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BIOMASS ACTIVATED CARBON PROPERTIES THROUGH ACTIVATION METHOD FOR SUPERCAPACITOR – A MINI-REVIEW

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Abstract

Recently, the development of activated carbon electrodes from agricultural waste biomass for application in carbon-based electrode of supercapacitor is increasing. The use of agricultural waste biomass as a precursor for the production of activated carbon become popular because it is economical, easily available and also beneficial in reducing waste disposal problem in agricultural industries. In this review, the biomass material for activated carbon using various activators is presented. The effects of activating methods which is physical and chemical activation on the properties of activated carbons are reviewed. Carbonaceous materials with high surface area, which is above 1000 m^2g^{-1} and good porosity with total pore volume approximately 1.0 cm^3g^{-1} promote fast ion-transport, making them an ideal choice to be used in supercapacitor. Previous study had shown that different types of activation method influence significantly on the properties of activated carbon produced. Producing a high porosity and high surface area of activated carbon are essentials to fabricate a high quality of supercapacitor. With proper treatment, it is found that many agriculture wastes have high potential and carry good properties as an electrode in supercapacitor.

Keywords: Activated carbon, biomass, electrodes, supercapacitor, renewable energy.

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Introduction

Nowadays, the pollutant of the environment keeps on increasing due to human and social interaction especially, the biomass material. This is due to the abundance production to meet the human needs such as agriculture corp residue, forestry residue and wood processing residue. According to previous researchers (Ahmed et al., 2018) with the ongoing pollution, investigators are trying to find new alternatives on how to handle the problem by an ecofriendly solution. Turning the pollutants into activated carbon is among of the safest and most beneficial method. Khalil et al., (2013) claim that activated carbons were applied since ancient age and have important performance in a lot of fields. Transformation of the biomass material into activated carbon shortened the expenditure of the waste materials and also contributes to economic alternative (Saygili & Guzel, 2016; Dhelipan et al., 2017). This transformation of the biomass into activated carbon was aligned with the increasing of technology in the present age. Beside the usage of activated carbon as adsorbent to purify liquids and gases, it also plays a great role as electrodes in different energy storing devices. The technology nowadays is experiencing great progress in approaching the revolution changed to our community and together with the serious development of environmental concern due to the heap of plastic waste and electronic. The light, compact and moveable electronic create phenomenal growth in the past decades. These consequences have attracted the investigators to develop adaptable energy storage gadgets, for examples fuel cells, batteries and supercapacitors.

Previous researcher, (Senthilkumar & Selvan, 2013) stated that it is common knowledge that carbon which is activated carbon, conducting polymers and metal oxides are broadly review as electrodes for supercapacitor. Supercapacitors can reserve and provide energy at a rapid speed that supplies high current in a limited time (Pagketanang et al., 2015; Bhat et al., 2019). Other researchers, (Mensah et al., 2019) had observed that supercapacitors bring lots of benefits. Supercapacitors can survive in intense temperature, which is better than batteries. Due to the charge memorizing apparatus, supercapacitors are competent at extended cycling period (Ahmed et al., 2018; Ghosh et al., 2019; Mensa-darkwa et al., 2019). It had been stated that supercapacitors had a cycling period of more than 500000 which is greater than other memory technologies. Thereby, producing a high porosity and high surface area of activated carbon are essentials.

Methods

Preparation of activated carbon

Activated carbon was one of the most well-known methods that were used in the Electric Double Layer Capacitor (EDLC) because it is economical and not polluting the environment. With the profusion of micropores activated carbons are comprehensively utilized for the absorption of little particles contaminants. Based on Kumar et al., (2016) the elements like raw substances, the activation approach, activating agent and requirements of activation process influence the physical and chemical characteristic of activated carbons. The raw substances was collected from various sources mainly from agriculture waste and washed by deionized water to remove any residue on the surface. Then, the raw substances were dried overnight before crushed into powder. After that, activated carbons were developed through two procedures which are physical and chemical activation. This stage will be elaborated in next session. Both characterizations were treated at different temperatures which are at high and low temperature respectively.

Physical activation

In physical activation, it involves the activation agent such as air or carbon dioxide and predecessor of the carbonization in an inert of environment. The stage of carbonization includes the process of pyrolysis at a certain temperature which are from 400 ºC to 500 ºC and at an inert environment that heads to the accomplishment of established carbon. It was then positioned at high temperatures which are range from 800 ºC to 1100 ºC by the existence of oxidizing agents like carbon dioxide, water or air. The formation of the porosity on the surface of the activated carbon is influenced by the activating agent during the activation process. The agricultural wastes studied by this method are coffee endocarp (Nabais et al., 2008), corncob (Aworn et al., 2008) and date stones (Chafia et al., 2018).

Chemical activation

As for chemical activation, the predecessor was combined with some quantity of active agents. For instance, potassium hydroxide (KOH), Sodium hydroxide (NaOH), phosphoric acid (H_3PO_4) and Zinc Chloride ($ZnCl_2$) that head to the form of porous configurations in the substantial. Based on all of the active agents, the most favored is phosphoric acid due to the atmosphere and financial matter lately. Although the zinc chloride is being compared with phosphoric acid, the phosphoric acid still the most favored since there is an inadequate chemical restoration that effects the environment. This claim was supported by Sivachidambaram et al. (2017) and Ahmed et al. (2018). Phosphoric acid enables the activated carbon progress of mesopores and micropores. The procedure of chemical activation was conducted at a lower temperature than physical activation method, which is below 800 ºC. The activating agents work as dehydrating agents that prevent the creation of tar and also the unstable matter throughout the procedure. It supports the yield of porous carbon to assist and also lower down the activation temperature and time. The agricultural wastes studied using this method is rotten carrot (Ahmed et al., 2018), orange peel (Dhelipan et al., 2017) and baobab fruit shell (Vunain, 2017). There are some studies that combine both physical and chemical activating process as summarize in Table1.

Table 1. Preparation of activated carbon using different types of activation methods.

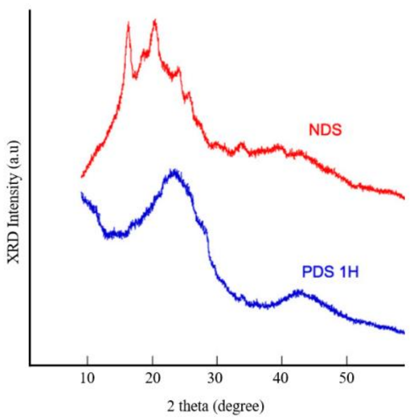
Biomass	Activation method	Activating agent	Reference
Coffee endocarp	Physical	Co_2, steam	(Nabais et al., 2008)
Corncob		Steam & Co_2	(Aworn et al., 2008)
Date stones		Steam	(Chafia et al., 2008)
Rotten carrot	Chemical	$ZnCl_2$	(Ahmed et al., 2018)

Orange peel		H_3PO_4	(Dhelipan et al., 2017)
Baobab fruit shell		H_3PO_4	(Vunain, 2017)
Cassava Peel	Physical and Chemical	KOH and CO_2	(Ismanto et al., 2010)
Coconut shell		KOH and CO_2	(Azam et al., 2009)
Oil palm empty fruit bunch		KOH and CO_2	(Farma et al., 2013)

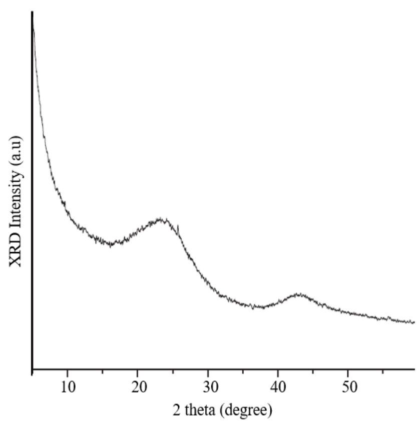
Result and Discussion

X-Ray Diffraction (XRD)

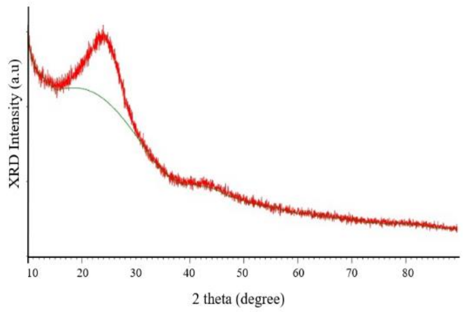
XRD is a technique used to determine the existence of carbon in activated carbon. Figure 1 shows the various diffraction peaks by different biomass. From XDR pattern of the pyrolysed date stones, it may be seen that the effect of the pyrolysis process is significant. The date stone diffraction peaks obtained at $2\theta = 16.3^o$ and 20.60^o disappear due to the decomposition of cellulose and hemicellulose during the thermal treatment. After pyrolysis, it remains only two broad diffraction peaks at around 23.5° and 43°, which could be attributed to the presence of carbon and graphite. Based on Ahmed et al. (2018), the activated carbon from rotten carrot was scanned and the pattern was viewed with two peaks at 23.5^o and 43.1^o. These peaks arise due to high-temperature treatment (600–900 °C), employed during the activation process. The use of such high temperature boosts the formation of the graphitic carbon structure. This leads to production of a adequate amount of graphitization that clearly confirms that the rotten carrot has been continuously converted into amorphous and partially graphitic carbon. The amorphous nature of the sample is depicted by the broadness of the observed peaks. Besides that, the pattern generated for orange peel activated carbon (Dhelipan et al., 2017), was at 22.57^o and 42^o. A similar broad XRD peaks were observed indicates that carbon is highly amorphous. This finding was agreed with Ahmed et al. (2018) and Xie et al. (2014). Lastly, the pattern produced by the raw baobab fruit shells and the activated carbon form display good peak around 20^o -30^o indicating the existence of carbonaceous materials (Vunain, 2017). Based on the above findings, it is shown that the great temperature conducted which is around 700 ºC were raised the graphite carbon construction where it can be seen clearly in XRD broad peaks. At this temperature the raw material was faster to release volatile matters from the char. Nevertheless, the whole graphitization takes place at maximum temperatures. The graphitization of the substantial fully reiterates that it had been transformed into graphitic carbon successively.



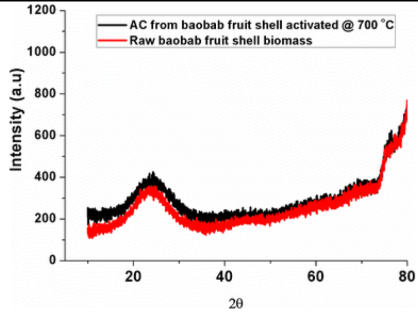
(a) XRD patterns of natural (NDS) and pyrolysed (PDS 1H) date stones (Chafia et al., 2008).



(b) XRD pattern by activated carbon from rotten carrot (Ahmed et al., 2018).



(c) XRD pattern by activated carbon from orange peel (Dhelipan et al., 2017).



(d) XRD pattern of baobab fruit shell (Vunain, 2017).

Figure 1. Diffraction peaks of XRD by different biomass.

Brunauer Emmet Teller (BET)

BET was utilized for the surface area of activated carbon. The apertures of the activated carbon have variable formed and diameters due to the outer surfaces. The surface areas were decided at variable temperatures for the activated carbon between 600 ºC to 800 ºC. The finding shows that the increasing in the carbonization temperature gives rise to decreasing of pore volume and surface area. As mention by Ahmed et al., (2018) in his research the specific capacitance values are directly proportional to the surface area. As the activated carbon undergone activation process with 700 ºC offers the best porous characteristics. This statement is also proved by other researchers (Xu et al., 2010; Liu et al., 2010). Proper treatment of carbonization and different types of activation methods also lead to certain range of surface area and pore size on activated carbons. Table 2 summaries the characteristic of activated carbon at variance condition. From previous study, Nabais et al. (2008) said the steam activation has higher activation rate than the CO_2 activation. The CO_2 activation leads to samples with higher BET surface areas and pore volumes when compared with samples produced by steam activation and with similar burn-off value. From these results, it is shown that the properties of activated carbon are most advantageous when undergone combination of physical and chemical activation with higher surface area and great total pore volume. The other properties of activated carbon such as electrochemical properties, mainly the value of capacitance is not discuss in this paper as the activated carbon is sand alone and not assemble in electrolyte yet.

Table 2. Characteristics of activated carbons produced at optimum condition.

Biomass	S_{BET} (m^2g^{-1})	V_{tot} (cm^3g^{-1})	V_{micro} (cm^3g^{-1})	V_{meso} (cm^3g^{-1})	Reference
Coffee endocarp	CO_2:1287	0.64	-	-	(Nabais et al., 2008)
	steam: 630	0.35	-	-	
Corncob	CO_2: 836	0.4258	0.3850	0.0408	(Aworn et al., 2008)
	steam: 675	0.3590	0.3590	0.0373	
Date stones	635	-	0.716	-	(Chafia et al., 2008)
Rotten carrot	1154.99	0.9294	-	-	(Ahmed et al., 2018)
Orange peel	508.68	0.088859	-	-	(Dhelipan et al., 2017)
Baobab fruit shell	1089	0.4330	0.3764	-	(Vunain, 2017)
Cassava Peel	1352	0.579	-	0.356	(Ismanto et al., 2010)
Coconut shell	1026.0	0.5768	-	-	(Azam et al., 2009)
Oil palm empty fruit bunch	1704	0.889	0.62	-	(Farma et al., 2013)

Conclusion

There were a lot of biomass materials that had been successfully prepared to become activated carbon. However, the performances of the agriculture waste biomass activated carbon are influenced by several aspects such as the preparation techniques, activation approach, activating agent and requirements of activation process influence the physical and chemical characteristic of activated carbons. Hence, the results revealed that there are differences of activated carbon properties depending on the different types of activation method and activation temperature. To sum up, the combination of both chemical and physical activation leads to samples with higher surface area and pore volume. The highest BET surface area was achieved when the biomass waste undergo both chemical and physical activation with a surface area. It is also found that the activator agent also play some rule in yielding good properties of activated carbon and KOH has attracted attention because it is more friendly to the environment. However, this review is mainly focus on the surface area and pore volume properties of biomass waste. The author recommend to adding several qualitative properties of electrochemical properties such as capacitance and surface morphology of activated carbon for future study.

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