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Effects of chemical impregnation agents on the characterisation of porosity and surface area of activated carbon prepared from sago palm bark

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ABSTRACT

Unprocessed sago palm bark (SPB) is a material that has been newly utilised for preparations of activated carbons (AC), using physicochemical activation techniques comprising dual carbonisation and activation phases. Activations have been conducted utilising three agents: sulphuric acid (H_2SO_4), potassium hydroxide (KOH), and zinc chloride (Z_nCl_2). Characterisations of the porosities of AC preparations were performed using N_2 adsorption-desorption to ascertain BET and micropore surface areas as well as micropore volumes and pore-size distributions. Existing groups on the AC surfaces were resolved using Fourier Transform Infrared Spectroscopy (FTIR) analyses. The morphologies of the activated carbons were assessed via scanning-electron microscopic methods (SEM) combined with energy-dispersive X-ray spectroscopic techniques (EDX). The maximal surface areas (1639.34 m^2/g), pore volume (0.649 cm^3/g), micropore volume (0.335 cm^3/g), and micropore surface area (1,148.58 m^2/g) of the prepared AC using sago palm bark were discovered at activation temperatures of 700^oC and with chemical impregnation ratios of 1.51/ zinc chloride to precursors. In the instance of KOH and H_2SO_4 utilisation, the surface areas of the AC preparations corresponded to 970.38 m^2/g and 630.73 m^2/g with pore volume of 0.458 and 0.196 cm^3/g, respectively.

Keywords: sago palm bark, activated carbon, activation agent, porosity characterisation.

INTRODUCTION

The treatment of wastewaters involves numerous sustainable technology advances comprising biological, chemical, physical, and physicochemical approaches. Activated carbons (AC) are among the most broadly used substances in adsorptive removals of inorganic and organic contaminations and impurities from wastewaters as a result of their highly porous microstructures, large interior surface areas, and porosities (Mezohegyi et al., 2012). Much research has been recently conducted in order to synthesise more effective material types with lower costs and greater local availabilities as precursor materials for activated carbon manufacture (Momčilović, et al., 2011). Agro-industrial by-products are seen as superior sources in the synthesis of activated carbons due to available and abundant supplies (Li et al., 2009). Among agro-industrial outputs, some of the most common unprocessed material types are palm oil wastes (Hamad et al., 2010; Hameed et al., 2007; Ahmed et al., 2012), coconut shells (Li et al., 2008; Phan et al., 2006; Kirubakaran et al., 1991), date palms (El Nemr et al., 2008; Haimour et al., 2006), rice husks (Bishnoi et al., 2004), wood fibres (Matos et al., 2011; Diaz et al., 2004; Danish et al., 2011; Danish et al., 2012), and bagasse (Inyang et al., 2011). Some recent studies reported on how to use waste materials for recylcing purposes (Mia et al., 2018; Imteaz et al., 2018; Imteaz et al., 2017; Hainin et al., 2014; Daud et al., 2016). Many studies were conduced on electrolysis, biofilter and activated carbon preparation and utilization to treat wastewater and landfill leachate (Ahsan et al., 2014a; Ahsan et al., 2016; Erabee et al., 2018a & b; Erabee et al., 2017a, b, c & d; Tadda et al., 2016; Shaheed et al., 2015; Khaleel et al., 2015; Daud et al., 2015a & b). Many researchers studied on how to manage waste properly and how to use waste materials for energy recovery, production of biogas and biomass energy; and for reduction of greenhouse gases (Ahsan et al., 2014b; Ahsan et al., 2015; Rosli et al., 2016; Huda et al., 2014; Arafat et al., 2015; Shams et al., 2017).

Both chemical and physical processes can be utilised in AC production (Bansal and Goyal, 2005), although each requires the application of higher temperatures.

Physical activation processes require the carbonisation of precursors at a range of temperatures from 200°C to 950°C, depending on the precursors used (Pahan et al., 2006; Srinivasakannan et al., 2004). Gaseous agents for activation including argon, steam, nitrogen (N_2), and carbon dioxide (CO_2) are utilised in this phase in the pyrolisation of precursors.

In the course of chemical activations, adsorbent compounds are added to mixtures of chemical activation agents including potassium hydroxide (KOH), phosphoric acid (H_3PO_4), and zinc chloride (Z_nCl_2) (Corral et al., 2006; Guo et al., 2002). Upon completion, heat is applied to the precursors at lower activation temperatures of no more than 800°C.

In chemical activations, both carbonisations and activations occur at the same time. Precursors are mixed with activation agent compounds to induce oxidisation and dehydration at lower temperature ranges. These agents lower the amount of ash in the carbonised output and enlarge surface areas with characteristically higher porosities (Rodriguez-Reinoso and Molina-Sabio, 1992). Table 1 presents the different precursor and activation agents utilised in the synthesis of activated carbons from diverse raw by-products.

This study aimed to prepare activated carbon with high porosity characterizations from low cost and highly cellulosic agricultural waste used for the first time as an adsorbent, which is sago palm bark. This surface area precursor leads to increase the removal efficiencies for most of organic and inorganic contaminations in wastewater, contributes in the reduction of treatment cost, saves energy, and helps in protecting the environment.

Table 1: Different types of precursors and activating agents used in AC production.

Precursor	Activating agent	Carbonisation temperature (°C)	Surface area (m^2/g)	Source
Bituminous coal	Z_nCl_2	600	960	(Hsu et al., 2000)
Bituminous coal	KOH	800	3300	(Hsu et al., 2000)
Chestnut wood	H_3PO_4	500	783	(Gomez-Serrano et al., 2005)
Coconut shells	Z_nCl_2	560 W (Microwave radiation)	794.84	(Deng et al., 2009)
Cotton stalks	H_3PO_4	420	834	(Girgis et al., 2009)C
Date pits	Z_nCl_2	550	1172	(Belhachemi et al., 2014)
Date pits	CO_2	825	1359	(Belhachemi et al., 2014)
Fox nut	Z_nCl_2	500	2136	(Kumar & Jena, 2015)
Fox nut	Z_nCl_2	600	2869	(Kumar & Jena, 2015)
Fox nut	Z_nCl_2	700	2520	(Kumar & Jena, 2015)

H_3PO_4, Z_nCl_2, and alkaline metallic substances including KOH are widely utilised as activation agents for activated carbon preparations (Srinivasakannan et al., 2004). H_3PO_4 exhibits less toxicity than the others and is readily recoverable through water washing (Deng et al., 2009). The primary benefit of Z_nCl_2 is its broad and efficient utilisation in activated carbon preparations (El Qada et al., 2008). KOH usage necessitates increased ranges of temperatures in the course of activations than in the cases of Z_nCl_2 and H_3PO_4, as a result of the gasification reaction effects in KOH. Chemical reactions between precursors and KOH are described in the following equation (El Qada et al., 2008):

$$2K0H_{(S)} + C_{(S)} \rightarrow 2K_{(S)} + H20_{(g)} + 3CO_{(g)} \tag{1}$$

The application of excessively high activation temperatures in the preparation of activated carbons can result at times in lesser adsorption capacities in the compounds. It was discovered by Aber et al. (2009) that increases in the range of activation temperatures of up to 700°C resulted in higher adsorption capacities. Further increases of up to 750°C progressively lessened the adsorptive abilities of the activated carbons. The influence of activation times on the adsorptive capacities through optimisations of activation times limited to two hours was also researched by Aber et al. (2009). The outcomes demonstrated that excessively increased activation times resulted in progressive collapses of micropore wall elements and enlarged pore sizes. Extended activation times of four hours resulted in lesser activated carbon adsorptive capacity.

The comparatively new techniques of physicochemical activations are courses of processes that combine dual physical and chemical methods in the preparation of activated carbons. Previously presented activation courses are used in this approach to evolve micropores. The approach produces compounds with greater surface areas compared to those produced with physical or chemical processes (Aber et al., 2009; El Qada et al., 2008). Palm frond materials were used as unprocessed sources by Salman et al. (2010). Physicochemical activations were utilised by employing CO2 as physical agents and KOH as chemical agents. Preparations involve carbonisations at 700°C for two hours and the maintenance of a 10°C/min rate of heating subject to N_2 flows, with subsequent immersion in KOH solutions featuring varied impregnation ratios. For the final phase, activations were performed in CO_2 atmospheres at varying temperatures and intervals. Optimal values for impregnation ratios and activation temperatures and times corresponded to 3.75, 850°C, and one hour. Carbon yields of the optimally prepared compounds averaged 21.6%, with BET surface areas averaging 237.13 m^2/g.

Pistachio shell material was reportedly used as unprocessed sources by Hu et al. (2007). Physicochemical as well as chemical activations were utilised by employing corresponding $KOH–CO_2$ and KOH agents. Chemical activation at 780°C for one hour resulted in surface areas averaging 1,013 m^2/g. However, activations using CO_2 led to enlarged activated carbon surface areas of up to 2,145 m^2/g, demonstrating a doubling in surface areas using physicochemical activation compared to those using chemical methods.

Sago palm bark (SPB) is an economically significant crop of the three top Southeast Asian producers—Indonesia, Malaysia, and Papua New Guinea. The crops are a renewable source of lignocellulosic materials (Ethaib et al., 2016) utilised in the manufacture of sago starches. More than 20,000 tons is disposed of every year by the Malaysian sago starches industry. Sago crops grow well in tropical lowland areas of high humidity and feature maximal plant diameters of around 40 centimetres and heights of about 25 metres (Singhal et al., 2008). Sago palm bark is Malaysia's primary source of carbohydrates, with corresponding 60% and 70% cellulose and hemicellulose contents (Ethaib, et al., 2016), which are significant in activated carbon preparation.

EXPERIMENTS

ACTIVATED CARBON PREPARATIONS UTILISING SAGO PALM BARK (SPB)

Sago Palm Bark (SPB) materials were procured from native plantations in Melaka, Malaysia, for use in preparations of activated carbons. Sago palms are species of the genus *Metroxylon* of the Palmae family, with maximal plant diameters of around 40 centimetres and heights of about 25 metres (Singhal et al., 2008). Sago palm bark materials are primary sources of carbohydrates in Malaysia, with corresponding 60% and 70% cellulose and hemicellulose contents (Ethaib et al., 2016).

Preparations of precursors initially involve removals of inner-part pith from the trunks of sago palms in order to acquire the outer-layer fractions of bark, followed by dehydration of the gathered materials at 105°C temperature over a 24-hour period. The dried sago palm bark materials were then sliced and separated into smaller portions from 20 mm to 30 mm in size and sealed in plastic bags for storage at a 20°C temperature for later usage.

Smaller bits were ground and mashed with ball mills, and ground samples were subsequently sieved to acquire particles of between 0.3 mm and 0.6 mm in size. Activated carbon preparations involve dual phases as described; after 10 g samples were collected, the first preparatory phase of carbonisation was commenced. Samples were moved to a stainless-steel cylindrical reactor that was closed at one end and which featured at the opposite end a detachable lid with a 2 mm diameter opening at its centre, to enable venting the pyrolytic gas and vapour discharges. The reactor was then introduced into a horizontal electrically powered cylindrical furnace with a diameter of 50 mm and a length of 800 mm that was subject to constant nitrogen flows at 100 mL/min. Heat was applied with adjustments of furnace temperatures until desired values were reached. Between 2 and 2.5 hours passed before the desired interior temperature was attained, with an average rate of heat increase of 10oC per minute. Carbonisation temperature was set at 300oC, with the reaction duration fixed at four hours. Measurement of the carbonisation interval began at the point when the required temperature was attained and not from the point when heat was first applied. Once cooled down to ambient temperatures and while subject to the continuing nitrogen flows, samples were removed from the interior and left to cool. Each carbonised sample taken from the reactor was stored in a plastic bottle with attached label.

In the following phase of activation, the carbonised samples were activated with various chemical agents including H_2SO_4, KOH, and Z_nCl_2. Impregnations were performed at ambient temperatures in cylindrical flasks stirred with heated magnetic agitators. The agitation ensured that the interiors of the particulate precursors would be accessible to the impregnates. The chemical agents and precursors were completely mixed over a 24-hour mixing period, and then the sample mixtures were dehydrated in ovens at a 100oC temperature over a further 24-hour drying period. Once dried, the impregnated materials were introduced into a cylindrical regulated furnace, with the activation temperature and duration set to 700oC and one hour, subject to constant nitrogen flows at 100 mL/min. Once cooled down to ambient temperatures while continuing to be subject to nitrogen flows, heated distilled water was used to completely wash activated carbon samples removed from the interior, until neutral PH were obtained. The samples were then dehydrated overnight at a 100oC temperature and eventually stored in a desiccator for later usage. A schematic illustration of the preparation and activation phases for activated carbons is presented in Figure 1.

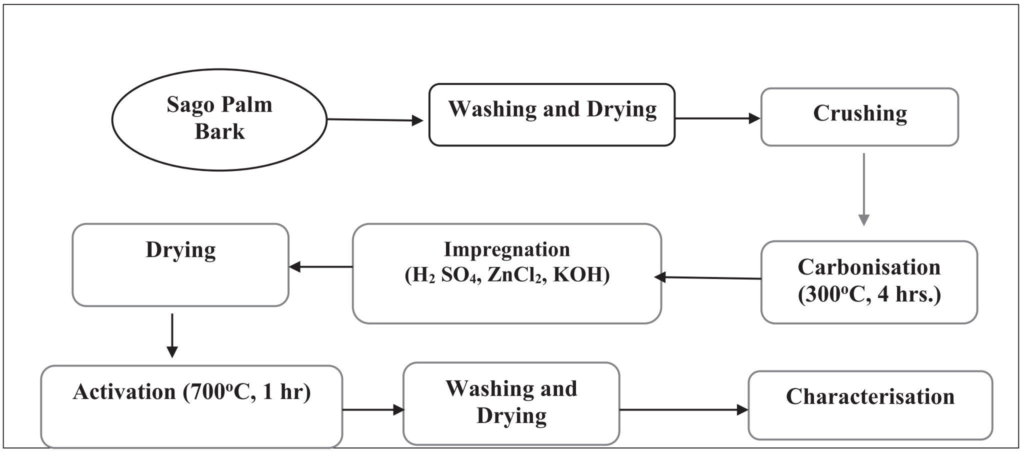


Figure 1. Schematic diagram of preparation of AC from SPB.

The formulated course of activations of SPB materials with H_2SO_4 concentrations has been attained, resulting in activation of agent-to-precursor impregnation ratios of around 151/ (Niu, Li, Ma, He, & Li, 2015) at a 700°C temperature over a 2-hour holding period.

CHARACTERISATION OF PRECURSORS

A critical aspect that determines the choice of precursors concerns the structures of raw materials. SPB chemical structures mostly comprise celluloses, hemicelluloses, lignins, and ash (Van Soest et al., 1991). Chemical analyses of elemental concentrations in SPB were conducted with Energy-Dispersive X-Ray Spectroscopic (EDX) techniques via NORAN System 7 X-ray Microanalyses (Thermo Scientific, USA). Tests of SPB ash contents were conducted with XRF (EDX-720 Fluorescent Spectrometer, Shimadzu, Japan).

MEASUREMENTS OF MOISTURE

Moisture amounts were determined by the oven-dry method of testing in accordance with ASTM D286709- (Gottipati, 2012). An activated carbon sample is placed inside an enclosed dry capsule of known mass and then weighed. The casing is then unsealed and placed with its cover in a dehydrating oven at a range of temperatures from 145oC to 155oC. Once dried, the capsule is taken from the oven with the cover sealed and left to cool to ambient temperatures. The entire casing is then weighed once more, with the percentage variation between weights indicating the sample's moisture content.

YIELD

The activated carbon's yield is calculated by dividing the percentage weight of the resultant activated carbon following carbonisation with the dried weight of raw material.

$$\text{Yield (\%)} = \frac{\text{weight of AC after carbonisation}}{\text{weight of the raw material}} \text{ x } 100 \tag{2}$$

THERMOGRAVIMETRIC ANALYSIS

An approximation regarding the weight loss corresponding to the temperature is obtained by performing thermogravimetric analysis (TGA) of the raw material. A thermogravimetric analyser (SDTA851e, Mettler Toledo, Switzerland) was employed to conduct TGA of the raw material. The sample was then heated at the rate of 10°C/min from 25°C to 800°C.

POROSITY CHARACTERISATION

The characterisation of porosity includes determining the total pore volume (V_{tot}), prepared activated carbon's surface area, and pore size distribution with the help of N_2 adsorption-desorption isotherms at -195.6°C by employing an automatic adsorption instrument. The Brunauer, Emmett, and Teller (BET) method was selected to analyse the sample's surface area (S_T) over a relative pressure range of 0.01–0.3 (Brunauer et al., 1938).

The calculation of total pore volume (V_T) was based on the total volume of N_2 gas adsorbed under high relative pressure (0.995) (Sricharoenchaikul et al., 2008).

The Dubinin–Radushkevich (DR) equation (McEnaney, 1987) was followed to determine the micropore surface area (S_{mi}) and microvolume (V_{mi}).

ANALYSIS OF SURFACE CHEMISTRY

Fourier Transform Infrared (FTIR) spectroscopy was used to determine the surface functional groups of the prepared AC. It was recorded between 400 and 4,000 cm^{-1} for different samples.

SCANNING ELECTRONIC MICROSCOPY (SEM) AND EDX ANALYSIS

A scanning electron microscopy (SEM model S-3400 N, Hitachi, Japan) was employed to detect the morphology of AC. This technique was combined with Energy Dispersive X-ray (EDX) spectroscopy to perform elemental analysis of the AC.

RESULTS AND DISCUSSIONS

Low-cost feed stocks that were easily available were used in the production of activated carbon. Researchers have extensively used lignocellulosic materials such as coconut shells, apricot stones, palm stones, and nutshells. In this study, sago palm bark was the new raw material employed for the preparation of activated carbon along, with date pits and garden waste as the two other raw materials. The goal here was to utilise low-cost materials with high surface for the preparation procedure. The physical properties and chemical composition of these three raw materials (sago palm bark, garden waste, and date pits) are shown in Table 2. A CHNS analyser was employed to conduct the final analysis. The procedures described in the previous chapter were followed to carry out the proximate analysis.

Table 2. Comparison of chemical and physical properties of precursors.

Property	Coconut shell	Sago palm bark
Chemical composition (%)	(Gottipati, 2012)	
Cellulose	19.82	44.13
Hemicellulose	50.07	21.09
Lignin	30.11	23.3
Proximate analysis (%)	(Mozammel et al., 2002)	
Moisture	10.46	9
Yield	-	65
Ash	3.58	1.53
Ultimate analysis (%)	(Yusup et al., 2010)	
C	40.12	45.16
H	2.56	6.306
N	0.61	-0.0144
S	0.23	0.013
O	56.48	48.54

The results reported in Table 2 reveal that the sago palm bark has a low lignin content (23.3%) and a high cellulose content (44.13%) when compared with three other precursors. This plays a crucial factor in the preparation of activated carbon. The final analysis demonstrated that the SPB contained high content of carbon and oxygen (45.16% and 48.54%, resp.) with low sulphur and nitrogen content. This high content of carbon and oxygen in the raw material of sago palm bark indicated that this raw material is a good choice for the preparation of activated carbon, which generally contents of carbon and oxygen as essential elements in the precursor.

The thermogravimetric profile of the raw materials for the three precursors used in the study is presented in Figure 2.

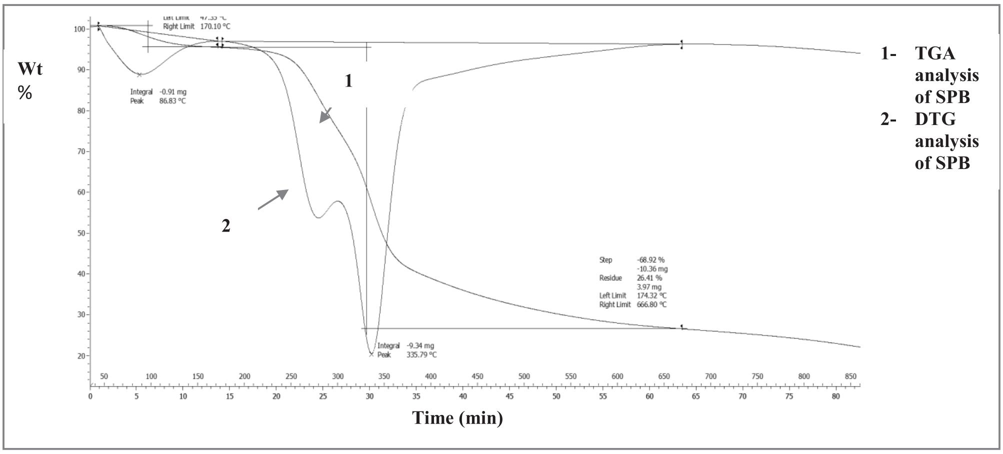
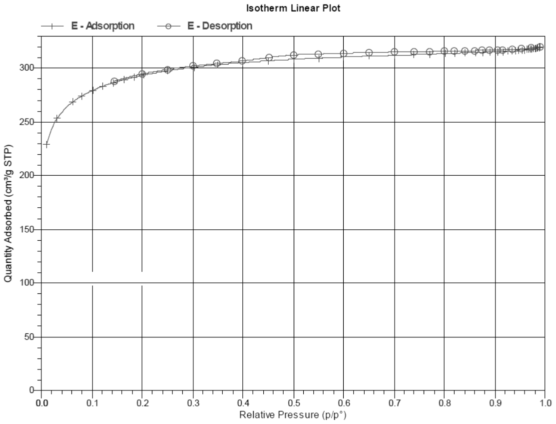


Figure 2. TGA & DTG analysis for raw material of SPB.

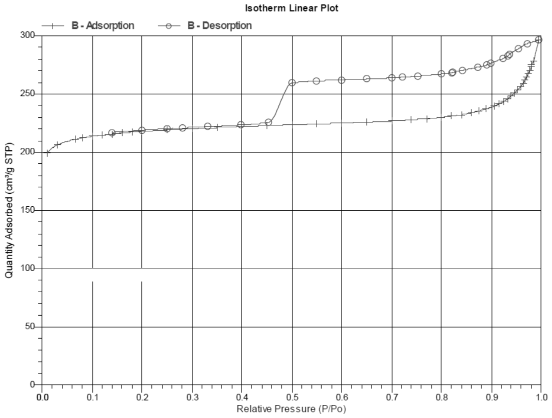
Figure 2 presents the thermogravimetric profile of the raw materials, garden waste and date pits used in SPB. The TGA for SPB was then performed in an environment containing N_2 with temperature ranging from 25°C to 900°C. A heating rate of 10°C/min was maintained in the process. It presents the different stages in the thermal degradation of the SPB sample. Three main stages are involved in the thermal decomposition of SPB. (1) In the first stage, at the temperature range of 25oC–125oC, the elimination of unbounded and bound water molecules in the sample results in weight reduction (Rhim et al., 2010). (2) The maximum weight loss is observed in the second stage, which is due to the main component's thermal degradation, in the temperature range of 150°C–400°C. (3) The third stage is characterised by slow weight loss as a result of higher lignin content present in the sample when the temperature rises above 400°C. The maximum weight loss (68.92%) occurred in the temperature range of 174°–667°C.

NITROGEN GAS ADSORPTION-DESORPTION ISOTHERMS

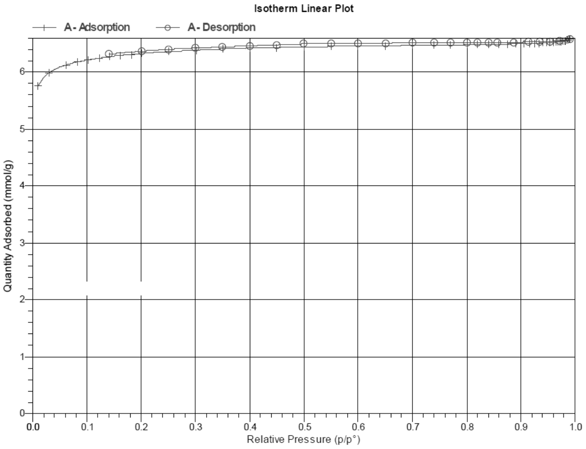
The adsorption–desorption isotherms of N_2 gas for the prepared AC by making use of different activating agents, such as Z_nCl_2, H_2SO_4, and KOH, with different impregnation ratios were employed to evaluate the porous characteristics of the prepared activated carbon. The volume of N_2 adsorbed on AC prepared at different concentrations of Z_nCl_2 is presented in Figure 3.



(a) AC-ZC



(b) AC-KH



(c) AC-HS

Figure 3. N_2 gas adsorption-desorption isotherms of AC-SPB sample prepared using different chemical activation agents (a) AC-ZC, (b) AC-KH, and (c) AC-HS.

Figure 3 illustrates the prepared activated carbon's N_2 adsorption–desorption isotherms from SPB, which employed different chemical activation agents, such as KOH (AC-KH), Z_nCl_2 (AC-ZC), and H_2SO_4 (AC-HS), all of which were activated at 700°C for one hour. From the above figure, it was clear that the volume of the adsorbed N_2 was greater than that of the activated carbon prepared with activation agents when employing Z_nCl_2 as an activation agent with H_2SO_4 and KOH. This is due to the destruction of pore walls as a result of the impregnated precursor with Z_nCl_2.

SURFACE AREA AND PORE VOLUME

Activating agents play a crucial role in maintaining the surface area and the development of porosity. Figure 4 presents the impact of three activating agents (KOH, Z_nCl_2, and H_2SO_4) on the prepared activated carbon's porosity features. The pore volume and the surface area of the prepared AC-ZC were found to be 0.649 cm^3/g and 1,633.94 m^2/g, respectively. For AC-KH, the pore volume and surface area were found to be 0.458 cm^3/g and 970.38 m^2/g. Similarly, the pore volume and surface area of AC-HS were found to be equal to 0.196 cm^3/g and 630.73 m^2/g, respectively. When Z_nCl_2 was used at an impregnation ratio of 1.51/ and activation temperature of 700°C with holding time of one hour, the pore volume and surface area increased in most cases. This may be due to Z_nCl_2 that acts as a dehydration agent during the activation process. That also results in inhibiting the tar formation or, for that case, any other liquids that may clog up the sample's pores (Rodriguez-Reinoso and Molina-Sabio, 1992; Guo and Lua, 2000).

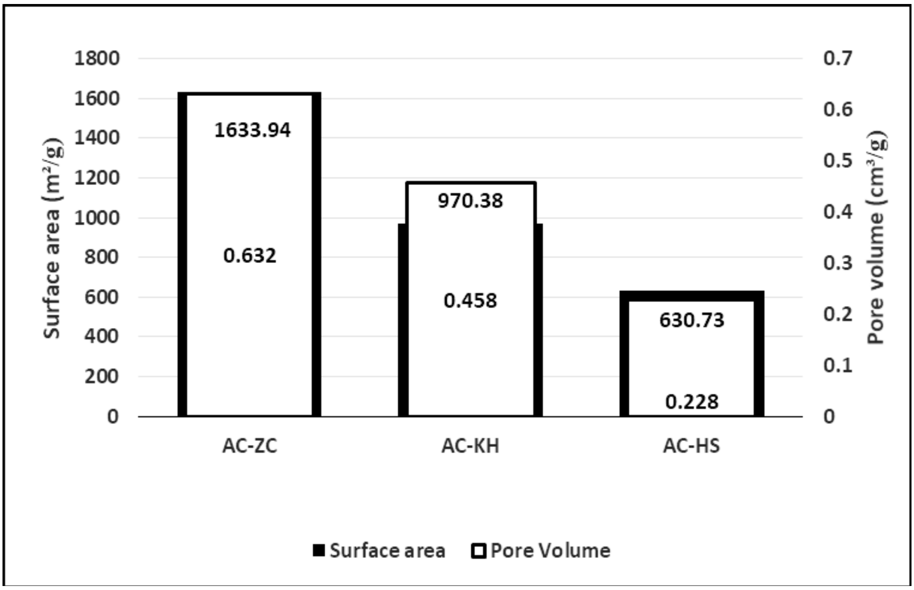


Figure 4. Surface area and pore volume for the prepared AC with different activation agents.

MICROPORE SURFACE AREA AND MICROPORE VOLUME

Figure 5 presents the impact of using different activation agents KOH, Z_nCl_2, and H_2SO_4 on the volume and surface area of the micropore for the prepared AC. AC-ZC displayed the maximum micropore volume of 0.335 cm^3/g and micropore surface area of 1,148.58 m^2/g. Similarly, the volume and surface area of the micropore for AC-KH were 566.63 m^2/g and 0.298 cm^3/g, respectively. In the case of AC-PH, the surface area and volume of the micropore were found to be 372.34 m^2/g and 0.196 cm^3/g, respectively.

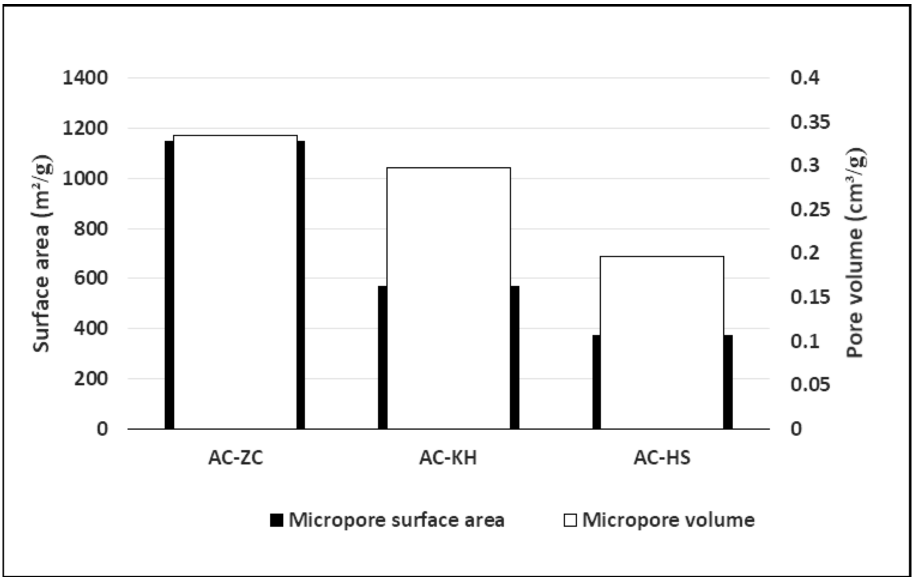


Figure 5. Micropore surface area and micropore volume for the prepared AC with different activation agents.

OPTIMUM CONDITIONS AND COMPARISON

Several chemical activation agents were employed to prepare conditions and compare porous characteristics of ACs from SPB (Table 3).

Table 3. Preparation conditions and comparison between porous characteristics of prepared ACs.

AC type	Impregnation	Carbonisation temperature (°C)	Holding time (hr)	Surface area (m²/g)	Pore Volume (cm³/g)	Micropore surface area (m²/g)	Micropore Volume (cm³/g)
AC-ZC	1.51/	300	4	1633.94	0.649	1148.58	0.335
AC-KH	1/1	300	4	970.38	0.458	566.63	0.298
AC-HS	15/1	400	4	630.73	0.228	372.34	0.196

Table 4 compares the porous characteristics of different ACs prepared using activation agents such as KOH, Z_nCl_2, and H_2SO_4\.

Table 4. Comparison of porous characteristics of prepared AC from different precursors by activation with Z_nCl_2.

Precursor	Surface area (m²/g)	References
Apricot stones	728	Youssef et al., 2005
Tamarind wood	1322	Achrya et al., 2009
Hazelnut bagasse	1489	Demiral et al., 2008
Pistachio nut shell	1635	Lua and Yang, 2005
Rice husk	750	Kalderis et al., 2008
Enteromorpha prolifera	1416	Li et al., 2010
Bael fruit shell	1488	Gottipati, 2012
Sago palm bark	**1634**	**Present study**

FTIR ANALYSIS OF THE PREPARED ACTIVATED CARBON FROM SPB

Figure 6 presents the surface chemistry of the prepared ACs from SPB with Z_nCl_2 activation. The FTIR analysis of the prepared AC is a very simple surface consisting of a considerable number of functional groups. For FTIR of AC, the broad peak between 1,052.11 and 1,512.29 cm^{-1} is a result of the N–H bond. The methylene group (C−H) is responsible for the sharp peak obtained at 2,660.87 cm^{-1}.

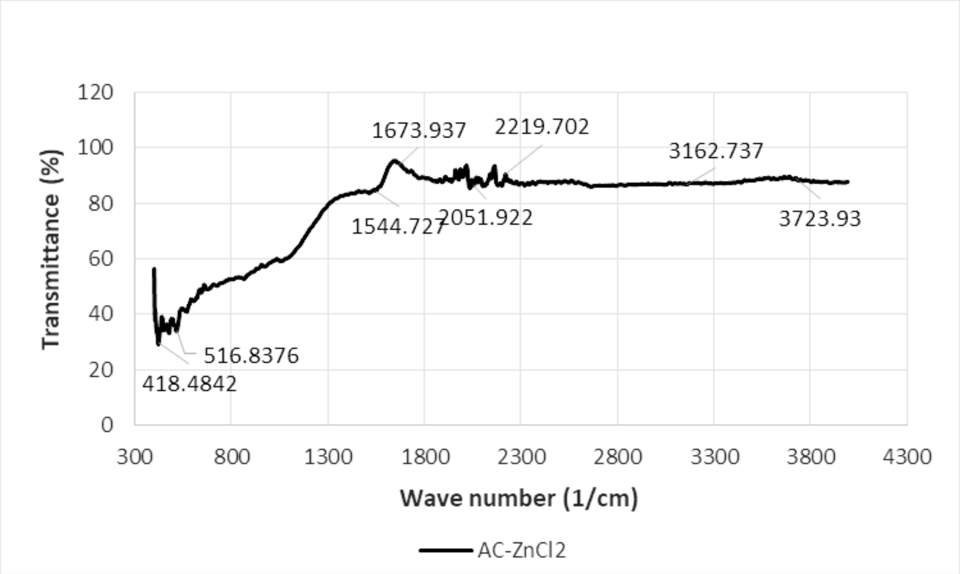
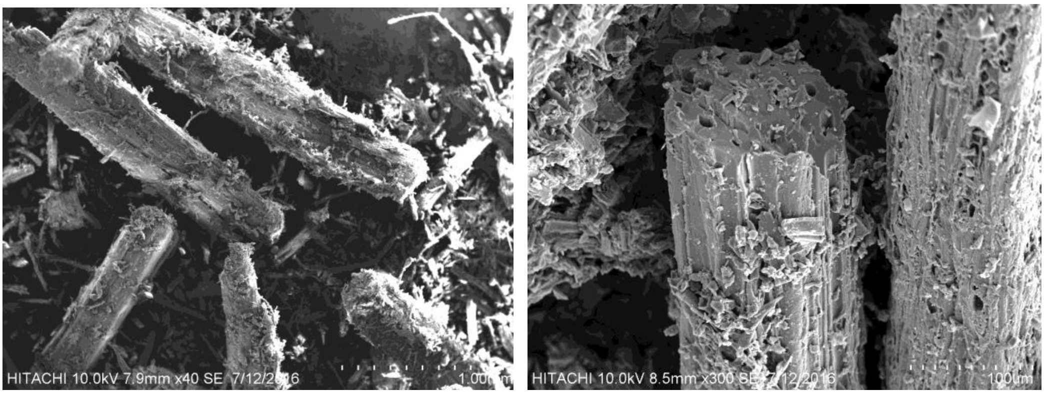


Figure 6. FTIR analysis of AC-SPB activated with Z_nCl_2.

SURFACE MORPHOLOGIES OF SPB AND PREPARED ACTIVATED CARBON

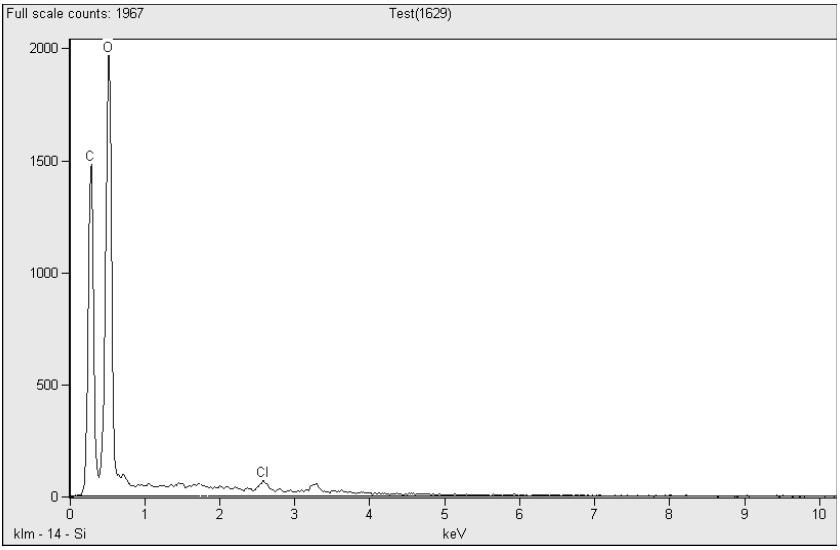
The SEM was employed to evaluate the surface morphology of AC by analysing the surface of the prepared AC (Figure 7). The texture of raw material of SPB was found to be non-porous and rigid (Figure 7a). However, in the case of prepared AC, at higher magnification, a well-developed porous surface was observed, which was considered as channels in the microporous network.



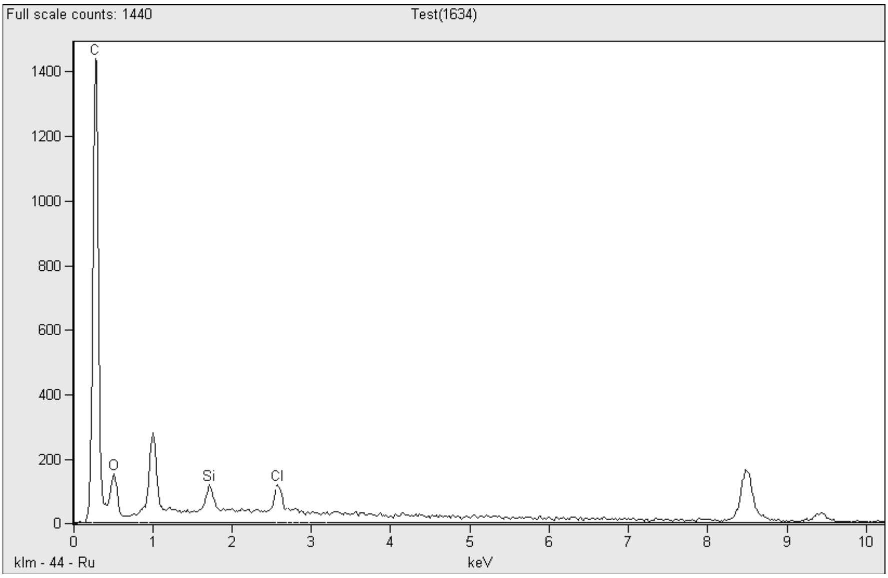
(a) (b)

Figure 7. (a) SEM image of raw material; (b) prepared AC.

Figure 8 presents the EDX analysis of the prepared AC and raw material SPB. Figure 8(a) shows the essential elements for the raw material, which were C, O, and Cl with weight percentages of 37.5%, 62.35%, and 0.15%, respectively. Figure 8(b) displays the prepared AC, where the weight percentage of C was 97.30% due to the carbonisation process and weight percentage of O was 0.955%. Also, small percentages of silica (Si) and Cl were found at 0.83% and 0.93 %, respectively.



(a)



(b)

Figure 8. (a) EDX analysis of raw material; (b) EDX analysis of prepared AC.

CONCLUSION

The activation technique of the prepared activated carbon by utilising Z_nCl_2 demonstrated maximum values for surface area (1633.94 m^2/g), pore volume (0.649 cm^3/g), micropore surface area (1148.58 m^2/g), and micropore volume (0.335 cm3/g) through activation temperature of 700^{o}C for holding time of an hour. These values of porosity characterisation for AC-ZC are higher compared to the values in case of AC made from sago palm bark as raw material, utilising chemical activation agents KOH and H_2SO_4. The resulting prepared AC can have various applications in water and wastewater treatments, such as polishing the colour and removing multi-pollutants (e.g., heavy metals). It is a cheaper and more sustainable technique that allows for the utilization of waste materials in the production of a useful substance.

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تأثير عوامل الخلط الكيمياويه على خصائص النفاذيه والمساحه السطحيه للكربون المنشط المُحضر من جذوع أشجار النخيل ساكو

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الخـلاصة

جذوع نخيل أشجار الساكو من المواد الخام المستخدمه لأول مرة في تحضير الكربون المنشط باستخدام تقنيات التفعيل الفيزياكيمياوي والتي تشمل مرحله الكربنه المزدوجه ومراحل التنشيط. تم اجراء التنشيط باستخدام ثلاثه عوامل هي : حامض الكبريتيك (H_2SO_4)، هيدروكسيد البوتاسيوم (KOH) وكلوريد الزنك (Z_nCl_2). تم تحديد خصائص المساميه من الكربون المنشط باستخدام N_2 الامتصاص –الامتزاز للتأكد من BET والمناطق السطحيه ميكروبور وكذلك أحجام ميكروبور وتوزيع المسام. تم تحليل المجموعات الموجوده على أسطح الكربون المُنشط باستخدام التحليل الطيفي للأشعه تحت الحمراء (FTIR). تم تقييم مورفولوجيه الكربون المنشط عن طريق المسح الضوئي (SEM) جنباً إلى جنب مع تقنيات تشتيت الطاقه الطيفيه للأشعه السينيه (EDX). تم اكتشاف مساحه السطح القصوى (1639.34 م^2 / جم) وحجم المسام (0.649 سم^3 / جم) وحجم الميكروبور (0.335 سم / جم) ومساحه السطح المجهريه (1،148.58 م^2 / جم) للكربون المنشط والمحضر باستخدام جذوع أشجار الساكو عند درجه حراره 700 درجة مئوية ونسبه الخلط الكيميائي لوزن كلوريد الزنك إلى وزن الماده المكربنه هي 1.5 / 1. بينما في حاله استخدام KOH وH_2SO_4 ، فإن المساحه السطحيه الناتجه للكربون المنشط هي (970.38 م^2 / جم) و(630.73 م^2 / جم) على التوالي. وحجم المسام للكربون المنشط المحضر باستخدام KOH و H_2SO_4 هي (0.458 سم^3 / جم) و(0.196 سم^3 / جم) على التوالي.

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