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Research Article

Synthesis of Activated Carbon from Different Biomasses

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ABSTRACT

In this study, activated carbon was synthesized from three different types of biomass: eggplant (Solanum melongena) stalks, banana (Musa sapientum) peels, and orange (Citrus sinensis) peels. The carbonization process was conducted at a temperature of 1200°C for two hours. Subsequently, the activated carbons were prepared by impregnating the resulting materials with 4N sulfuric acid (H2SO4) for a period of 24 hours. The resulting activated carbons were characterized and optimized according to the Indonesian National Standard (SNI 06-3730-1995), which specifies maximum values for water content (15%), ash content (10%), vapor content (25%), and minimum bound carbon content (60%). The resulting data showed that the activated carbon produced from eggplant stalks had the highest bound carbon content (78.0%), while the activated carbons produced from banana peels and orange peels had bound carbon contents of 65.3% and 54.8%, respectively. In terms of other parameters, the activated carbon produced from eggplant stalks had a water content of 13.8%, ash content of 6.50%, and vapor content of 15.5%. The activated carbons produced from banana peels and orange peels had water contents of 21.9% and 19.3%, ash contents of 8.50% and 22.4%, and vapor contents of 26.2% and 22.8%, respectively. Overall, the results of this study indicate that eggplant stalks may be the most promising biomass for the production of activated carbon.

Keywords: Activated carbon; Biomass; Carbonization

Farklı Biyokütlelerden Aktif Karbon Sentezi

ÖZET

Aktif karbonlar, enerji depolama sektöründen su ve hava temizleme sistemlerine kadar pek çok önemli alanda, geniş kullanım alanına sahiptirler. Bu çalışmada, patlıcan (Solanum melongena) sapı, Muz (Musa sapientum) ve

Portakal (Citrus sinensis) kabukları olmak üzere 3 farklı biyokütleden aktif karbon sentezlenme olasılığı araştırılmıştır. Biyokütleler, 2 saat süreyle 1200°C'de karbonizasyon işlemine tabi tutulmuş ve daha sonra 24 saat boyunca 4N sülfürik asit (H2SO4) ile aktive edilmiştir. Elde edilen aktif karbonlar, Endonezya Ulusal Standartı olan SNI 06-3730-1995.5'e göre değerlendirilmiştir. Bu standart, su içeriği (%15), kül içeriği (%10), buhar içeriği (%25) ve minimum bağlı karbon içeriği (%60) gibi parametreler için maksimum değerler belirler. Çalışmanın sonuçlarına göre, patlıcan sapı, muz ve portakal kabuklarından üretilen aktif karbonların su içeriği %13.8, %21.9 ve %19.3; kül içeriği %6.50, %8.50 ve %22.4; buhar içeriği %15.5, %26.2 ve %22.8; bağlı karbon içeriği %78.0, %65.3 ve %54.8 olarak ölçülmüştür. Bu sonuçlara dayanarak, üç farklı biyokütleden üretilen aktif karbonlar arasında patlıcan sapının en uygun kaynak olduğu tespit edilmiştir.

Anahtar Kelimeler: Aktif karbon; biyokütle; karbonizasyon

1. INTRODUCTION

As natural energy sources such as wind, hydro, and solar power become increasingly depleted due to the growing global population, scientists are seeking alternative energy storage technologies to reduce reliance on these resources (Wang et al., 2019; Bi et al., 2019). One promising option is the use of ultracapacitors or supercapacitors (SCs), which have demonstrated high charging and discharging performance and cyclability (Chmiola et al., 2006; Yadav and Hashmi, 2020). In order to manufacture energy storage devices using SCs, it is necessary to identify suitable electrodes and electrolytes, and researchers have therefore explored the use of various carbon-based materials with different morphologies, such as carbon nanotubes (Zhang et al., 2018; Khan et al., 2020) and graphene (Zhou et al., 2018; Ali et al., 2020), as electrodes in SC production.

Activated carbons (ACs) are highly effective at adsorbing gaseous or aquatic pollutants, making them a useful tool in water purification to remove organic and inorganic contaminants that can cause odors and tastes (Chingombe et al., 2005; Kazmierczak et al., 2013). ACs are typically made from environmental waste materials such as coal and lignocellulosic biomass and have been widely studied for their potential use in energy storage (Bader and Ouederni, 2017; Lu, and Zhao, 2017). Their complex chemical surface, microporous structure, and large surface area allow them to bind easily to molecules in both the gas and liquid phases. In addition, ACs have a broad range of applications in fields such as air treatment (Pietrzak and Bandosz, 2007; Bansode et al., 2003), solvent recovery (Karatepe et al., 2008), food processing (Singh et al., 2008), wastewater treatment for the removal of pesticides and heavy metals (Crini, 2006; Mudoga and Kincal, 2008), catalysis (Cui and Zhang, 2008; Holtz et al., 2008), and supercapacitors (Tsyntsarski et al., 2015; Zhang et al., 2018). They can also be used to enhance flavors and aromas (Santoro et al., 2003; Tan et al., 2017). ACs can be produced from woody biomass, agricultural wastes, and coal through pyrolysis and activation at high temperatures (Kim and Bae, 2007).

The increasing global population has led to an increase in the amount of organic waste in the environment. Organic waste can be classified based on the length of its chemical chain. Compounds with long chains are not easily decomposed and may require more time and effort to recycle. On the other hand, compounds with short chains can be more easily recycled with minimal effort. Carbonization, or the process of heating organic material in the absence of oxygen, is a suitable method for breaking down long chain organic compounds (Wang et al., 2009; Haji, et al., 2013). In this study, three different types of biomasses were carbonized to produce activated carbon, and their conversion efficiencies were compared.

2. MATERIALS AND METHODS

2.1 Materials

Eggplant stalks, banana peels, and orange peels were obtained from the local market in Zakho, Iraq. Sulfuric acid (H_2SO_4) was used as an activating agent and was purchased from Merck. The carbonization of all biomasses was carried out in a Furnace (UKAS) brand furnace in the chemistry laboratory at Zakho University.

2.2 Methods

2.2.1 Preparation of biomass powder

A sufficient amount of eggplant stalks, banana peels, and orange peels were dried at 103±2°C for 48 hours. Once dried, they were ground using a grinding machine (Arshia) brand (Figure 1).

2.2.2 Carbonization of biomass

Each biomass powder was subjected to a carbonization process at 1200 °C for two hours (Figure 1).

2.2.3 Activation of biomass

Activation was carried out by immersing each carbon sample of eggplant stalks, banana peels, and orange peels in 25 mL of sulfuric acid (H_2SO_4) at a concentration of 4 N for 24 hours. The activated carbons were then washed with a sufficient amount of distilled water and filtered until they reached neutral conditions. They were then dried at 110 °C for two hours (Figure 1).

The preparation, carbonization and activation of biomass were shown schematically in Figure 1.

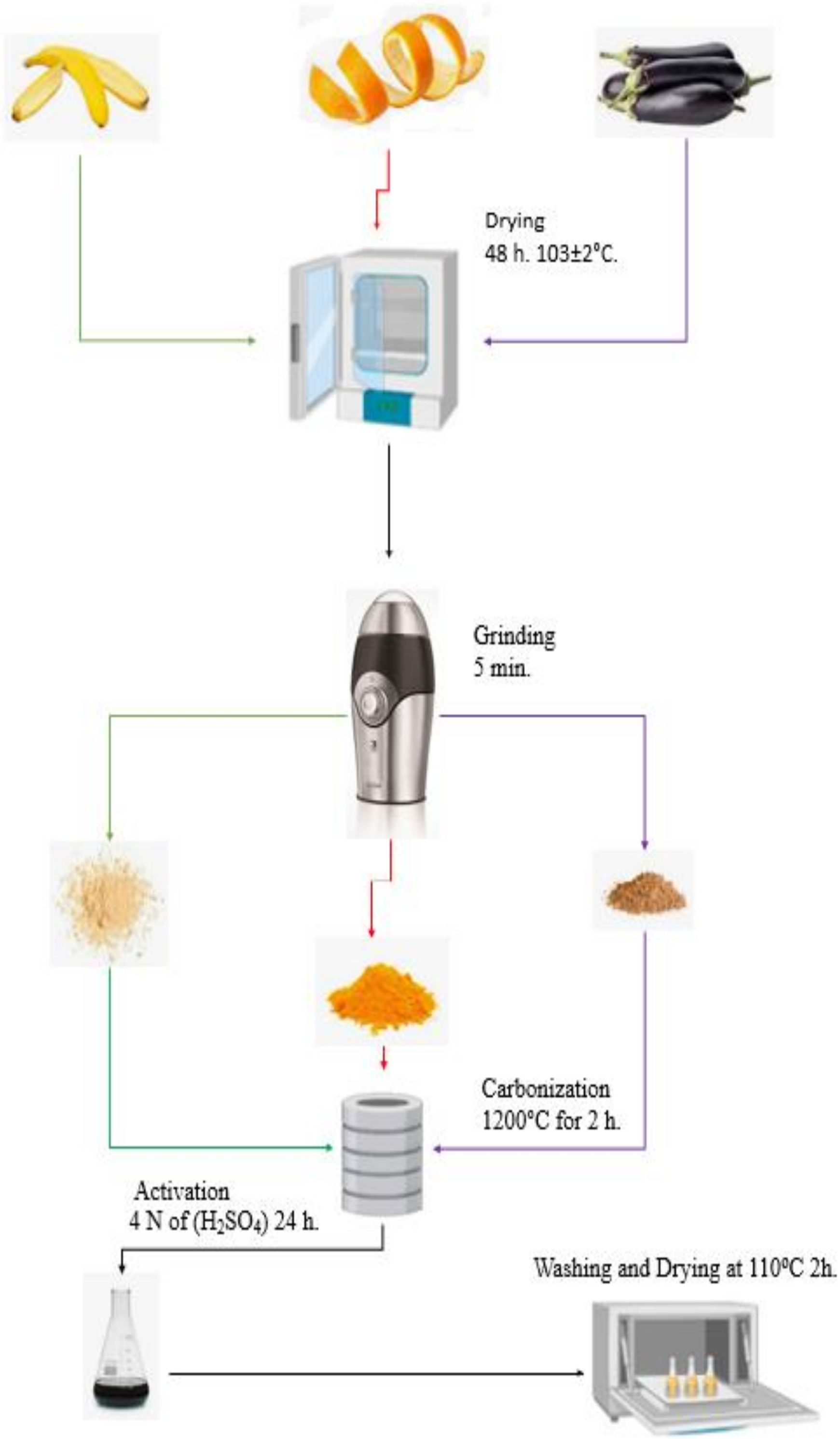

Figure 1. Schematic configuration of methods

2.2.4 Water content of activated carbons

One gram of each activated carbon was placed in a crucible porcelain and heated at 105°C for 1 hour. After one hour, the samples had cooled in the desiccator and weighed. The water content of activated carbons had calculated by Eq. (1)

$$\text{Water content} = \frac{a-b}{a} \text{ x } 100\% \quad (1)$$

Where:

a = The weight of the initially activated carbon (gram)

b = Activated carbon weight after drying (gram)

2.2.4 Ash content of activated carbons

To determine the ash content of biomass materials, a sample of the biomass is placed in a furnace and heated until all of the carbon is converted to ash. The sample is then cooled in a desiccator and weighed to determine the weight of the ash. The ash content is calculated using the following equation:

$$Ash\ content = \frac{Weight.of\ Ash}{Weight\ of\ biomass}\ x\ 100\% \quad (2)$$

Where:

a = Initial activated carbon of activated carbon (gram)

b = Weight of dried activated carbon (gram)

This equation allows for the determination of the ash content of biomass materials by expressing the weight of the ash as a percentage of the original weight of the sample. The ash content can be used to understand the composition of the biomass and its potential uses.

2.2.5 Vapor Content Analysis

To determine the vapor content of activated carbon, one gram of each sample was placed in a dried crucible porcelain and heated to 310°C. Once the furnace was turned off, the samples were taken out and placed in a desiccator to cool. The vapor content of the biomasses was then calculated using the following equation:

$$Vapor\ content = \frac{a-b}{a}\ x\ 100\% \quad (3)$$

Where:

a = The weight of the initially activated carbon (gram)

b = Activated carbon weight after heated (gram)

2.2.6 Bounded Carbon Content Analysis

The bounded carbon content was calculated based on the relation between the vapor and ash contents. A certain amount of bound carbon content was calculated by Eq. (4).

$$Pure\ activated\ carbon\ =\ 100\%\ -\ (A+V) \tag{4}$$

Where:

A = Ash content (%)

V = Vapor content (%)

3. RESULTS AND DISCUSSION

3.1. Water content (%)

The results of this study showed that the water content of activated carbon produced from eggplant stalks, banana peels, and orange peels was 13.8%, 21.9%, and 19.3%, respectively. The highest water content was found in banana peels, while the lowest was found in eggplant stalks. It is thought that the water content of biomass is related to its structure, with eggplant stalks having a woodier texture and therefore a lower water content compared to banana and orange peels. The water contents of biomasses were introduced in figure 2.

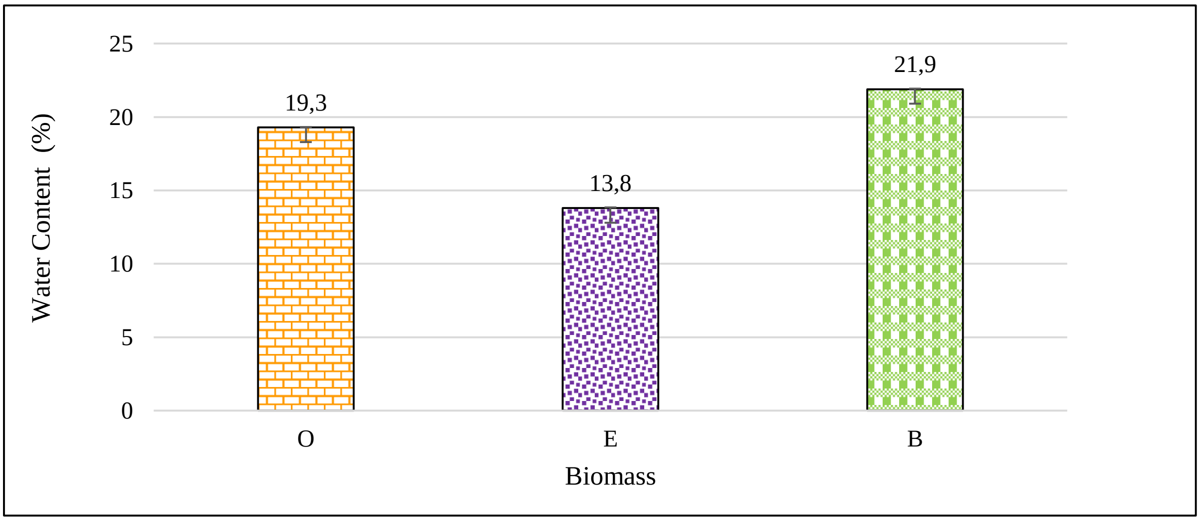

Figure 2: Water content of biomass (o) orange, (E) Eggplant and (B) Banana

The ash content of different biomass was shown in Figure 3. Orange peels had the highest ash content at 22.4%, followed by banana peels with 8.5% and eggplant stalks with 6.5%. Banana and orange peels had 23.5% and 70.9% more ash content than eggplant stalks, respectively. It is believed that the woody structure of eggplant stalks forms a protective layer on the surface that resists internal burning (Ramazanoğlu and Özdemir, 2022). It is possible that the surface of banana peels also acts as a protective barrier. The higher extractive content of orange peels may have contributed to their higher ash production. This could be a relatively high amount of ash with a high degree of accuracy.

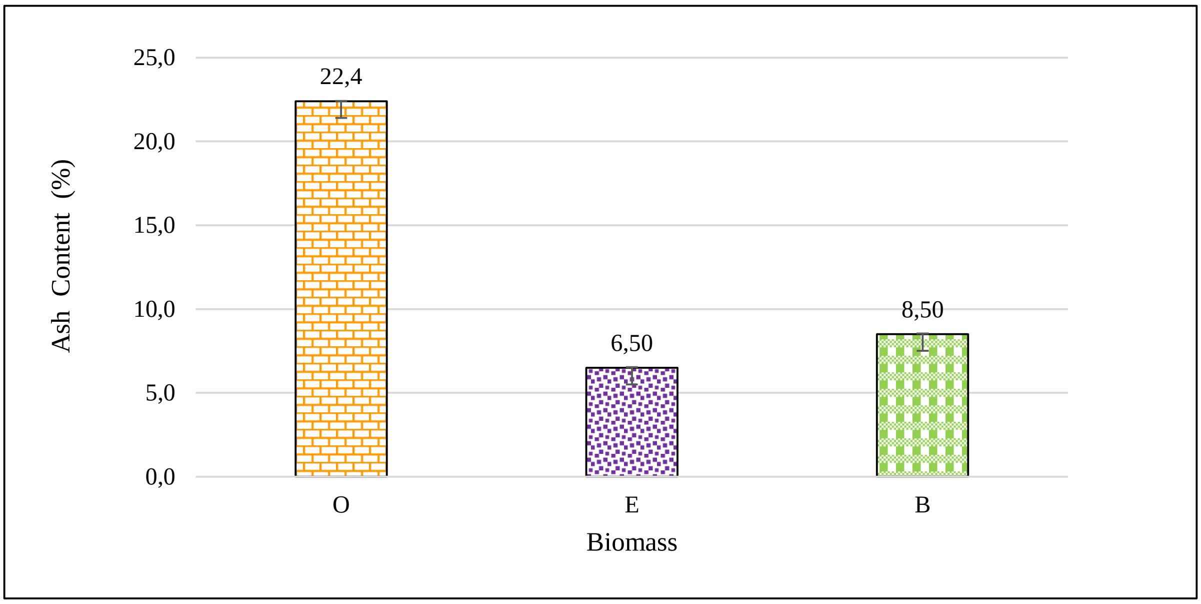

Figure 3 Ash content of biomasses (O) Orange, (E) Eggplant and (B) Banana

3.3. Vapor Content (%)

Figure 4 presents the vapor content of each biomass. Eggplant stalks had the lowest vapor content at 15.5%, followed by orange peels at 22.8%. Banana peels had the highest vapor content at 26.2%. Eggplant stalks had 29.8% and 40.8% less vapor content than orange and banana peels, respectively. The woody structure of eggplant stalks may be a contributing factor to their lower vapor content compared to the other biomasses.

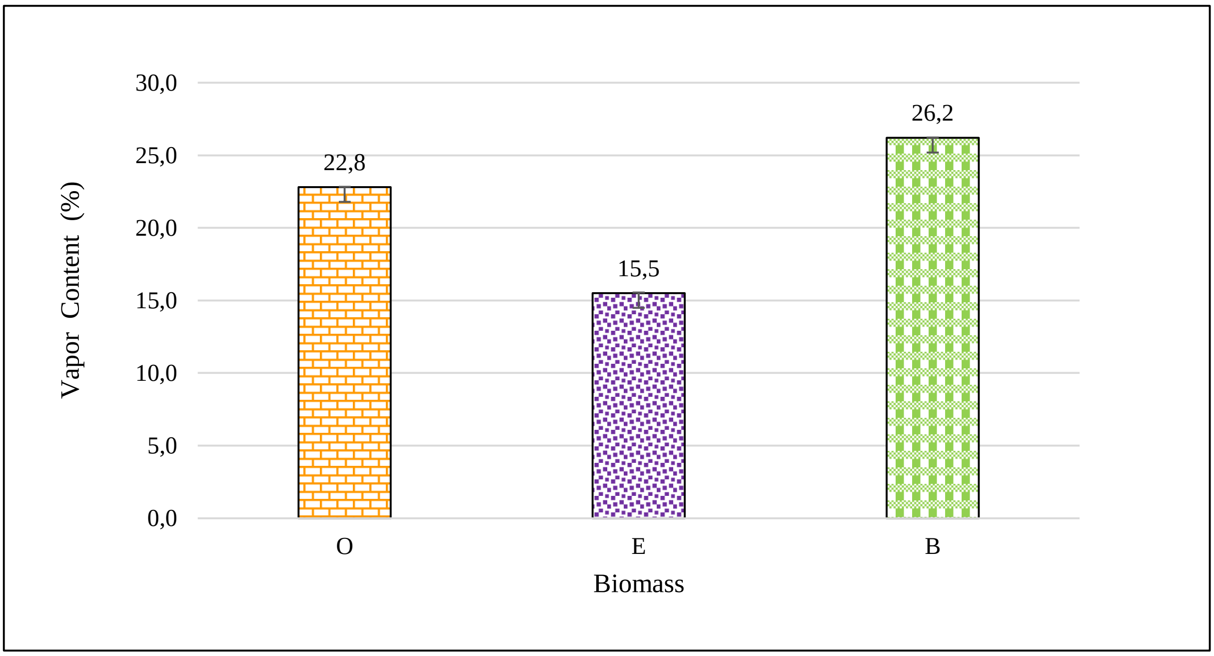

Figure 4 Vapor content of biomasses (O) Orange, (E) Eggplant and (B) Banana

3.4. Bounded Carbon Content

Figure 5 shows the bound carbon content of each biomass. Eggplant stalks had the highest bound carbon content at 78.0%, followed by banana peels at 65.3%. Orange peels had the lowest bound carbon content at 54.8%. Eggplant stalks had 16.2% and 29.7% more bound carbon than banana and orange peels, respectively.

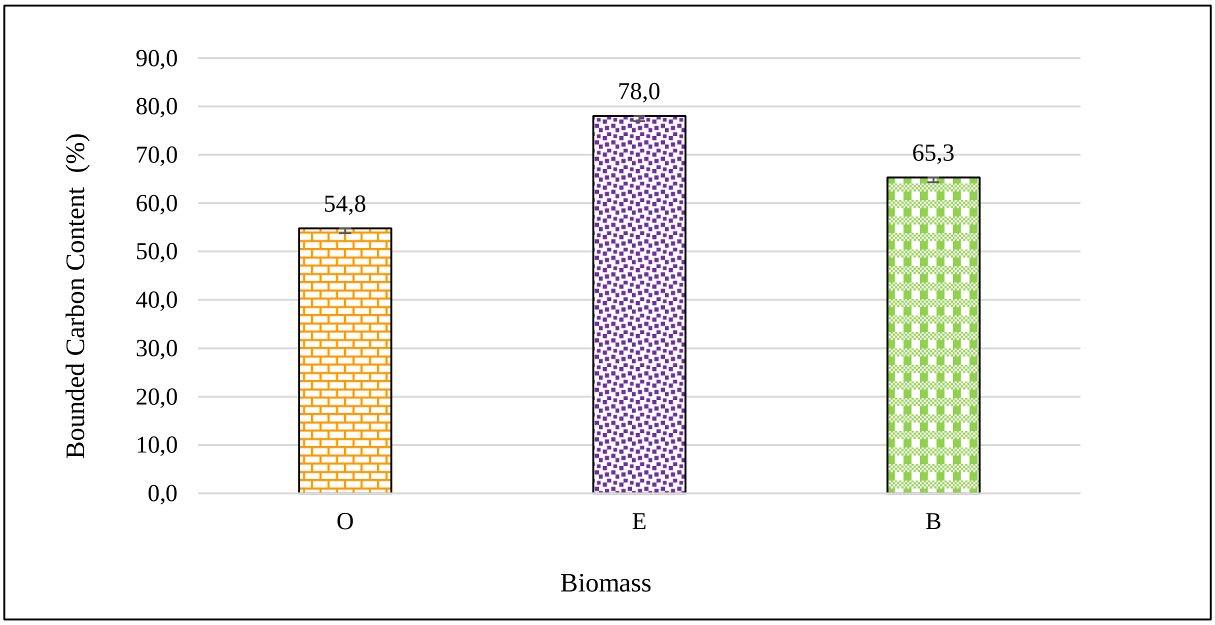

Figure 5 Bounded carbon content of biomasses (O) Orange, (E) Eggplant and (B) Banana

4. CONCLUSION

In this study, three different biomasses were used to create activated carbons, which have a significant role in energy storage systems. These activated carbons were classified according to the Indonesian National Standard (SNI 06-3730-1995), which determines the suitability of biomass as an activated carbon source. According to this standard, the maximum water, ash, and vapor content should be no less than 15.0%, 10.0%, and 25.0%, respectively, and the minimum bound carbon should be more than 60%. Among the three biomasses tested, eggplant stalks were found to be the best activated carbon source with a water content of 13.8%, ash content of 6.50%, vapor content of 15.5%, and bound carbon content of 78.0%. Banana peels had water, ash, vapor, and bound carbon values of 21.9%, 8.50%, 26.2%, and 65.3%, respectively. Orange peels had water, ash, vapor, and bound carbon values of 19.3%, 22.4%, 22.8%, and 54.8%, respectively.

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