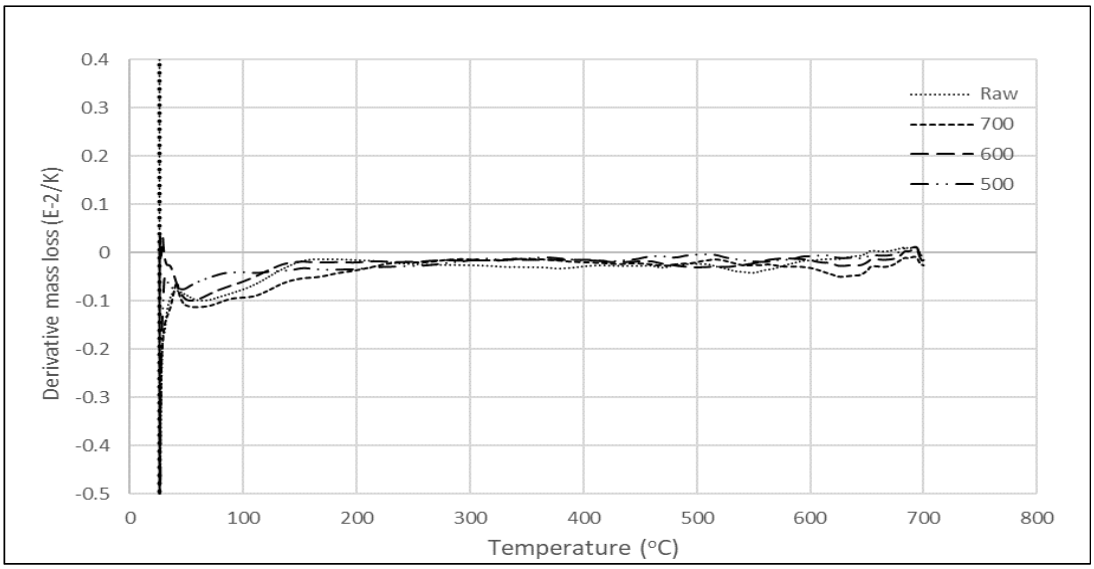


Figure 13: Comparison derivative mass loss of bamboo biochar sample

4. Conclusion

To summarize this research, the objective was to investigate the mass loss of the bamboo biochar when conducted under a Thermogravimetric analysis. After the study had been conducted, the result shows that the bamboo biochar from a 700ºC burned had highest mass loss compared to the others. This is because, before this sample undergoing the thermogravimetric analysis testing, they had been burned until temperature of 700ºC for 5 hours continuously. The highest temperature during the burned process in a furnace had significant effect on the thermogravimetric analysis testing after the result obtain. The process of burned in furnace causes thermal decomposition of volatile matters and moisture content more rapid loss to the air. From this study, the comparison of the results between the four different bamboo biochar type shows the highest temperature of burned bamboo biochar can rapidly affect the mass loss of the biochar condition based on result obtain from the derivative mass loss condition. To sum up overall of this study, the objective has been achieved.

Acknowledgement

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