Papaya peels as source of hydro char via hydrothermal carbonization

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Abstract. Papaya peels was converted into hydro char via hydrothermal carbonization (HTC) and used as adsorbent for methylene blue removal. The carbonization of the papaya peels was executed at six different temperatures ranging from 150 °C to 200 °C with 50 °C interval with reaction time of 120 minutes mainly to study the effect of the carbonization temperature on the hydro char formed via HTC. The hydro char produced was assessed in terms of mass yield, elemental compositions, and higher heating value (HHV) prior to degradation of methylene blue (MB). For all sample, the mass yield of the hydro char was reduced as the reaction temperature increased whilst contradict to carbon contents which increased as the HTC temperature increased. The HHV also increased as the carbonization temperature rise, but it was observed a slight decline of the HHV for hydro char formed at 170 °C which because of the carbon content in the hydro char. Moreover, result shows removal percentage of MB increased significantly along with the carbonization temperature.

1. Introduction
Currently, due to increasing of world population and the advancement of technology, the energy consumption has been increased drastically from year to year. Mostly, energy sources generated from fossil fuel such as coal, natural gas and oil and this nonrenewable energy identified as major provider to the negative environmental issues. For instance, global warming has known as contributor to the climate change as the result of enormous fossil fuel burning from various fuel-driven application. Furthermore, these resources are nonrenewable thus require another energy sources that renewable as well as sustainable and environmental benign [1]. Biomass resources is known as potential substitute to the conventional fossil fuel energy as it has an advantage of less emission of carbon dioxide and can be used as an alternative to diversify the energy system. Various biomasses obtainable abundantly as waste from agriculture as well as food industries particularly.

Hydro char produced from biomasses using hydrothermal carbonization (HTC) capable to be used as an alternative for non-renewable energy sources such as fossil fuel due to its higher heating value (HHV), higher energy density with less emission of greenhouse gases [2-4]. Furthermore, the process of using the fruit waste indirectly assist in reduce the amount of greenhouse gas release because it will consume carbon dioxide throughout the thermochemical process [5]. Also, it will reduce the release of nitrogen oxide and sulphur oxide as compared to the current fossil fuel. In addition to that, the price of fruit waste as feedstock is cheaper as compared to the fossil fuel whereby the price of fossil fuel is always fluctuating [6]. Hydrothermal carbonization consists of different chemical reactions namely hydrolysis, dehydration, decarboxylation, aromatization, and recondensation that responsible in chemical structure of produced hydro char. Hydro char produced differ completely from the feedstocks...
used as parts of it change into liquid and gaseous products whilst solid (hydrochar) remains as final product [7]. This process require medium range of temperature from 180 °C to 260 °C of which the fruit waste is submerged in water and heated in closed vessel under pressure (2–6 MPa) for 5–240 min [8]. The hydrochar composition and performance strongly depends on the feedstock type. Various feedstock such as fruit peels, seeds and pulp as well as vegetable residue show promising results as hydro char using HTC [9]. The fruit peels are the most appropriate residue to be employed due to its sugar content. Previously, Chen et al. and Eriska Putra et al. reported hydro char produced via HTC from watermelon and banana peels, respectively [10, 11]. Both presented the same trend of declining of hydro char mass yield as the hydrothermal carbonization temperature rise. The drop of mass yield is due to the degradation of biomass during the reaction at high temperature. Additionally, the hydro char produced will experience secondary degradation at high temperature that cause the hydro char yield reduction [10]. Previously, Chen et al. described used of watermelon waste as feedstock shows reduced in dry based matter yield percentage as the temperature increase from 190 °C to 260 °C [10]. Approximately, at temperature of 190°C, about 95% of the feedstock of the dry based are changed into hydro char. While only about 56% of the feedstock are changed into hydro char at temperature of 260°C. At high temperature, the feedstock undergo drastic degradation process which causing the feedstock to be formed in liquid and gas. This indicate the reason of mass yield decreasing as the temperature increase.

Banana peel exhibit low mass yield as compared to other feedstock due to low thermal stability that caused faster loss of masses [3]. Furthermore, energy yield of banana peels is increases even though the mass yield is reducing. The reasons are, banana peel consists of cellulose and hemicellulose which makes it simpler to decomposed during hydrothermal carbonization and then lead to reducing of mass yield [12]. However, up to now there is no research on papaya peel as feedstock has been done. Thus, this paper will report the use of papaya peel as feedstock as it contains large amount of moisture that are needed for the conversion process for hydro char production using HTC.

2. Methodology
The raw materials required for the production of hydro char using HTC were papaya peels, deionised water, distilled water and methylene blue powder. The papaya peels which were used as the feedstock were obtained locally at no cost from a papaya orchard located at Parit Jawa, Batu Tiga, 34300 Bagan Serai, Perak.

2.1. Feedstock Preparation
The papaya collected was peeled off to obtain the papaya peels that will be used as biomass feedstock. Impurities such seeds and dirt was sorted and removed. Then the sorted peels were cut into small sizes before dried in the oven at 100 °C for a day. After that, the peel was grinded using blender to reduce the size of the papaya peel to powder. Powder obtained were then sieved using a laboratory sieve shaker with a range between 75 to 150 μm.

2.2. Hydrothermal Carbonization for Hydro char Production
Hydrothermal Carbonization experiments were carried out using a 100 ml Hydrothermal Autoclave Teflon with PTFE liner and a furnace. Around 5 g of powder were mixed with deionized water and placed inside the autoclave. The autoclave containing the mixture of powder feedstock and deionized water were put inside the furnace at temperature 150 °C, 160 °C, 170 °C, 180 °C, 190 °C and 200 °C for 120 mins to initiate the hydrothermal carbonization conversion process. After 120 mins, the autoclave was taken out from the furnace and cooled down for about three hours. The hydro char obtained then was filtered by using a filter paper and 100 ml conical flask. Filtered hydro char was transferred to a petri dish and further dried in oven at 100 °C for 24 hrs. Once the drying process done, the dried hydro char was soaked with deionised water in a 100 ml beaker for a day to remove any colour or chlorophyllll completely from the hydro char formed [7, 13]. Then the hydro char was filtered once again and dried in the oven for a day to remove moisture. After that, the hydro char was collected and
put in a container. The container then labelled according to the temperature utilized, duration and also its weigh prior to physiochemical analysis and removal of methylene blue.

2.3. **Physiochemical Analysis**

2.3.1 *Mass Yield*. Mass yield were measured by weighing the wet and dried hydro char using analytical weigh balance. Then, the mass yield can be calculated using Equation 1.

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\text{Mass Yield} = \frac{\text{Mass of dried hydrochar}}{\text{Mass of dried raw biomass}} \times 100\%
\]  

2.3.2 *Chemical Composition Analysis*. The ultimate analysis (CHNSO) test was performed using Carbon-Hydrogen-Nitrogen-Sulphur Analyser (Perkin Elmer Series 8, USA). About 100 mg of dried hydro char were used by grinding into a very fine powder and then, the analyser will give the results for carbon, hydrogen, nitrogen, and sulphur.

2.3.3 *Higher Heating Value (HHV)*. Higher heating value of the hydro char were performed using bomb calorimeter (IKA C200, Germany). About 200 mg of the sample was dried for 24 hr. Then, the sample placed on a crucible that located in a vessel. A sufficient oxygen was supplied for the combustion process. The HHV are calculated using the temperature differences.

2.4. **Methylene Blue Adsorption**

About 0.4 g of the dry hydro char synthesized at 150 °C was weighed using analytical weighing balance and added to a conical flask that filled with methylene blue with concentration of 50 mg L⁻¹ and volume of 80 ml. The conical flask was then transferred to water bath shaker operated at 113 rpm and 25 °C for 24 hours. Every 30 minutes, the water bath shaker was stopped, and absorbance reading of that solution obtained using a spectrophotometer (Cary 60, Agilent Technologies, USA). Same procedure applied for the 100, 150 and 200 M concentration using hydro char formed at 150 °C. Again, the same procedure repeated for the hydro char formed at 160 °C, 170 °C, 180 °C, 190 °C and 200 °C accordingly.

3. **Results and Discussion**

3.1. *Mass Yield*

Table 1 shows mass yield of hydro char at different operating temperature. Mass of dried hydro char as well as mass yield was decreased with increased in operating temperature. This result in line with previous work done by Eriska Putra et al., Erdogan et al. and Hoekman et al. that reported as hydrothermal carbonization temperature increase, the mass yield percentage declined gradually [11, 14, 15]. The highest mass yield was reported at 150 °C whilst the value has remained unchanged of 58% at 170 °C and 180 °C. All samples were conducted for 120 minutes and the mass of the dried raw biomass utilized for HTC was 5g.

Generally, lignocellulose is a plant biomass that contained cellulose, hemicellulose and lignin. The cellulose and hemicellulose polymer are strongly linked to the lignin. Earlier, Jahid et al. documented different fruit waste with its lignocellulose content namely banana, pineapple, papaya and mango peels. Based on the results, the hemicellulose, cellulose and lignin content in the papaya waste was 24.6, 20.4, 2.7% respectively. From all the fruit waste, papaya peels displayed the lowest lignin content [3]. The lignocellulose content or also known as fibres contained in the biomass feedstock will be converted into

| Temperature (°C) | Mass of Dried Hydrochar (g) | Mass Yield (%) |
|-----------------|-----------------------------|----------------|
| 150             | 3.20                        | 64.0           |
| 160             | 3.15                        | 63.0           |

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the volatile matter and other non-sugar compounds which reduces the mass yield as the temperature increases. In this work, it is revealed that at temperature of 150°C, more than 60% lignocellulose content in the papaya peel biomass is not converted and remains after hydrothermally carbonized in the hydrochar. Even when the temperature increased to 160°C, the mass yield only reduced to 63% from 64% which explain that only small amount of lignocellulose content is converted when the temperature rises from 150 °C to 160 °C [12].

However, at 200 °C, about half of the lignocellulose content is converted which can be concluded that the mass yield reduced as the temperature increased. Hemicellulose and cellulose were much simpler to decompose via hydrothermal carbonization as compared to lignin. As shown in figure 1, the mass yield reduced significantly as the temperature increased due to the high decomposition of the lignocellulose content as hemicellulose and cellulose were major carbohydrate polymer. Additionally, it is known that approximately 90% of hemicellulose will decompose at temperature between 180 to 220°C [9]. Consequently, the mass yield starts to reduce significantly from 60 to 54% as the hydrothermal carbonization temperature reach 180°C. Moreover, the mass yield tends to easily decreased due to the fact that the fruit waste has low stability and low sugar content [11, 16]. The sugar content consists of monosaccharides, disaccharides, and starch. The sugar will be converted into glucose after the biomass is hydrothermally carbonized. Biomass feedstock with high sugar content will yield high amount of glucose in the hydro char which explain why the grape pomace and apple-based biomass displayed an increases in mass yield when the temperature rises [12].

| Temperature (°C) | Mass Yield (%) | Carbon Content (%) |
|-----------------|----------------|-------------------|
| 170             | 2.90           | 58.0              |
| 180             | 2.90           | 58.0              |
| 190             | 2.70           | 54.0              |
| 200             | 2.54           | 50.8              |

**Figure 1.** Hydro char mass yield prepared at different hydrothermal carbonization temperature.

### 3.2. Ultimate analysis

The carbon content analysis of hydrochar formed by utilization of papaya fruit waste at different HTC temperature is displayed in table 2. From table 2, it is indicated that as the hydrothermal carbonization temperature increases, the carbon content also increases. This trend is similar with the result utilized grape pomace and watermelon peels as the feedstock [10, 12]. All the samples were hydrothermally carbonized for 120 minutes at temperature of 150 °C, 160 °C, 170 °C, 180 °C, 190 and 200 °C and the
carbon content increases considerably from 38.844% to 46.145%, respectively. It is obvious that the elemental composition of hydro char affected appreciably by the hydrothermal carbonization temperature.

Table 2. Elemental analysis of hydro char at different HTC temperature

| Treatment Temperature (°C) | Carbon Content (%) | Hydrogen Content (%) | Nitrogen Content (%) |
|-----------------------------|--------------------|----------------------|----------------------|
| 150                         | 38.844             | 6.410                | 3.735                |
| 160                         | 41.941             | 6.438                | 3.825                |
| 170                         | 40.611             | 6.440                | 4.301                |
| 180                         | 42.844             | 6.447                | 4.335                |
| 190                         | 43.744             | 6.718                | 4.457                |
| 200                         | 46.145             | 6.992                | 5.114                |

Hydrothermal carbonization process will break the chemical structure of the biomass and this phenomenon can be observed by carbon, hydrogen and nitrogen content in the solid product which is hydro char [11]. The carbon content enrichment in hydro char was due to the fact of condensation and aromatization reaction during the hydrothermal carbonization process of the feedstock biomass. Furthermore, the increase of carbon content in the hydro char after hydrothermal carbonization process also shows that mostly the carbon in the biomass was kept stored in the solid hydro char. While only small amount of the carbon was converted as liquid and gas phase during the treatment and therefore the HTC is the most appropriate to be utilized for carbon sequestration [10, 13]. Papaya peels hydro char yield about 38 to 46% of the carbon content at temperature range from 150 to 200°C while the grape pomace and watermelon waste produced around 50 to 65% carbon content at temperature range from 190 to 260°C [10, 12]. The low carbon content in the hydro char produced from the papaya peel feedstock compare to grape pomace and watermelon peel is due to the low content of the sugar in papaya. As the sugar content was low, thus lead to low carbon content because by HTC, the sugar contained in the feedstock will eventually converted into carbon. Additionally, the reaction time for the papaya peels was 120 mins while for the grape pomace and watermelon waste were 15 minutes and 60 mins, respectively. As the carbon content differ slightly with the literature, it can be concluded that carbon content contained in hydro char might be differ due to different compound in the fruit waste and other operating factors such as temperature, reaction time, feed to water ratio used and reactor design.

The results for papaya peels shows that from 150 °C to 200 °C, hydrogen content increases from 6.4 to 6.9%. The results show similarities with watermelon waste but the grape pomace exhibited reduce in hydrogen content as the temperature increases. The reaction of dehydration and decarboxylation could lead to the reduce in the hydrogen content from the feedstock [10]. Rises in hydrothermal carbonization temperature leads to exhaustive hydrothermal carbonization process and inefficiently steer the reaction of both dehydration and decarboxylation during the treatment causes the hydrogen to be unconverted or reduced in percentage [10]. Moreover, the reaction time also one of vital factor affecting the hydrogen content. The reaction time for both papaya and watermelon waste were 120 mins and 60 mins respectively while the grape pomace was hydrothermally carbonized at the shortest reaction time among all the fruit waste which is 15 minutes. From this comparison, it can be indicated that longer reaction time causes the hydrogen content to reduce as the temperature increases.

The nitrogen content of hydro char produced from papaya peels shows an increase from 3.7 to 5.1% when the hydrothermal carbonization temperature increase from 150 °C to 200 °C at constant reaction duration of 120 mins. Results show similarities with preceding work done by Chen et al. that reported increased in nitrogen content from 2.51 to 3.12% with increased in temperature from 190 to 260°C for 60 mins of the reaction time. Both papaya and watermelon waste displayed similarities where the nitrogen content increases from 1.62 to 1.74% with increased in temperature but contradicted to the grape pomace that illustrates lower nitrogen content as temperature rise [10, 12].
content in the hydro char from the feedstock caused by the polymerization of the hydrolysates of aldehyde and amino groups [1].

3.3. Higher heating value (HHV)

Table 3 tabulated higher heating values of the treated papaya peels biomass at six different temperatures range from 150 °C, 160 °C, 170 °C, 180 °C, 190 °C and 200 °C. The results obtained in line with previous work done by Zhang et al. and Eriska Putra et al. which reported the increase in higher heating value as rise in hydrothermal carbonization temperature [11, 12]. HHV shown in table 3 further clarified the carbon content of hydro char produced through HTC [17]. The ascending order of HHV for all six reaction temperatures are 200 °C > 190 °C > 160 °C > 180 °C > 170 °C > 150 °C respectively and at temperature of 200 °C recorded the highest HHV of 17.810 MJ Kg⁻¹. The HHV of papaya peels based hydro char ascend from 12.646 to 17.810 MJ Kg⁻¹ when the hydrothermal carbonization temperature increase and the increase percentage of the HHV is approximately 40.83%. As the reaction temperature intensified from 150 °C to 160 °C, the HHV exhibited the most substantial changes as it increases from 12.646 to 15.649 MJ Kg⁻¹ and then increases gradually up to 17.810 MJ Kg⁻¹.

| Carbonization Temperature (°C) | Mass × 10⁻⁴ (Kg) | HHV (MJ Kg⁻¹) |
|-------------------------------|-----------------|---------------|
| 150                           | 1.597           | 12.65         |
| 160                           | 1.934           | 15.65         |
| 170                           | 1.946           | 15.26         |
| 180                           | 1.352           | 15.49         |
| 190                           | 2.158           | 16.13         |
| 200                           | 1.736           | 17.81         |

Generally, carbon content and HHV plays a vital role in the determination of the quality of hydro char produced. The papaya peel based hydro char yield low HHV compare to banana peel and grape pomace studied by [11, 12] respectively but the heating values shows about the same with the hydro char formed from HTC of loblolly pine which exhibit HHV, 19.22 MJ Kg⁻¹ [18]. Zhang et al. reported that HHV and mass yield are greatly influenced by the reaction temperature whereas the mass yield decreases while the HHV increase when the hydrothermal carbonization temperature elevated. This is because the decarboxylation reaction will be reduced as the temperature increases and thus lead to the high carbon content in the hydro char formed [12].

As mentioned before both the mass yield and HHV also depend on the carbon content whereas the elemental composition of the hydro char in particular carbon content, positively linked to the heating value of fuel, HHV. Table 3 displayed that at 170 °C, HHV decreases from 15.649 to 15.258 MJ Kg⁻¹. The major contribution of this decline even though the temperature rise is because of the carbon content of the hydro char formed at temperature of 170 °C. From table 2, it is shown that carbon content of the hydro char formed at 160 °C is 41.941% while at 170 °C, carbon content is 40.611%. This shows the hydro char formed at 170 °C has lower carbon content compare to the hydro char produced at 160 °C. Carrasco et al. stated that greater partial degradation of cellulose from the biomass feedstock leads to decrease in the mass yield whilst increases the HHV [19]. As papaya mostly consist of hemicellulose and cellulose with small amount of lignin, thus enable papaya to decompose easier via HTC. As the consequences, the carbon content and HHV of the papaya peel hydro char increases significantly as temperature increases. Furthermore, since the carbonization temperature act as the manipulating variable instead of reaction time, the hydro char properties as carbon content and HHV differ greatly with the temperature applied [2]. For this reason, it can be indicated that the temperature of the hydrothermal carbonization treatment prominently influenced the hydro char produced.

3.4. Adsorption of Methylene Blue
3.4.1. Effect of Carbonization Temperature on the Methylene Blue Removal. Figure 2 displayed the methylene blue (MB) percentage removed by the hydro chars that formed at different carbonization temperature. Result shows that the MB removal percentage increases drastically and then reach an equilibrium stage for all the initial concentrations range from 50 to 200 mg L\(^{-1}\). This can be explained that the hydro char adsorption capacity reach its limit to remove or adsorb the MB solution at the end of adsorption process which was conducted for 24 hours. The average removal percentage for reaction temperature of hydro char at 150 °C to 180 °C between 87 to 88% which was lower as compare to the reaction temperature of 190 °C and 200 °C that ranges up to 90%. Result obtained from this work shows that hydrochar produced from papaya peel act better as adsorbant for MB removal as compared to lignocellulosic biomass milled corncob that reported low removal of MB as increase in HTC temperature from 180 °C to 350 °C [8]. The HTC reaction temperature is greatly influenced the adsorption efficiency of the hydro char.

Figure 2 illustrated that as the reaction temperature increases, the removal percentage also rise. As mentioned previously, the temperature of the carbonization affects the structure and strength of the hydro char formed.

![Figure 2](image_url)

**Figure 2.** Removal percentage of hydro char produced at different temperature to the initial concentration of MB

Hydro char produced at high temperature possess higher carbon content and HHV as well as enhance in structure. Particularly, hydro char exhibit bigger sizes at high HTC temperature that leads the particles to coagulate with each other which allow the hydro char to adsorb the MB efficiently. Additionally, the hydro char at high temperature was more porous compare at low temperature hydro char. Theoretically, finely particles are good adsorbent due to its high surface area, but in this case, the volume of MB solution set up was approximately 80 ml and the fine powder of hydro char sizes that formed at low temperature was too small makes it harder to adsorb the MB. Therefore, by increasing the carbonization temperature to form the hydro char can increase its adsorption efficiency and the optimum carbonization temperature of the hydro char for methylene blue removal was at 200 °C that recorded the highest percentage, 92.57%.

3.4.2. Effect of Contact Time on the Methylene Blue Removal. The relationship of both adsorption capacity and time taken was utilized to investigate the impact of the contact time between the hydro char
with the MB solution on the removal ability of the hydro char. Three different reaction temperature was used, 150 °C, 170 °C and 200 °C respectively. Figure 3 (a-c) shows three different HTC temperatures yield about the same trends whereas the contact time of the hydro char and MB was longer, the adsorption capacity increases steeply at the beginning and reached a stable increment at 6 hrs time onwards. The solution contained hydro char was placed in the water bath and shaken moderately and continuously. The hydro char able to adsorb the MB vigorously at the beginning of the process as the pores and adsorption site of the adsorbent were abundantly available for adsorption to occur. However, as the time of the hydro char been contacted with the MB solution increases, the hydro char reach the limit to adsorb which also known as an equilibrium limit. This was the reasons why the adsorption capacity was constant at the end of the duration. For all the HTC temperature 150 °C, 170 °C, and 200 °C, it was indicated at high concentration of MB solution of 200 mg L⁻¹, the removal capacity of the hydro char recorded the highest percentage as compare to 50 mg L⁻¹. At low concentration of 50 mg L⁻¹, the hydro char only required to adsorb low amount of the MB concentration thus yield low percentage of removal which contradicted to higher concentration of MB that results greater adsorption efficiency. Thus, for all the HTC reaction temperature, adsorption capacity of hydro char increases as the contact time increases and reached a steady state due to its adsorption limitation. The average adsorption capacity at the end of reaction for all hydro char that formed at 200 °C were 5.59, 14.76, 22.91 and 31.57 mg g⁻¹ for initial concentration of 50, 100, 150 and 200 mg L⁻¹ respectively. The highest adsorption capacity equilibrium at 200 mg L⁻¹ MB concentration was recorded at temperature of 200°C, 36.89 mg g⁻¹. To add on, the adsorption capacity at time of 24 h, \( q_e \) was also indicated as the adsorption capacity at equilibrium, \( q_e \) as the capacity reached the equilibrium point at time of 24 h. It would explain why the experiments stopped at 24 h, as even if it is prolonged, the capacity will remain the same or decreased between the range.

### 3.4.3. Batch Adsorption at Equilibrium Studies

The adsorption capacity at equilibrium increases as the carbonization temperature increase for all initial concentration, \( C_0 \) from 50 to 200 mg L⁻¹ which clearly displayed by figure 4 (a-d). However, at \( C_0 \) of 200 mg L⁻¹, the capacity at equilibrium slightly show a fall as compared to 180 °C as the \( q_e \) recorded was 37.12 mg g⁻¹ then decrease to 37.03 mg g⁻¹, respectively. Thus, it is indicated that carbonization temperature of 170 °C was the most optimum temperature for the adsorption of the hydro char since the highest amount of adsorption capacity obtained at this temperature.
Figure 3. Adsorption capacity of hydro char produced at (a) 150 °C, (b) 170 °C and (c) 200 °C with varied contact time.
4. Conclusion
Hydro char produced from papaya peels via hydrothermal carbonization has demonstrated promising result as adsorbant for methylene blue removal. From physiochemical characterization, it is obvious that the mass yield greatly influenced by the carbonization temperature. Mass yield also reduced when the papaya peels undergo HTC. This is due to the fact that the lignocellulosic feedstock content, mainly hemicellulose and cellulose undergo a decomposition throughout HTC process. Also, as the carbonization temperature increases, the carbon content in the hydro char also increase. This is because of the condensation and aromatization reaction during the hydrothermal carbonization process of the feedstock biomass. The higher heating value (HHV) of the hydro char was analysed and it shows a trend where, the higher the temperature, the higher the HHV can be seen. Moreover, as the temperature increase, the percentage removal of methylene blue also increases. Besides, the adsorption capacity also increases drastically at first and then gradually increase until reach at the equilibrium point where the hydro char already reaches its maximum point to adsorb the MB solution. Lastly, both yield and properties showed that HTC process was an appropriate approach to convert the papaya peels to a carbonaceous product, hydro char. The hydro char also executed a decent adsorption ability and it can undergo further activated or advancement in order to be utilized as one of adsorbent to reduce the amount of contaminant in wastewater to lower the water pollution in Malaysia.

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