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# Why 200°C is Effective for Creating Carbon from Organic Waste (from Thermal Gravity (TG-DTA) Perspective)?

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## ABSTRACTS

The purpose of this study was to evaluate the decomposition of organic waste into carbon microparticles under atmospheric conditions. Carbon microparticles are made by drying and carbonizing raw water hyacinth. Then, the carbon microparticles that have been produced are ground using a saw-milling apparatus. Carbon microparticles prepared from raw water hyacinth were heated in an electric heating furnace at a specific temperature for the analysis. The experimental results show that the thermal decomposition process has three steps. Water hyacinth is stable at temperatures below 100°C. As carbon decomposes at higher temperatures, the process of decomposition into smaller molecules occurs. Then, at temperatures ranging from 150 to 280°C, an effective carbonization process occurs to form carbon. The advantages gained, in this case, will provide a better understanding of how to use heat treatment on water hyacinth.



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## 1. INTRODUCTION

Carbon-related materials are among the most researched materials due to their excellent properties such as excellent thermal conductivity, biocompatibility, and corrosion resistance. These materials have been used in a variety of applications, including supercapacitors, greater electrochemical properties in batteries, and photoluminescence materials (Nandiyanto *et al*., 2016; Nandiyanto *et al*., 2017).

Organic waste is one of the carbon sources because of its high carbon element content. Organic waste is made up of organic matter that can be produced by the plant, animal, or microbial cell communities. Carbohydrates, proteins, and fats, as well as animal-derived nutrition food (milk or flesh), non-consumable starches, and residual plant materials (lignocellulosic components), are more useful types of organic matter (Rehman and Anal, 2019). Many papers have described various strategies for producing carbon from organic wastes (Nandiyanto *et al*., 2020a, Nandiyanto *et al*., 2020b, Nandiyanto *et al*., 2020c, Nandiyanto *et al*., 2017, Nandiyanto *et al*., 2021). **Table 1** provides detailed information on carbon production from organic waste.

Based on previous studies, we have reported the process of producing carbon particles from organic waste and evaluated its adsorption studies. Here, this study aims to evaluate the effective temperature for carbonization of organic waste from one of the results of TG-DTA analysis of carbon particles from water hyacinth waste. In this study, we used a low-cost biomass water hyacinth as a precursor to prepare carbon particles. The plant used in this study was chosen because these plants can become weeds in aquatic systems if they grow and multiply rapidly enough to cover the surface water and cause environmental problems. Furthermore, water hyacinth contains 60% cellulose, 8% hemicellulose, and 17% lignin (Nuria *et al*., 2020).

**Table 1.** Detailed information on carbon production from organic waste.

| Organic Waste Type | Method | Results | Ref. |
|---|---|---|---|
| **Pineapple Peel Waste** | In ambient conditions, pineapple peel was carbonized for 1 hour at a temperature of 250°C. | Carbon particles with sizes ranging from 45 to 2000 µm were discovered. Carbon particles ranged in size from 100 to 500 µm, with a mean size of 248.09 µm. | (Nandiyanto *et al*., 2020a) |
| **Soursop (*AnnonaMuricata L.*) Peel Waste** | 500 g of soursop peel was cleaned, cut into small pieces, and carbonized at 275°C for 3 hours. | Carbon from soursop peel had a heterogeneous surface with agglomerate particles. The sieve test results showed that the carbon particle size ranged from 48 to 2000 µm. | (Nandiyanto *et al*., 2020b) |

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**Table 1 (continue).** Detailed information on carbon production from organic waste.

| Organic Waste Type | Method | Results | Ref. |
|---|---|---|---|
| **Red Dragon Fruit (*Hylocereus undatus*) Peel Waste** | To produce carbon particles, red dragon fruit peel waste was sliced, washed with water to remove impurities, physically dried at 100°C to remove the presence of water on the surface, and carbonized at 250°C for 8 hours in an electric furnace under atmospheric conditions. | The surface of the carbon microparticles is heterogeneous, and the particles are agglomerated. Carbon particles have sizes ranging from 20 to 270 µm. The average particle size is 210 µm, and the size of carbon is mostly in the 95-210 µm range. | (Nandiyanto *et al.*, 2020c) |
| **Rice Straw** | For about 4 hours, the dried rice straw was burned at 250°C. After that, carbon particles were activated using KOH. | The carbon produced is pore carbon with pores of 10 nm in size. The specific surface areas of samples before and after activation treatment were 7.45 and 100.77 $m^2/g$, respectively, according to the Brunauer–Emmett–Teller (BET) theory. | (Nandiyanto *et al.*, 2017) |
| **Pumpkin (Cucurbita maxima) Seed** | Pumpkin seeds were carbonized at 250°C for 2 hours under atmospheric conditions. | The sizes of the carbon microparticles ranged from 55 to 2000 µm. | (Nandiyanto *et al.*, 2021) |

## 2. METHODS

The water hyacinth used in this study was obtained from Purwakarta, Indonesia. To produce carbon particles, raw water hyacinth (stems and leaves) was washed, cut into pieces, dried in the sun for 3 hours, carbonized at 150°C for 2-3 hours, and grounded using a saw-milling apparatus.

In a typical procedure, 50 mg of particulate carbon from water hyacinth is introduced into the electric furnace (TG-DTA apparatus) under atmospheric conditions at a certain temperature. The heating rate is 10°C/min. Then, when the temperature reaches a certain temperature, the heating process was held for 10 minutes. To get the effect temperature at the particle carbon properties exactly, the temperature remains between 25 and 600°C. Then, the heated material is cooled to room temperature.

## 3. RESULTS AND DISCUSSION

**Figure 1** shows the analysis of the thermal decomposition of carbon particles produced from the stems and leaves of the water hyacinth plant using the TG-DTA apparatus. Based on **Figure 1**, the mass loss begins at approximately 25°C and ends at approximately 500°C. The mass after being heated at a temperature of 25-100°C is more than 65% (see **Figure 1(a)**), and it is more than 75% (see **Figure 1(b)**), which is associated with loss of water content. A further increase in temperature causes several steps of mass degradation, each of which occurs at specific temperatures depicted in **Figure 1** by the vertical dotted line. This is due to differences in thermal properties and reactions. The final mass after heating to 600°C was approximately 52% in the stem water hyacinth sample and 75% in the leaf water hyacinth sample. After being heated to this temperature, the sample becomes a black powder, indicating that the water hyacinth has completely decomposed into carbon.

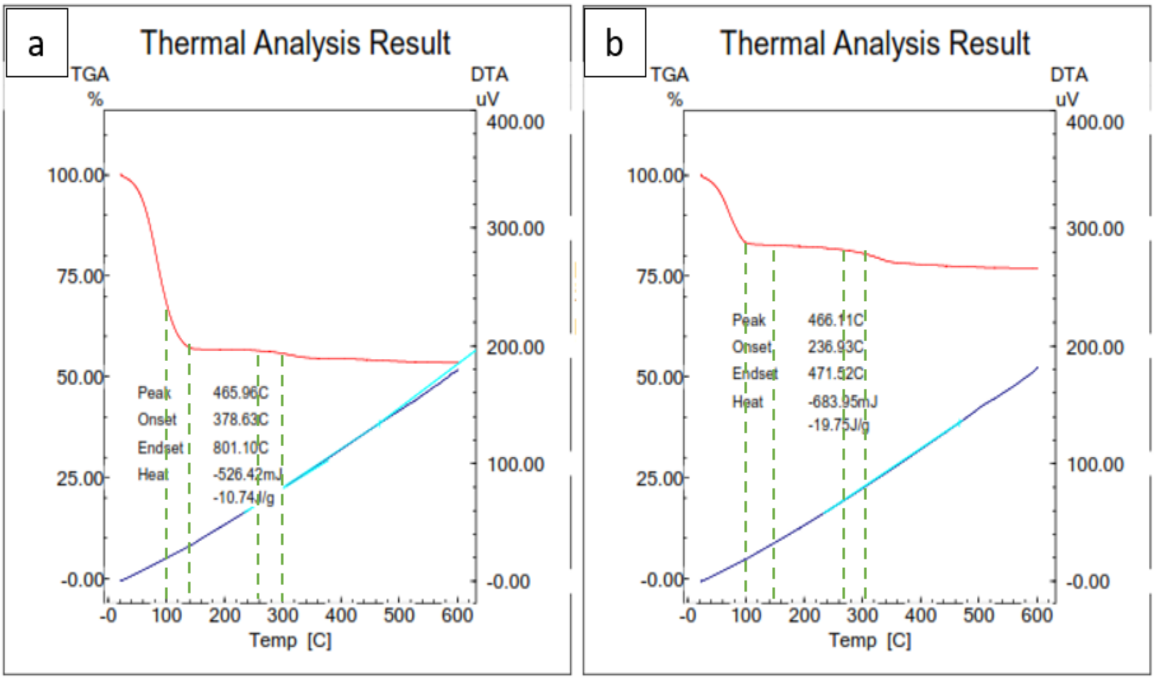


**Figure 1.** Analysis of thermal decomposition of carbon particles produced from the stems (a) and leaves (b) using the TG-DTA apparatus.

The detailed steps are as follows:

(i) Stage I (starts at about 25°C and ends at about 100°C). There was a decrease in mass that came from the removal of water content that was physically adsorbed in the water hyacinth sample and release light volatile compounds. Moisture content in biomass affects the physical properties and quality of the liquid, resulting in pyrolysis, in which dry feedstocks produce highly viscous oils, especially at higher reaction temperatures (Demirbas, 2004).

(ii) Stage II (begins at about 150°C and ends at about 280°C). This stage was also known as the active carbonization stage, and it was a significant and effective organic component degradation stage (Bach & Chen, 2017).

(iii) Stage III (starts at about 280°C and ends at about 300°C). This stage is indicated by the TG curve, which tends to be flat with only a slight slope as temperature increases. This suggests that the carbon in biochar continues to decompose at a very slow rate with little mass loss (Sukarni *et al*., 2018).

Based on the results of thermal analysis, as presented in **Figure 1**, the process of carbonization of organic matter in organic waste (in this case water hyacinth as a model) occurs in the temperature range of 150-280°C. When the temperature rises above 280°C, the carbonization process becomes ineffective because the carbon in biochar continues to decompose at a very slow rate with little mass loss. Furthermore, when the carbonization of organic waste occurs above a temperature of 300°C it will produce silica instead of carbon (Permatasari *et al*., 2016).

## 4. CONCLUSION

We successfully evaluated the thermal decomposition of water hyacinth under atmospheric conditions in this study. The results showed that water hyacinth was stable at temperatures below 100 degrees Celsius. The decomposition of water hyacinth into smaller molecular compounds, such as carbon, was influenced by temperature changes. The water hyacinth carbonization process, which produces carbon particles, is then effective at temperatures ranging from 150 to 280 degrees Celsius. This study's findings are limited to the effect of temperature on the physicochemical properties of water hyacinth.

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## 6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

## 7. REFERENCES

Bach, Q. V., and Chen, W. H. (2017). Pyrolysis characteristics and kinetics of microalgae via thermogravimetric analysis (TGA): a state-of-the-art review. *Bioresource Technology*, 246, 88-100.

Demirbas, A. (2004). Effect of initial moisture content on the yields of oily products from pyrolysis of biomass. *Journal of Analytical and Applied Pyrolysis*, 71(2), 803-815.

Nandiyanto, A. B. D., Arinalhaq, Z. F., Rahmadianti, S., Dewi, M. W., Rizky, Y. P. C., Maulidina, A., and Yunas, J. (2020b). Curcumin adsorption on carbon microparticles: synthesis from soursop (annonamuricata l.) peel waste, adsorption isotherms and thermodynamic and adsorption mechanism. *International Journal of Nanoelectronics and Materials*, 13, 173-192.

Nandiyanto, A. B. D., Girsang, G. C. S., Maryanti, R., Ragadhita, R., Anggraeni, S., Fauzi, F. M., and Al-Obaidi, A. S. M. (2020a). Isotherm adsorption characteristics of carbon microparticles prepared from pineapple peel waste. *Communications in Science and Technology*, 5(1), 31-39.

Nandiyanto, A. B. D., Hofifah, S. N., Inayah, H. T., Putri, S. R., Apriliani, S. S., Anggraeni, S., and Rahmat, A. (2021). Adsorption isotherm of carbon microparticles prepared from pumpkin (Cucurbita maxima) seeds for dye removal. *Iraqi Journal of Science*, 1404-1414.

Nandiyanto, A. B. D., Maryanti, R., Fiandini, M., Ragadhita, R., Usdiyana, D., Anggraeni, S., and Al-Obaidi, A. S. M. (2020c). Synthesis of carbon microparticles from red dragon fruit (Hylocereus undatus) peel waste and their adsorption isotherm characteristics. *Molekul*, 15(3), 199-209.

Nandiyanto, A. B. D., Putra, Z. A., Andika, R., Bilad, M. R., Kurniawan, T., Zulhijah, R., and Hamidah, I. (2017). Porous activated carbon particles from rice straw waste and their adsorption properties. *Journal of Engineering Science and Technology*, 12(8), 1-11.

Nandiyanto, A.B.D., Fadhlulloh, M.A., Rahman, T., and Mudzakir, A. (2016). Synthesis of carbon nanoparticles from commercially available liquified petroleum gas. *IOP Conference Series: Materials Science and Engineering*, 128(1), 012042.

Nandiyanto, A.B.D., Putra, Z.A., Andika, R., Bilad, M.R., Kurniawan, T., Zulhijah, R., and Hamidah, I. (2017). Porous activated carbon particles from rice straw waste and their adsorption properties. *Journal of Engineering Science and Technology*, 12, 1-11.

Nuria, F. I., Anwar, M., and Purwaningsih, D. Y. (2020). Pembuatan karbon aktif dari enceng gondok. *Jurnal Tecnoscienza*, 5(1), 37-48.

Permatasari, N., Sucahya, T. N., and Nandiyanto, A. B. D. (2016). Agricultural wastes as a source of silica material. *Indonesian Journal of Science and Technology*, 1(1), 82-106.

Rehman, Z. U., and Anal, A. K. (2019). Enhanced lipid and starch productivity of microalga (Chlorococcum sp. TISTR 8583) with nitrogen limitation following effective pretreatments for biofuel production. *Biotechnology Reports*, 21, e00298.

Sukarni, S., Widiono, A. E., Sumarli, S., Wulandari, R., Nauri, I. M., and Permanasari, A. A. (2018). Thermal decomposition behavior of water hyacinth (Eichhornia crassipes) under an inert atmosphere. *In MATEC Web of Conferences*, 204, 00010.