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Production of Activated Carbon from Watermelon Peels for Treatment of River Water

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Abstract

The utilization of agricultural waste, such as from the watermelon peels, presents an intriguing alternative due to its potential for conversion into activated carbon. Hence, this study used watermelon peels to produce activated carbon (AC) to treat river water. The watermelon peels were washed and dried for 24 hours at 60 °C. Then, the watermelon peels were carbonized at 300 °C for 60 minutes and chemically activated in 1.0 M of H_2SO_4 for 24 hours. The ash, moisture, volatile carbon, and fixed carbon content were examined to evaluate the quality of AC. Besides, the surface morphology was analyzed using scanning electron microscopy (SEM) at ×500 magnification. The effectiveness of the material in treating Muar River water samples was measured by measuring biochemical oxygen test (BOD), turbidity, and pH with various activated carbon masses (0.5 g, 1.0 g, 1.5 g, 2.0 g, and 2.5 g). Results demonstrated an increase in the amount of AC, giving an increase in reduction of BOD (24.79-0.54 mg/L), turbidity (0.70-0.00 NTU), and pH (6.5-7.5 pH) of the treated Muar River water. In addition, SEM image appeared spongy, indicating the development of pores, thus increasing the adsorption capacity. Therefore, this study established the feasibility of employing watermelon peels as a cost-effective and efficient raw material to produce AC for the treatment of river water.

1. Introduction

Since its founding, activated carbon (AC) has been a sought-after commodity due to the general belief that it is beneficial for treating various types of water and wastewater. AC are adsorbents made from raw carbonaceous material. Any organic substance with a high carbon content is said to be carbonaceous. More importantly, it is widely used in water treatments as it effectively purifies and eliminates a wide range of contaminants from water and protects other water treatment units like reverse osmosis membranes and ion exchange resins from potential damage due to oxidation or organic fouling and dechlorinates, deodorizes, and decolourize polluted waters. Two activation techniques are used to create AC: carbonization and physical and chemical activation. The efficacy of AC is influenced by the temperature and time of carbonization [1]. It was shown that the quality of the carbonized product was diminished when the carbonization period was shortened because severe burning or oxidation caused the AC's pore structures to collapse. Besides, the surface area of AC increases with increasing fineness size of AC, resulting in better and more effective adsorption [1]. Additionally, the AC's porous structure is enhanced when carbonization and activation are carried out simultaneously at a lower temperature during the chemical activation process [1]. Several variables must be considered while producing higher-quality AC: the ash, volatile, and moisture content of AC are used to evaluate its quality standards.

Agricultural waste, which includes fruits and vegetables, is also carbonaceous biomass. It is stated that Malaysia produces about 1.2 million tonnes of agricultural waste annually [2]. Numerous environmental problems are being caused by the high amount of agricultural wastes being released into the environment. Therefore, taking a different scientific path is crucial to turning agricultural waste into something beneficial. One of the options is to transform them into what is more widely known as AC. Many benefits come with utilizing agricultural waste to produce AC, such as increasing crop value while easing solid waste management issues. This is because it transforms undesirable, low-value agricultural waste into valuable, high-value adsorbents in the first place. Additionally, it offers a great way to manage agricultural solid waste, which lowers environmental contamination.

Due to the physical and chemical processes employed during manufacture, the poor yield, the high energy consumption during production, and the heat or solvent processes necessary for regeneration, AC is considered as a costly material. According to this study, watermelon peels have a high potential to be a cost-effective raw material in the production of AC, making it a potential food waste recycling process to produce affordable AC, boosting the national economy and promoting environmental protection, as well as being able to treat river water. This is further supported by the fact that watermelon peel is an additional agricultural waste that may be used to make AC and is known to have a significant number of solid components with high potential [3] therefore somewhat decreasing agricultural waste. The objective of this study is to make AC from watermelon peel in order to determine the value in parameters that affect the AC's quality, such as performing proximate analysis and scanning electron microscopy (SEM) surface morphology and to assess its effectiveness by treating river water and comparing its biochemical oxygen test (BOD), turbidity, and pH levels before and after.

2. Materials and Methods

2.1 Preparation of Activated Carbon

The watermelon peels were obtained from the nearby restaurants around Pagoh area and Muar River water was used for this research. The watermelon peels were washed thoroughly with tap water and again with distilled water to remove any visible dirt. The washed watermelon peels were dried under the sun for 5 to 7 days to reduce its moisture content before carbonization [3] drastically. The dried watermelon peels are dried again in an oven at 60 °C for 24 hours. The dried watermelon peels are carbonized at 300 °C for 60 minutes in a muffle furnace [3]. The carbonized peels were left to cool down for 3 hours at room temperature, and they were ground and crushed into powder using a grinder, and a carbon product was obtained.

The powdered carbon product was put into a 500 ml beaker, followed by 1.0 M of H_2SO_4, and the content was left at room temperature to soak for 24 hours [3]. The soaked content was rinsed with distilled water, and the excess water was drained with a cheesecloth strainer. The AC was dried again in a muffle furnace at 300 °C for another 60 minutes, and the AC was set to cool to room temperature for 4 hours.

2.2 Characterization of Activated Carbon

An Apollo 300 field-emission SEM equipped with a backscattering electron detector at 15 kV was used to examine and to capture AC's morphology and surface properties. The magnification level was set to 500.

Ash content is a measurement of the quantity of residue that spreads into the pores of AC and comprises minerals like calcium, sodium, magnesium, calcium, etc [4]. Ash content is measured by the amount of remaining inorganic materials after burning organic matter. Volatile content is any substance that can be quickly turned into vapour. The quality of the AC increases with decreasing volatile content. Water molecules attached to AC are measured as moisture content [4]. Less moisture content might boost the adsorption ability of AC, according to a prior study report [4]. The ash, volatile and moisture content were determined by using the following equations:

$$\%\ \text{ASH} = \frac{\text{Mass of ash}}{\text{Mass of dry}} \times 100 \qquad (1)$$

The ash content was calculated by using (1) in [5], where the mass of ash was obtained by burning 2 g of AC at 550 °C for 24 hours in a muffle furnace, while the mass dry was the mass of AC, which is 2 g.

$$\%\ \text{Volatile Content} = \frac{\text{Mass of dry} - \text{Mass of ash}}{\text{Mass of ash}} \times 100 \qquad (2)$$

Volatile content was determined by using (2) where the mass of dry was the mass of AC, which is 2 g, while the mass of ash was obtained by burning 2 g of AC at 950 °C for 7 minutes in a muffle furnace.

$$\text{Moisture Content} = \frac{\text{Mass of ash}}{\text{Mass of dry}} \times 100 \quad (3)$$

Meanwhile, moisture content was calculated by using (3) in [4] where the mass of wet was the mass of AC, which is 1 – 2 g, while the mass of dry was obtained by drying the AC at 150 °C for 3 hours in the oven.

2.3 Muar River Water Treatment

250 mL of untreated river water was measured five times using a measuring cylinder and poured into a 1000 mL beaker. An analytical balance was used to weight the AC into five different masses which is 0.5 g, 1.0 g, 1.5 g, 2.0 g, and 2.5 g. The weighed AC was mixed with the 250 mL of untreated river water into five different beakers. The mixture was put into a flocculator to mix at 60 rpm for 6 hours. Then, the treated sample was drained using a cheesecloth and filtered using a filter paper to remove the AC. The treated river water sample with different masses of AC was obtained and tabulated.

2.4 BOD Test

A dilution water was prepared by dissolving a BOD nutrient pillow into 3 L of deionized water and aeration was carried out for 2 hours in the dark. Seven units of 300 mL BOD bottles were prepared. The dilution water was mixed thoroughly and brought the temperature to 20 ± 3 °C. A blank was prepared by filling a BOD bottle with only deionized water. 50 mL of treated and untreated river water was poured into a 100 mL beaker, respectively, and the pH was measured using a pH meter. The samples were neutralized by adding 1.0 M of H_2SO_4 if alkalic and 1 M of NaOH if the sample is acidic until the pH reaches 6.5 –7.5. Then, 11 mL of untreated river water was pipetted into a BOD bottle and deionized water was filled up until full. The five remaining BOD bottles were labelled according to the weight of AC used to treat the river water, which is 0.5 g, 1.0 g, 1.5 g, 2.0 g and 2.5 g. Then, 11 mL of treated river water sample with five different masses of AC was pipetted into each BOD bottle according to the label and deionized water was filled up until full. The BOD bottles were placed in an incubator at 20 °C and incubated for 5 days. The initial and final DO readings of all the samples were measured by a DO meter.

$$\text{BOD} = \frac{\text{Initial DO} - \text{Final DO}}{\text{Dilution factor of dilution water}} \quad (4)$$

The BOD was calculated by using (4) where Initial DO = Initial dissolved oxygen reading, Final DO = Final dissolved oxygen reading and Dilution factor of dilution water = Volume of sample water/ Volume of incubation bottle.

2.5 pH Test

The pH meter was calibrated before the test for an accurate reading. 50 mL of untreated and treated river water with five different masses of AC was poured into a 100 mL beaker, respectively and the pH was measured by using the pH meter by inserting the pH meter in each beaker. The pH reading was recorded.

2.6 Turbidity Test

A sample's turbidity can be measured in terms of how clear or hazy it is. Water turbidity is influenced by a number of elements, including the presence of dissolved and suspended solids, particle size and shape, and particle composition. The plug was put into the socket and the instrument was turned on and left for 15 to 20 minutes to warm up. A 400 NTU solution-filled cell was placed in the cell holder and then shielded the cell from light. Then, the device was calibrated to 400 NTU using the fine and coarse dials. Then, a second cell containing the test sample was taken, and the identical process was continued. The turbidity vials were filled with untreated and treated river water with five different masses of AC, respectively. There were six turbidity vials with the sample. The vials were wiped with cotton cloth before insert in the turbidity meter. Then, "READ" was pressed to display the turbidity reading of the samples. The readings were recorded in the unit of NTU.

3. Results and Discussion

3.1 Proximate Analysis of Activated Carbon

The properties of watermelon peel AC determine the quality standard of the AC. Table 1 shows the properties of watermelon peel-AC that was carbonized at 300 °C for 60 min and chemically activated with 1.0 M of H_2SO_4 for 24 hours.

Table 1 *Properties of watermelon peel AC [3], [6]*

Properties	Unit	Value	Malaysia Standard of specification for powderedAC for portable water supply by Ranhill SAJ [6]	Literature value [3]
Ash Content	%	1.37	<10	18.6
Moisture Content	%	10.65	<5	1.4
Volatile Content	%	9.64	-	10.3
Fixed Carbon	%	78.34	-	66.0

Based on Table 1, it was indicated that the ash content is 1.37% which was in the range below 10 according to the Malaysia Standard of specification for powdered AC used for portable water supply by Ranhill SAJ [6]. Research indicates that excessive amounts of ash can reduce the ability of AC to absorb adsorbate. This is due to the possibility of excessive ash blocking pores and decreasing the AC's surface area. Additionally, the mechanical strength of carbon decreases with increasing ash concentration, thus influencing adsorption [4]. Therefore, a low ash content in the AC results in the most active AC.

The moisture content is 10.65%, higher than the value required by the Malaysian Standard of specification powdered AC [6]. The activator concentration could influence the high moisture content value. This is due to the leftover pyrolysis and organic minerals on the surface of the AC dissolving process, which will improve as the activator concentration rises. As a result, it will enhance the quantity and size of pores as well as the surface area, improving the ability of AC to absorb water from air [7]. Another explanation would be that porous materials can absorb moisture [8]. Although the amount of moisture in AC does not affect its ability to absorb substances, too much moisture can dilute the material and reduce the amount of material needed for an adsorption experiment [8].

Analysis of volatile content is also necessary since it will impact the quality of the AC. The volatile content is 9.64%, which is better than the literature value of10.3% [3]. The concentration of the activator influences volatile content. Including activators alters AC's structure and characteristics, giving it a greater adsorption rate [9]. Additionally, this activator creates an active carbon micro pore structure and releases volatile chemicals [7]. The non-carbon component connected to the surface of the AC and accessing the bottom surface of the carbon through its pores can be reduced during the impregnation process utilizing the activator. As a result, the activator's presence will clean and increase the pore surface [7]. For the developed AC, the fixed carbon also known as the non-volatile fraction of the sample, is 78.34, higher than the literature value of 66.0%. Fixed carbon is not a fixed quantity, but its value, measured under standard conditions, gives a useful evaluation parameter of the AC. In the thermochemical conversion process, char formation as a product yield increases with fixed carbon concentration [9].

3.2 SEM Analysis

Fig. 1 displays a SEM image of watermelon peel-AC. It appeared spongy and more porous can be seen. As porosity increases, adsorption capacity climbs [1]. Additionally, surface attraction has an impact on the rate of adsorption. Surface attraction causes an increase in the rate of adsorption. Adsorption is brought on by chemisorption, a chemical reaction between the adsorbate andabsorbent. At the micropores of AC, molecules bind together due to van der Waal's forces [10]. As a result, it is employed in a number of environmental applications such as wastewater treatment, water impurity absorption, and fertilization.

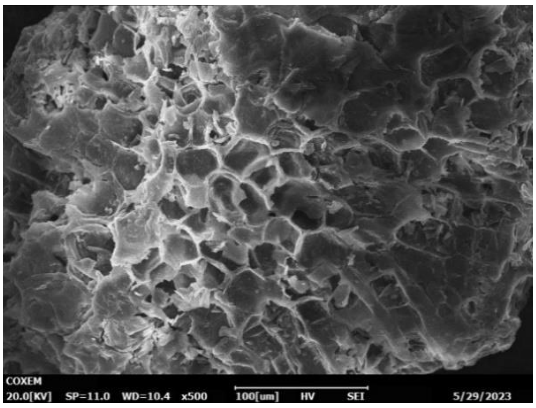

Fig. 1 *SEM of watermelon peel-AC*

3.3 BOD Test Analysis

BOD test is a test that is usually carried out to assess how much oxygen is needed for an organic matter sample of water to degrade. There are many main sources of BOD such as, twigs, branches, and leaves, animals' waste, dead plants and animals, septic systems that are broken or completely fail, feedlots, food processing facilities, paper and pulp mill effluent, rainfall runoff and plants that treat sewage. Figure 2 was obtained by analyzing the BOD of Muar River water. The amount of biodegradable organic molecules in the water was measured by the dissolved oxygen concentration in a five-day period [11]. Dissolved oxygen levels fell during these five days, proving that bacteria and other microbes are actively metabolizing organic waste. This is because organic matter must be broken down by bacteria, which require some dissolved oxygen. There is significant organic matter breakdown in the water, and dissolved oxygen levels may drop sharply. The mechanism that transforms big molecules into smaller ones, eventually transforming into carbon dioxide and water, also requires oxygen [12]. The higher the BOD readings the lower the water quality.

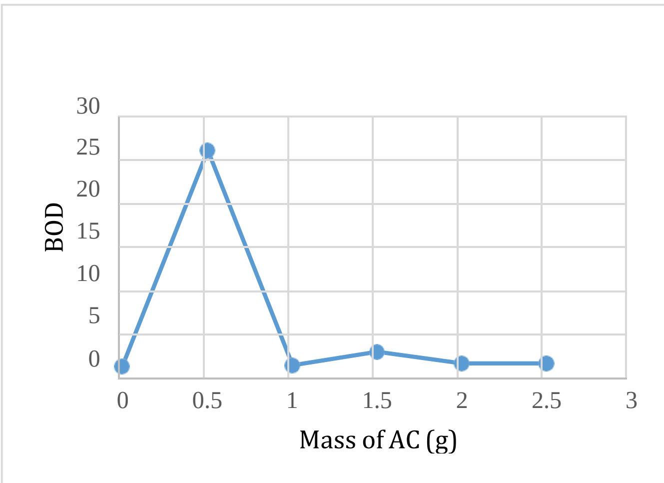

Fig. 2 *BOD and the mass of AC*

3.4 pH Test Analysis

The initial pH of untreated river water was 6.75. The pH of the treated river water sample with five different masses of AC is shown in Table 2.

Table 2 *The pH of the treated river water sample with five different masses of AC*

Mass of AC (g)	pH
0.5	6.74
1.0	7.10
1.5	6.72
2.0	6.77
2.5	7.46

With a pH range of 6.5-7.5, the water is neutral, meaning it is neither acidic nor alkaline. Thus, based on Table 2, the treated water is considered neutral after the treatment. Therefore, the water shows neutral properties, which are safe to be used by animals, plants, and humans.

3.5 Turbidity Test Analysis

The turbidity of untreated river water is 209 NTU. Table 3 shows the turbidity of the river water samplethat was treated with five different masses of AC.

Table 3 *Turbidity of water sample treated with five different masses of AC*

Mass of AC (g)	Turbidity (NTU)
0.5	0.70
1.0	0.35
1.5	0.00
2.0	0.00
2.5	0.00

The higher the turbidity the more the water is polluted. From Table 3, it is clearly shown that the readings are lower and even have 0.00 NTU as the mass increased, indicating the river water is at the cleanest state it can be. The higher the amount of AC, the more the number of pollutants can be trapped and cleaned. Thus, the water appears to be clean at increasing use of AC and lowers the turbidity reading.

4. Conclusion

Watermelon peels are effective precursors for AC based on their values of ash, moisture, and volatile content, which are at their best range. Besides, watermelon peel-AC showed excellent removal efficiency of Muar River water's BOD, pH, and turbidity levels with the increasing amount of AC. Meanwhile, the treated river water's pH, turbidity, and BOD levels are within the permitted limits of the regulations. Producing AC from agricultural waste materials can reduce waste disposal costs and provide a more cost-effective replacement for present adsorbents derived from non-renewable sources. Therefore, the government has a big responsibility to help researchers identify simple, financially feasible solutions to increase the production of AC at the highest quality.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Bethany Albert Charles, Eshwary Thanabalan, Norain Ahmad Nordin, Nuramirah Juma'at;* ***data collection:*** *Bethany Albert Charles, Eshwary Thanabalan, Norain Ahmad Nordin, Nuramirah Juma'at;* ***analysis and interpretation of results:*** *Bethany Albert Charles, Eshwary Thanabalan, Norain Ahmad Nordin, Nuramirah Juma'at;* ***draft manuscript preparation:*** *Bethany Albert Charles, Eshwary Thanabalan, Norain Ahmad Nordin, Nuramirah Juma'at. All authors reviewed the results and approved the final version of the manuscript.*

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