SCIENTIFIC PAPER

SYNTHESIS AND CHARACTERIZATION OF ACTIVATED CARBON PRODUCED FROM HAZELNUT PEELS BY CHEMICAL ACTIVATION

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Abstract

Activated carbon was prepared in this research from hazelnut (*Corylus avellana*) peels with some additives which included polymeric waste (polymethyl methacrylate PMMA) and the raw material was ground to facilitate handling and different amounts of sodium hydroxide were added to it and the ratio [*Corylus avellana peels*: NaOH] was as follows: [1:0.5 - 1:2.5]. (*Corylus avellana*) peels were also treated with polymeric waste materials at ratios of [5 - 25]% and a basic ratio of [1:2] at a temperature of 550 °C as it is considered an environmental pollutant and then part of it was disposed of by preparing a material with great economic feasibility. Then the adsorption properties of the prepared samples (methylene dye), iodine number, density, humidity and yield were evaluated and compared with the British and Russian commercial models, and (SEM, FT-IR) techniques were used to characterize the prepared activated samples. The results showed that activated carbon samples prepared from hazelnut peels were characterized by high iodine number (894.521 mg/g), methylene blue dye adsorption capacity (98.425 mg/g) and the yield (14.973%).. As for the samples prepared from hazelnut peels with PMMA an increase was observed in the iodine values (1015.021mg/g) and adsorption capacity for methylene blue dye reached (148.000mg/gm) and yield also increased. This indicates that the addition process was a positive step in improving the specifications and productivity of activated carbon. As for the density and ash, humidity values, they were within the permissible limits for all the prepared activated carbon samples, and thus they greatly exceeded the specifications of commercial carbon samples.

Keywords: Carbonation; Polymeric waste; Polymethyl methacrylate; Methylene blue dye; Physical properties

Introduction

Activated carbon can be defined as a carbon material that has high porosity as well as a large surface area between particles, which is ready for chemical reactions or adsorption [1, 2]. The pore size distribution of activated carbon and its adsorption properties depend on the chemical composition and physical properties of the primary material as well as the process conditions and methods used for activation [3]. The composition of matter is one of the factors that distinguish one from the other. Whereas cellulose, lignin, and materials that contain large percentages of lignin, such as cherry pits and grape seeds, develop activated carbon with a predominance of large pores, while other raw materials that contain large percentages of cellulose, such as almond shells and apricot stones, produce activated carbon with a highly porous structure mostly [4, 5].

Activated carbon is used in various media, such as liquid and gaseous, either in powder or granular form. It is applied in liquids by treating water by removing compounds that affect taste, smell, and color. It can also be used to purify proteins or separate metal compounds such as gold and silver [1]. Activated carbon is mainly prepared in two ways: chemical activation and physical activation. It is manufactured in two basic stages: the first includes carbonization of the raw material and the second includes activated coal. The first method includes carbonizing the raw material and then activating it at a high temperature in the presence of steam or carbon dioxide, while the second method includes carbonating the raw material that was previously impregnated using a chemical agent such as potassium hydroxide [6], zinc chloride [7], and phosphoric acid [8]. Activated carbon prepared from many resources that depends on plant as a raw material.

Kumar and Jena [9] prepared activated carbon from the shell of fox nut (*Euryale ferox*) by chemical activation with H_3PO_4 in a nitrogen atmosphere. The effect of both temperature and impregnation ratio was studied, and found that the best activation temperature was 700°C with an impregnation ratio of 1.5 and time of activation for one hour. It was also found that the surface area of the prepared activated carbon, BET = 2636 m^2/g, its surface contains many active groups. Jamion and Hashim [10] prepared activated carbon from tamarind seeds *Tamarindus indica* and activated it using phosphoric acid in a ratio of [1:1] at temperature of (500°C) for (4 hrs). The BET surface area analysis gave a value of 594.04 m^2/g. The analysis showed FESEM showed that the development and formation of pores was mostly in a circular and oval pattern and the highest adsorption capacity for methylene blue dye equal to (102.77 mg/gm).

Ramalingam et al. [11] prepared activated carbon from dead *Eucalyptus tereticornis* and neem leaves *Azadirachta indica* by washing, drying, grinding and mixing them in equal proportions and placing them in an oven at a high temperature of up to 750°C for 6 hours. The carbon powders were then characterized. The results obtained using electron microscopy (SEM), (EDAX) and (XRD) showed that the prepared carbon has good properties that enable it to be used in medical fields. Viena et al. [12] prepared activated carbon from banana peels using different activation agents H_2SO_4, KOH, and $ZnCl_2$ for three hours. The resulting activated carbon had a low moisture content and better ability to absorb iodine and was used as an adsorbent to remove gases emitted from motorcycles.

Mistar et al. [13] were able to produce activated carbon from the plant *Bambusa vulgaris striata* through a chemical activation process using KOH [1:3] and an activation temperature of 800°C for an hour. The porosity and advanced surface chemistry were examined using (BET), (SEM) and (FTIR). The results were BET = (980 m^2/g) and (0.559 cm^2/g), and the SEM images showed an advanced development of high porosity. Using FTIR technology, it was found that its surface contains different functional groups. Abudaia [14] was able to prepare activated carbon from rice hulls (KOHRH) and corncobs (KOHCC) as an available and inexpensive material to study the absorption of dimethoate from its aqueous solution. It was prepared by chemical activation with KOH and obtained a high yield, so it can be used in wide application fields. It was concluded that it is possible to use agricultural residue with low cost, such as rice husk and corncob adsorbent materials for remove water pollutants due to their high ability to absorb various pollutants. Ramutshatsha-Makhwedzha et al. [15] were able to manufacture and activate carbon derived from orange and lemon peels (OPAC) using phosphoric acid. Characterization was performed on OLAPC and the material was used to remove methyl orange (MO) and methylene blue (MB) dyes from wastewater. The results showed that the method is successfully applicable to real wastewater samples with satisfactory percentages of (MO) and (MB)% (98, 96). Islam et al. [16] prepared activated carbon from *jute stick* by chemical activation using H_3PO_4, $ZnCl_2$, H_2SO_4 and studied the effect of activation factors and carbonization temperatures that ranged between 300-350°C. The properties of prepared samples were studied by iodine absorption and FT-IR spectroscopy.

Gomaa et al. [17] prepared activated carbon from olive seed residue by chemical treatment with KOH [1:1], then dried at a temperature of 150°C for 60 minutes, where 100g of the material was activated at levels (250, 350, 450, 550) ^{o}C for (15, 20, 25, 30) min and at four pressures (1, 3, 1.6, 1.9) bars in the presence of nitrogen at a flow rate of (50cm^3/min). The results indicated that the surface area of the prepared activated carbon had a significant effect, which amounted to (1091.58 m^2/gm) at uttermost rotation of (1099.9 mg/gm), temperature degree as 450°C, and time of activation is 25 minutes.

Sarici et al. [18] were able to prepare activated carbon from hazelnut shells using potassium carbonate for activation at different ratios ranging from (1:1, 1:2, 1:3) and carried out a carbonization process under nitrogen gas pressure and characterized the prepared activated carbon using (X-ray, FT-IR, SEM) techniques after drying the sample and determining its adsorption capacity and found that the BET value was equal to 644 m^2/g and the absorption numbers of iodine and methylene blue dye were equal to 489 mg/g, 1974 mg/L respectively and also conducted a thermodynamic and kinetic study.

Altintig et al. [19]were able to prepare activated carbon from hazelnut shells using H_3PO_4 as an activating agent and coated with silver ions to prepare nanoparticles and mixed them in different ratios (1:0.5, 1:1) using the chemical reduction method. It was found that the prepared activated carbon has a high adsorption capacity through the BET value equal to 1208 m^2/g and the iodine number. The results showed that the prepared model contains 66.01% carbon with an efficiency rate of 36.22%. The prepared activated carbon was distinguished by its use in drinking water applications.

Abo Hay Allah and Alshamsi [20] prepared activated carbon from *Pontederia rassipe* leaves and used it to remove Malachite Green, Congo Red dyes. The prepared materials were studied using diagnostic techniques including: FT-IR, XRD, SEM, EDX, TEM and Raman results showed that optimum efficiency for removing both dyes was achieved and was (98.87%) for Congo Red dye and (99.23%) for Malachite Green dye.

Olam [21] was able to carbonize waste coffee, duck weed together and separately at 800^oC and N_2(100ml/min) in a tubular reactor for 90 minutes and the results showed that it is an effective adsorbent for removing Crystal Violet dye from wastewater with a removal rate of 83%. He was also able to prepare activated carbon by carbonizing gelidium corneum at a temperature of 800^oC for 90 minutes. The prepared activated carbon was characterized using (SEM, EDX, FT-IR, XRD, UV) and it was found to be a suitable adsorbent for removing dyes from their aqueous solutions [22]. He was able to prepare activated carbon by carbonizing lemna minor, hazelnut shell at a temperature of 800^oC in the presence of N_2 (100ml/min) for 90 minutes. The prepared activated carbon was examined using spectroscopic methods and the results showed that the resulting carbon is a good adsorbent for removing Crystal Violet dye, as the adsorption capacity reached (87.95mg/gm) and the removal capacity was 88% [23].

Khaleel et. al [24] were able to prepare activated carbon from pomegranate peels alone and treat it with polymeric additives (Novolak resin) and asphalt by carbonization and activation at a temperature of (550 ± 25 ^oC) using potassium hydroxide in different proportions. It was found that the best proportion is [1:2.5]. The results showed that the prepared activated carbon samples are excellent adsorbents for removing Bromocresol Green and Bromocresol Purple dyes from their aqueous solutions.

In this research, activated carbon was prepared from a plant source *Corylus avellana* peels with some additives from polymeric wastes, which are environmental pollutants, using the method of carbonization and activation by NaOH. The prepared samples had very excellent adsorption properties compared to the British and Russian commercial models.

Experimental

Materials

In this research, hazelnut peels residues (plant waste), polymethyl methacrylate (polymer waste) NaOH with 99% purity supplied by Fluka, HCl with 98% purity, iodine (starch, sodium thiosulfate with 95% purity supplied by Fluka, potassium iodide with 99% purity from B.D.H.), methylene blue dye with 97% purity supplied by B.D.H.

Instrumentation

All instruments and equipment used in the research work are UV-9200 spectrophotometer from Biotechnology Engineering (UK) used to make a calibration curve for methylene blue dye at a wavelength (λ_{max} = 665 nm), The surface morphology of the materials was characterized by using scanning electron microscopy (SEM) (Made in India), Fourier transform infrared (FT-IR) absorption spectrophotometer) for each sample of activated carbon in the range between (400-4000 cm^{-1}) from the German company Bruker-Optics.

Procedure

Preparation of Activated Carbon

Activated carbon is prepared by performing several steps as follows:

Preparation of the raw material: The raw material was taken from *Corylus avellana* peels in its natural, dry form, then ground and made into a fine powder to react with the carbonated material completely and to obtain good results.

Primary carbonization process: 10g of the prepared material in powder form were mixed by various weight proportion of sodium hydroxide [1:0.5, 1:1, 1:1.5, 1:2, 1:2.5] [*Corylus avellana* peels: NaOH]. In a stainless steel crusible, the mixture was homogenized well by adding (5-10 ml) of water, then heated to a temperature of (450)°C with continuous stirring for three hours until the release of gases stopped.

Final carbonization and activation process: After completing the initial carbonization of the *Corylus avellana* peels, raised temperature to (550 ^{o}C) for two and half hours in order to complete process of carbonization, activation of prepared carbon samples, after which the models are left to cool to laboratory temperature.

Purified activated carbon prepared: It is washed with water repeatedly until samples that do not contain sodium hydroxide are obtained and metallic components. Then it is washed with a solution of (10%) hydrochloric acid with thermal sublimation for hour to remove ions and then wash many times with water until it ensured free from traces acid. The resulting carbon samples are dried at a temperature of 120°C for 24 hours, crushed well, and kept in a dryer isolated from air and moisture.

Preparation of carbon from a mixture *Corylus avellana* peels and Polymethyl methacrylate PMMA: Polymethyl methacrylate sheets, which represent organic glass waste, were cut into small pieces and placed in a ceramic crusible covered with aluminum foil. Then the lid was heated in oven at (350°C) for three hours. And then, it taken out, the material was left to cool to laboratory temperature, then it was crushed into a fine powder using mortar.

Certain percentages of carbonated *Corylus avellana* peels were taken as primary carbonation, and thermally crushed polymeric waste was added in ratios of 5, 10, 15, 20, 25% and steps above were repeated, using a fixed ratio of sodium hydroxide [1:2] [*Corylus avellana* peels: NaOH] as the best ratio used to prepare activated carbon from *Corylus avellana* peels.

Measurements for determining the effectiveness

To determine the effectiveness of activated carbon that prepared, several measurements are performed on it, as shown below:

1. **Measure the iodine number of activated carbon [25]:** This operation is one of the well-known and common methods for giving information about the internal surface area of carbon that activated. It is expressed as number of milligrams of iodine, adsorbed from solution of (1 gm) from carbon. It includes the following:

- (1 gm) of carbon is taken, then placed in a conical flask with a capacity (250 ml).
- Transfer using a pipette (100 ml) of a solution of HCl (5%) to conical flask.
- Heat the conical flask with its contents until it boils for 0.5 hrs., then leave it to cool at temperature of laboratory.
- (100 ml) of iodine solution with a concentration of (0.1N) is taken with a pipette and placed in conical flask.

- The conical flask is placed in the electric shaking device for a period of half a minute, and the contents of the conical flask are then filtered. Approximately (20-25 ml) of filtrate is discarded at beginning of filtering process, then the remainder is collected in clean conical flask.
- (50 ml) of the filtrate obtained from the previous step is taken and placed in conical flask at capacity (250 ml) and flushed with a standard solution of sodium thiosulphate (0.1N) until the color of the solution becomes pale yellow. Then (1 ml) of starch indicator is added and the clarification is completed until the blue color of the starch indicator no longer appears. The volume of thiosulfate used is calculated, and iodine number (I.N) also computed through this equation:

  $$I.N = WIO/WAC.CF \qquad (1)$$

  where:

  WIO = weight of iodine adsorbed in milligrams.

  WAC = weight of activated carbon prepared.

  CF = Correcting Factor.

2. **Measurement of the adsorption capacity of prepared carbon samples to methylene blue dye:** The external surface area is measured to activated carbon by taking (0.1gm) of dry activated carbon, placing it in (250 ml) conical flask. A certain amount of (20 ppm) methylene blue dye is added, then it is placed in an electric shaking device for (24 hrs.) until becomes colourless, also another amount of dye solution is added, thus obtaining an increase of the unadsorbed dye. After that, the solution is separated using a centrifugation process, and the clear solution is taken and its absorbance is measured at a wavelength (λ_{max} = 665 nm), and the solution is calculated. Concentration of the dye through the standard curve that was prepared by taking different concentrations of the dye solution, ranging from (5-25 ppm) with an increase of 5ppm, and measuring absorbance of solution at same wavelength mentioned above, then the relationship between concentration and Absorbency is drawn [26].
3. **Calculating the humidity percentage:** This method involves exposing the activated carbon to a laboratory temperature for (24 hrs.), then drying it at a temperature of (140°C) for (2 hrs.), after that cooling it, weighing it accurately, the humidity percentage is calculated by difference in weights [27].
4. **Ash content measurement:** The ash content can be measured by taking (1gm) of prepared carbon and it placing in a ceramic crusible. After that, the crusible is placed in oven at (1000^{o}C) for an hour, then left to cool for the purpose of weighing it, the weight

of remaining material which is the ash for each sample of activated carbon is calculated from it. prepared and thus the percentage of ash for each sample [28].

5. **Density measurement of activated carbon:** The density of activated carbon is measured by placing a certain weight of it in a volumetric flask with a capacity of (5 ml). It is carefully compacted in order to get rid of the gaps between the molecules until the carbon occupies the entire volume of the bottle. The prepared carbon in volumetric flask is weighed using an accurate balance, density is calculated according to equation below [29]:

$$density\ g/cm^3 = mass/volume \qquad (2)$$

6. **Calculating the yield of activated carbon:** The yield is calculated by weighing the raw material, the carbonated and activated material, so that the difference between them is divided by the weight of the initial sample, as shown in the following equation [30]:

$$yield = w_c/w_o \times 100 \qquad (3)$$

Where:

w_c : final dry product weight (gm).

w_o : dry raw weight (gm).

Results and Discussion

Activated carbon (AC) is considered porosity, the chemical structure suffers from a crystalline defect. This defect leads to the appearance of pores that are energetically or effectively unstable. Activated carbon is produced from raw materials with a high carbon content, such as bituminous materials and wood rich in lignin, using thermal carbonization processes that remove hydrogen and leave it rich in carbon. The resulting carbon is then activated thermally in an atmosphere of argon or nitrogen or steam at high temperatures.

Due to the advantages that activated carbon possesses, it has been used in various fields, such as removing dyes, treating pollution, and reducing its damage. In addition to the availability of primary raw materials, researchers were encouraged to prepare it in a variety of ways. It was produced from plant sources, especially those in which lignin is abundant, i.e. nut shells, hardwoods, etc. In this research, one of the types of nut shells, which are *Corylus avellana* peels, which is unique in its extreme hardness and high lignin content for preparing carbon by mixing them dry with sodium hydroxide for the purpose of removing hydrogen in the form of water and disposing of it thermally. That is, the carbonization process in this case is a fusion melting process followed by a process of loss of water and other gases, resulting in a black mass that is washed and activated with mineral acids.

Sodium hydroxide is considered an influential factor in the activation process, as it works to develop the fine porous structure in producing activated carbon by chemical treatment. In addition, hydroxide ion works to necrotize the structure of the raw material and thus leads to the development of the porous structure of the produced carbon. Table 1 shows the measurements made on the activated carbon samples that were prepared.

Table 1

From the above table, was noted the method of chemical activation using NaOH and increasing the percentage of the added base leads to an increased adsorption values of iodine, from its solution to extent of a ratio [1:2], as it was observed that the adsorption values of iodine begin to decrease. This is due to the fact that an increase in OH leads to the destruction of part of pores and hiatus formed on the surface of the prepared carbon using a ratio [1: 2.5]. This is due to the role of sodium hydroxide in expanding the internal pores, as the iodine number values increased regularly with the increase of the base added to the original sample.

An increase in the concentration of methylene blue dye adsorbed using the positive portion of sodium hydroxide was also observed, which works to increase the capacity of the pores and organize them. When comparing it with the commercial model (B.D.H) and (Russ), it was found that the amount of iodine absorbed by activated carbon was much better than the commercial sample of both types. As for the humidity content values, they ranged between (7.528-9.835)%, which is a relative measure that shows the extent to which the prepared samples can be used in the water vapor adsorption process. We have found some prepared carbon samples which has the ability to absorb water vapor. The ash content is within the permissible limits due to the thermal sublimation process with HCl, which removes the bulk of the metal components. As for the density values, their values were low, and this is good evidence that the prepared activated carbon has high porosity and thus has a high ability to adsorb small molecules.

Regarding the yield, we notice that it decreases with the increase of added NaOH, and this is self-evident because when the percentage of the base added to the carbon increases, it results in an increase in the percentage of loss in the carbon content of the original material, which leads to a decrease in the yield. From the results obtained in the table above, it is clear to us that the best sample is AC_4 because of its high effectiveness for adsorption of iodine and methylene dye and its low density, through which activated carbon can be used in the medical fields to absorb gases from the stomach and intestines because it is free of carcinogenic nitrogen and sulphate compounds. To improve the specifications of carbon prepared from *corylus avellana* peels, the original material was treated by polymethyl methacrylate using a fixed ratio of the base

[1:2]. Table 2 shows the specifications of activated carbon samples prepared from a mixture of *corylus avellana* peels with the polymer.

Table 2

It was noted from the above table that the use of polymer as an additive to *Corylus avellana* peels led to improving the adsorption properties of activated carbon in terms of iodine value, as its value increased and reached (1015.021mg/gm) and the adsorption capacity of methylene blue dye also increased and reached (148.000 mg/gm) and it was found that the best model was AC_{10}, which gave the highest value of iodine value, as these properties exceeded those of activated carbon prepared from hazelnut peels alone and the properties of commercial activated carbon, and the values of density and humidity were acceptable, and it also increased the result very well, and from the above we conclude that the addition process was a positive step in improving the specifications and productivity of activated carbon. Thermogravimetric analysis of activated carbon prepared from *Corylus avellana* was performed as shown in Fig. 1. And Fig. 2 -5 illustrate the various graphical relationships in this research.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Activated Carbon Characterization

Scanning electron microscopy (SEM): The SEM technique was implementing to evaluate the prepared activated carbon samples, and the Fig. 6 Shows the changes in the shape of the samples in terms of size and pore formation. It was noted that the process of adding the PMMA polymer led to the production of different types of pores and cavities on the surface.

Fig. 6

Infrared spectrum (FT-IR): When comparing the infrared spectrum (FT-IR) of the two samples: the raw material before carbonization in Fig. 7 with the material after carbonization and activation shown in Fig. 8 The FT-IR measurement of the raw material before carbonization showed many bands, as shown in the Table 3, which shows the frequency of each band and the type of bond before carbonization.

Fig. 7

Table 3

When measuring infrared radiation (FT-IR) of the material carbonization and activation by adding sodium hydroxide at 550°C, it was observed that some of the bundles disappeared and new ones appeared, as shown in the Table 4, which shows the frequency of each bundle, the type of bond after carbonization and activation.

Table 4

Fig. 8

Conclusion

As a result of the completed research, *Corylus avellana* peels and added polymer waste are excellent raw materials for preparing activated carbon, and the yield of using polymer waste is increased by 25% for *Corylus avellana* peels, due to the increase of carbon mass. All the prepared activated carbon samples showed high adsorption capacity for methylene blue dye, high iodine value and high yield, while the density and humidity and ash values were within the permissible limits, thus exceeding the specifications of commercial activated carbon. *Corylus avellana* peels charcoal is a promising raw material for producing activated carbon for various industrial purposes.

Future research recommendations include preparing activated carbon from hazelnut peels using different carbonization and activation agents and select other adsorbent materials that are available and inexpensive, by utilizing agricultural residues that pollute the environment.

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Figure Captions

Fig. 1. Thermogravimetric analysis (TGA) for *Corylus avellana*

Fig. 2. Relationship of added NaOH ratio and:(a) I.N, (b) MeB, (c) Humidity content, (d) Ah content in activated carbon

Fig. 3. Relationship of added NaOH ratio and: (a) De , (b) Yield in activated carbon

Fig. 4. The ratio between the organic glass polymer and the: (a) I.N, (b) MeB, (c) Humidity content, (d) Ah content, of activated carbon

Fig. 5. The ratio between the organic glass polymer and the: (a) De, (b) Yield of activated carbon

Fig. 6. SEM images (a) Activated carbon prepared from *corylus avellana* peels (b) Activated carbon prepared from *corylus avellana* peels and PMMA

Fig. 7. The infrared spectrum (FTIR) of the raw material before carbonization

Fig. 8. FT-IR spectrum of the material after carbonization and activation

Table 1: Specifications of prepared activated carbon from *Corylus avellana* peels by modified carbonation and chemical treatment

AC	Ratio *Corylus avellana*: NaOH	I.N (mg/gm)	MeB (mg/gm)	Humidity (%)	Ah (%)	De (gm/cm^3)	Yield (%)
AC_0	1:0	412.390	23.721	9.152	3.117	0.401	20.021
AC_1	1:0.5	670.300	64.534	9.835	3.100	0.380	18.572
AC_2	1:1	689.502	70.951	10.029	3.010	0.367	17.514
AC_3	1:1.5	757.280	76.860	11.108	2.958	0.291	16.230
AC_4	1:2	894.521	98.425	12.061	2.100	0.287	14.973
AC_5	1:2.5	789.672	78.002	7.528	3.975	0.293	9.021
C B.D.H	-----	908.000	90.000	0.800	3.200	0.345	-----
C Russ	-----	61.000	34.800	0.620	1.500	0.325	-----

AC_0 = activated carbon prepared from *Corylus avellana* peels without any additives.

CB.D.H [31] = British commercial granular activated carbon.

CRuss [31] = Russian commercial granular activated carbon.

MeB : Adsorption capacity of Methylene Blue, Ah: Ash , De: Density

Table 2: Specifications of activated carbon prepared from a mixture of (*corylus avellana* peels with polymethyl methacrylate) using [1:2] [raw material: NaOH]

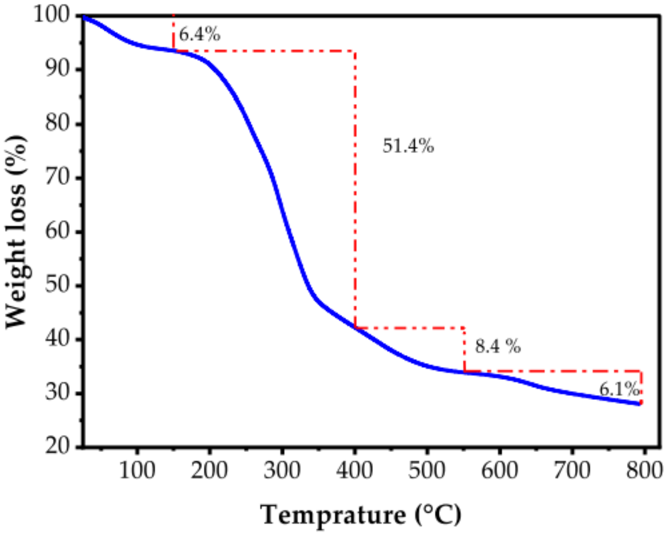
AC	Polymer %	I.N (mg/gm)	MeB (mg/gm)	Humidity (%)	Ah (%)	De (gm/cm^3)	Yield (%)
AC_6	5	904.217	105.000	12.000	1.975	0.270	15.751
AC_7	10	953.000	117.028	11.831	1.961	0.261	17.090
AC_8	15	997.215	125.000	11.957	1.952	0.246	20.807
AC_9	20	1000.700	137.115	12.280	1.871	0.184	23.465
AC_{10}	25	1015.021	148.000	13.500	1.330	0.103	30.970
C B.D.H	-----	908.000	90.000	0.800	3.200	0.345	-----
C Russ	-----	61.500	34.800	0.620	1.500	0.325	-----

Table 3: (FT-IR) spectrum bands for the raw material before carbonization

Type of bond	Frequency(cm^{-1})
Stretch (O -H)	3308
Stretch (C -H) Aliphatic	2852 ,2921
(C= O)Ketone	1731
(C= N)	1605
Stretch (C- C)	1512
Bending (CH_3)	1370
Stretch (C -O)	1139
Stretch (C -N)	1021

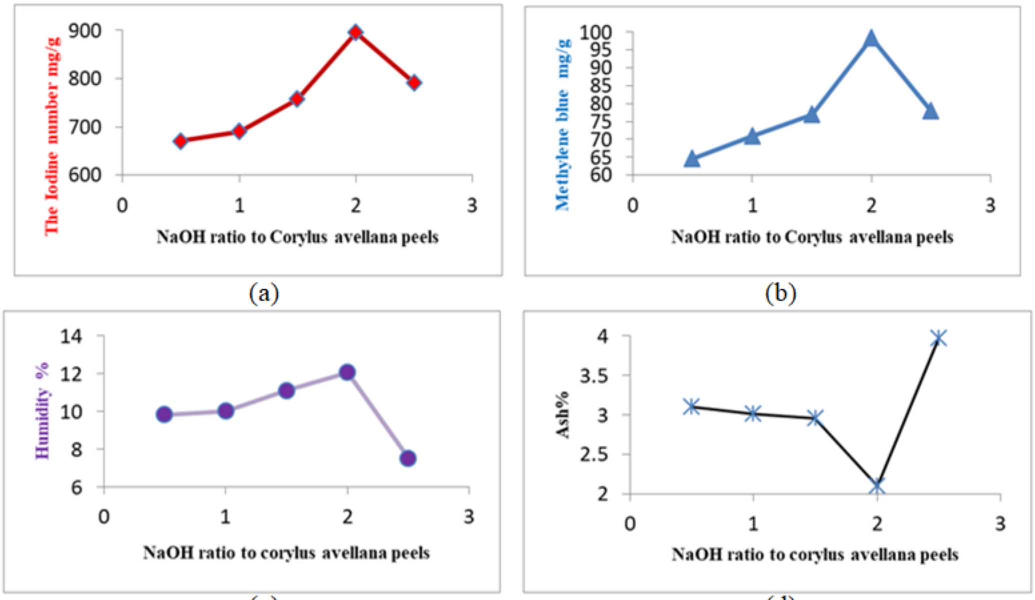
Table 4: (FT-IR) spectrum bands of the material after carbonization and activation

Type of bond	**Frequency(cm^{-1})**
Stretch (O -H)	3265
Stretch (C- C)	1574
Stretch (N= N)	1416
Stretch (C -N)	1074
Stretch (C -H)	873



100
90
80
70
60
50
40
30
20
Weight loss (%)
100
200
300
400
500
600
700
800
Temprature (°C)
6.4%
51.4%
8.4 %
6.1%

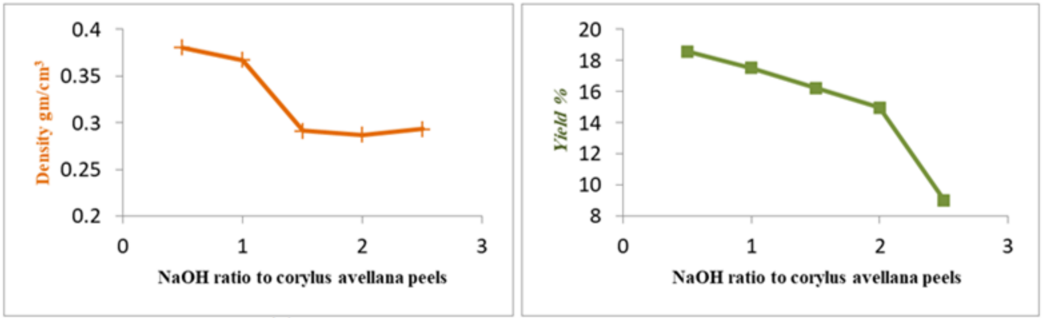
Fig. 1


The Iodine number mg/g
900
800
700
600
0
1
2
3
NaOH ratio to Corylus avellana peels
Methylene blue mg/g
100
95
90
85
80
75
70
65
60
0
1
2
3
NaOH ratio to Corylus avellana peels
Humidity %
14
12
10
8
6
0
1
2
3
NaOH ratio to corylus avellana peels
Ash%
4
3.5
3
2.5
2
0
1
2
3
NaOH ratio to corylus avellana peels

(a) (b)

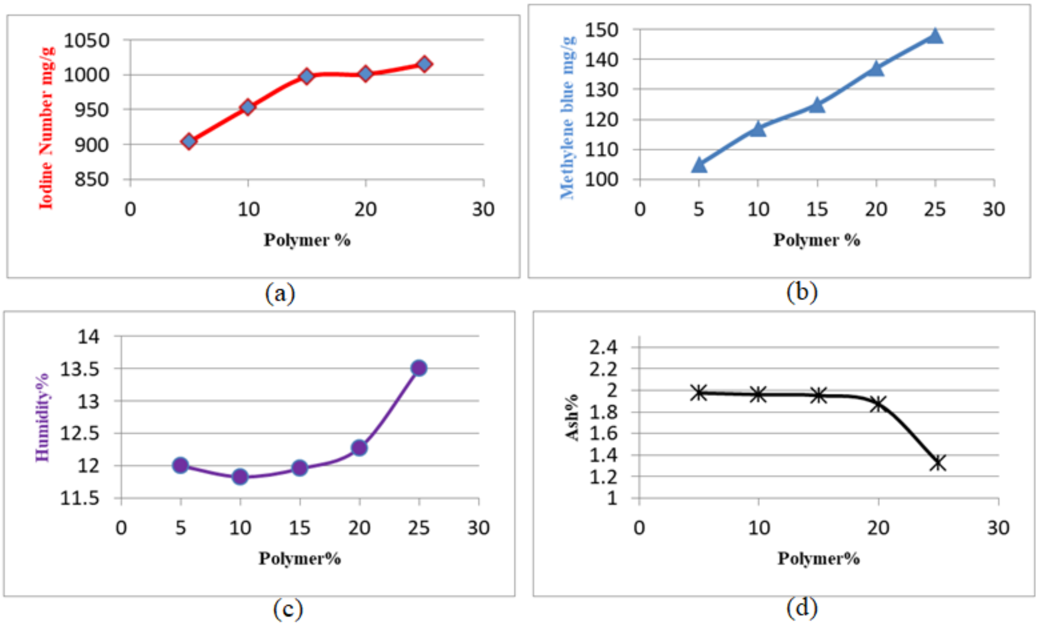
(c) (d)

Fig. 2


0.4
0.35
0.3
0.25
0.2
Density gm/cm3
0
1
2
3
NaOH ratio to corylus avellana peels
20
18
16
14
12
10
8
Yield %
0
1
2
3
NaOH ratio to corylus avellana peels

(a) (b)

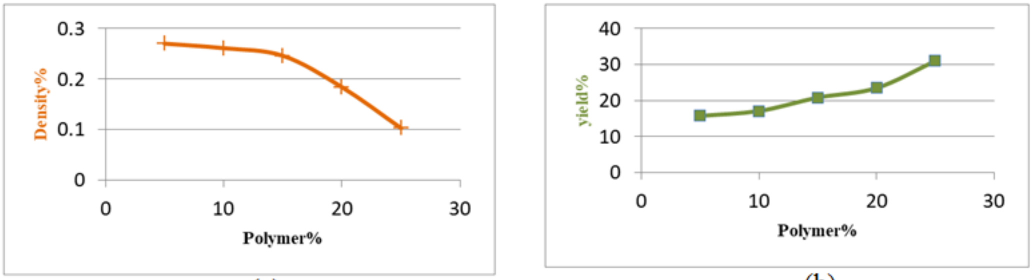
Fig. 3


Iodine Number mg/g
1050
1000
950
900
850
0
10
20
30
Polymer %
Methylene blue mg/g
150
140
130
120
110
100
0
5
10
15
20
25
30
Polymer %
Humidity%
14
13.5
13
12.5
12
11.5
0
5
10
15
20
25
30
Polymer%
Ash%
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0
10
20
30
Polymer%

(a) (b)

(c) (d)

Fig. 4


0.3
0.2
0.1
0
Density%
0
10
20
30
Polymer%
40
30
20
10
0
yield%
0
10
20
30
Polymer%

(a)

(b)

Fig. 5

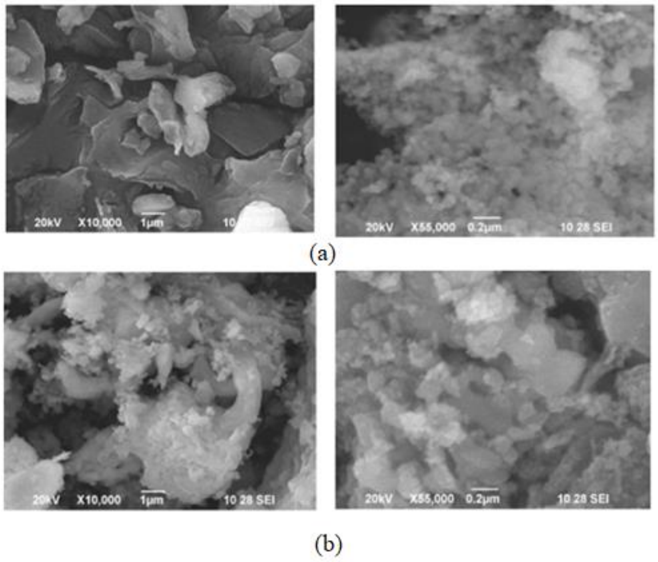

20kV X10,000 1μm 10
20kV X55,000 0.2μm 10 28 SEI
(a)
20kV X10,000 1μm 10 28 SEI
20kV X55,000 0.2μm 10 28 SEI
(b)

Fig.6

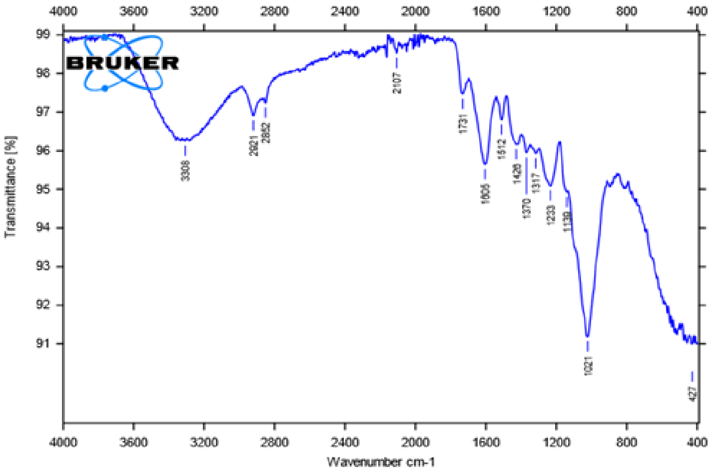

BRUKER
Transmittance [%]
99
98
97
96
95
94
93
92
91
4000
3600
3200
2800
2400
2000
1600
1200
800
400
Wavenumber cm-1
3308
2921
2852
2107
1731
1606
1512
1426
1370
1317
1233
1139
1021
427

Fig. 7

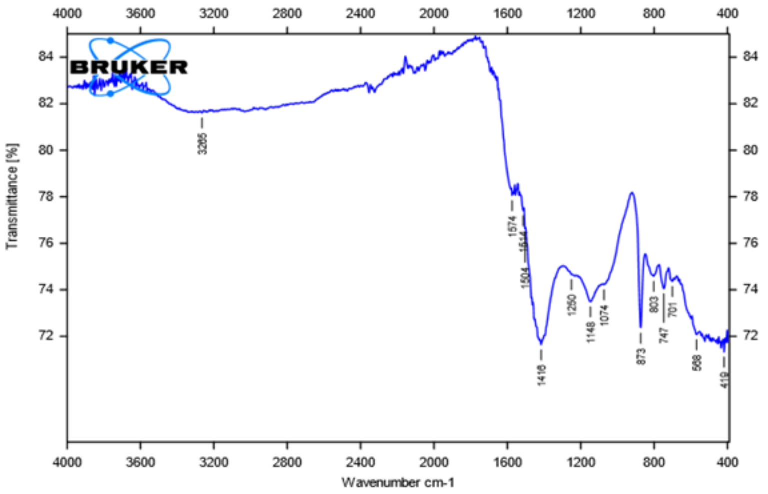

BRUKER
Transmittance [%]
Wavenumber cm-1
4000
3600
3200
2800
2400
2000
1600
1200
800
400
84
82
80
78
76
74
72
3266
1574
1514
1504
1416
1250
1148
1074
873
803
747
701
568
419

Fig. 8