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ACTIVATED CHARCOAL PRODUCTION FROM *CERATOPHYLLUM DEMERSUM* BY PYROLYSIS FOR TREATING ACUTE POISONINGS

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Abstract

Ceratophyllum demersum (*C.d.*) is one of the famous undesirable aquatic plants diffuse in quiet Stream and pond. This work focuses on the dispose of this plant and convert it by microwave pyrolysis process to charcoal which is used to treat the acute poisonig after activation. Activated charcoal is used to treat many forms of oral poisonings caused by poisoned food or medicine, an overdose of drugs, etc. most poisoning cases are treated by activated charcoal which mixes and taken as oral dose or as nourishment tube in the emergency room.

The produced activated charcoal was analyzed by Field Emission Scanning Electron Microscope (FESEM) and Brunauer-Emmett- Teller (BET) method. These analyses showed that with increasing temperatures, the area of activated charcoal increases and becomes more porous, which leads to adsorption of a greater amount of the toxic substance and the higher BET surface area was 9519 m^2/g which is achieved when producing activated charcoal at a temperature of 650°C.

Key words: Activated charcoal; pyrolysis; *Ceratophyllum demersum*; physical activation.

Introduction

Acute poisoning is one of the most common cases in hospitals with different rates of morbidity and mortality (Journal and Medicine, 2016). Poisoning occurs as a result of excessive intake of drugs or because of some household chemicals, industrial or agricultural, as well as due to an overdose of drugs. Active charcoal is used to treat some cases of oral poisoning, as it helps prevents these toxins from being absorbed from the stomach to the rest of the body.

Activated charcoal also called (activated carbon) is a carbon rich solid produce from heating of biomass in the limiting or absent of oxygen by a process called pyrolysis under controlled conditions. Since a long time ago, charcoal has been used in a wide range of applications such as its traditional use in heating, cooking and environmental treatment such as treating soil from pollutants and absorbing carbon dioxide from the air. Moreover, in industrial application where it was used in the manufacture of batteries and in the medical field Manufacture of voltmeter sensor to detect toxic heavy metal ions such as Pb^{2+} and Cd^{2+} (Journal and Medicine, 2016) and to lower cholesterol level (Ahmad Zaini and Mohamad, 2015). The properties of activated charcoal can be adjusted to suit the desired application depending on the type of raw material used and pyrolysis conditions.

Pyrolysis is a thermochemical conversion process occurs with temperature range 350°C-1000°C (Ramangkoon, Saenjum and Sirithunyalug, 2016), pyrolysis is a flexible process and has the ability to adapt to a wide range of raw materials and products by controlling process conditions (Adams, Bridgwater, Ross, and Watson, 2018). The pyrolysis process was developed by microwaves to improve it in terms of energy input, cost, time and processing (Juurlink, 2016).

Materials and Methods

Biomass

The biomass used to produce activated charcoal is *Ceratophyllum demersum C.d*, it is a submerged, free-floating aquatic plant collected from AL Hindiyah River in Karbala, Iraq. In the beginning this plant washed with tab water then with distilled water in order to remove all dirt, dried in the oven at 70±5°C and finally ground in disk mill and sieved to 40 meshes to be used in the experiments.

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Table 1: Experiments of *Ceratophyllum demersum* microwave pyrolysis by Taguchi method.

Run No.	MW ratio	Temp. °C	P (bar)
1	0.7	350	1
2	0.8	350	4
3	0.9	350	7
4	1	350	10
5	0.8	450	1
6	0.7	450	4
7	1	450	7
8	0.9	450	10
9	0.9	550	1
10	1	550	4
11	0.7	550	7
12	0.8	550	10
13	1	650	1
14	0.9	650	4
15	0.8	650	7
16	0.7	650	10

Pyrolysis Reactor

The reactor used in this research is a thermal Teflon reactor with capacity of (80 ml) as shown in the fig. 1. This reactor was designed locally to withstand temperature and pressure of the pyrolysis process and has two connections one at the bottom for N_2 gas introduce to ensure good heat distribution and the other one at the top of the reactor for exit the gases produced with N_2 gas. The temperature of the reactor was measured by thermochemical type K.

Experimental procedure

The design of *Ceratophyllum demersum* experimental conditions were carried out by using Taguchi method, three parameters were selected (Temperature, Pressure and Microwave power) and the experimental run conditions are illustrated in table 1. In each experiment the reactor was charged with the biomass and specific amount of activated carbon to absorb the microwave energy and convert it to heat in which the biomass is pyrolysed to charcoal. The surface area, pore size and pore volume of the charcoal are obtained from the Brunauer-Emmett- Teller (BET) method, the morphologies of the charcoal were analyzed by Field Emission Scanning Electron Microscope (FESEM).

Fig. 1: Photograph of pyrolysis reactor.

Table 2: The physicochemical properties of *Ceratophyllum demersum*.

	(wt.%)
Ash content	12
Lignin content	6.10
Cellulose content	45
Hemicelluloses content	16.9
Extractives	20
Moisture content	87.6

Activated Charcoal

Charcoal also called activated carbon or activated coal is a fine black powder or black porous solid, it is scentless, tasteless and insoluble in water (Abdollahi and Hosseini, 2014). Charcoal has become one of the most important and widely used for the adsorbtion processes due to its structure which has highly advance internal porosity, large surface area and the high ability adsorption (Ramangkoon *et al*., 2016).

It produces for the medicinal use by a controlled the pyrolytic decomposition of biomass (Juurlink, 2016). Subsequently, the product submitted to the activation phase to corrode charcoal internal surface which leads to increasing of its adsorptive surface area (Bonilla-Velez, Bonilla-Velez, J Marin-Cuero and J. Marin-Cuero, 2017). The activation step can occur in two ways: physical and chemical activation. If caracole is produced specifically for medical applications, it is preferable to use the physical activation. The main reason is that the physical activation using inert non-toxic oxidizing gases such as; steam or carbon dioxide, while chemical activation uses toxic chemical agents such as; $ZnCl_2$ and KOH which leads to compromise the safety of the product (Ahmad Zaini and Mohamad, 2015).

Mechanism of Action

The mechanism of activated charcoal is represented in the adsorbtion process, where it adsorbs the toxic substances (medical drugs, poisonous chemicals and phytotoxins) (Zellner *et al*., 2019) in the gastrointestinal

Table 3: Structure properties of charcoal.

Pore Size nm	Pore Volume cm³/g	BET surface area (m2/g)	Single point surface area at p/p°	Temperature ºC	Experimental runs
7/23590	0/013175	7/2833	2/0723	350	1
17/46645	0/015630	3/5794	3/1250	450	6
12/48465	0/016300	5/2225	3/5050	550	11
18/02964	0/017813	3/9519	3/4826	650	16

tract and hold them in its porosity or attaches to the surface, so that activated charcoal minimizing the adsorption of the toxicity into the bloodstream and preventing or lessening the toxic spread (Bonilla-Velez *et al*., 2017); (Abdollahi and Hosseini, 2014).

The nature of activated charcoal is pharmacologically inert and unabsorbed by the Gl tract and not absorbed by the digestive system (Smith and Howland, 2019), so after the adsorption of the toxic substances by the activated charcoal, it stays inside the GI tract and eliminated in the feces (Abdollahi and Hosseini, 2014).

The activity of charcoal depends on several factors such as; the properties of the toxic substance (particle size, ionization, solubility, pH, etc.), the content of stomach (Zellner *et al*., 2019) and the time, where if the time from ingestion to administration is longer, the activated charcoal will reduce its capacity (Bonilla-Velez *et al*., 2017).

Activated charcoal production stages

Activated charcoal is produced in two stages: the first step is pyrolysis of *Ceratophyllum demersum* to produce charcoal then the product undergoes to the second stage which is the physical activation.

Pyrolysis

Pyrolysis is a thermochemical conversion of organic compounds (biomass) in the absence of oxygen (Abd, Al-Mayah and Muallah, 2018), this step was carried out in a thermal Teflon reactor placed in an automated microwave equipped with a temperature controller. Pyrolysis was performed in the presence of a continuous flow of purified nitrogen gas with a flow rate of 10 ml/ min; the unit of this process is shown in fig. 2. Most of the non-carbon elements present in the biomass such as nitrogen, hydrogen, sulphur and oxygen are removed as pyrolysis gas, This process also helps to expand the diameter of the charcoal pores so that increase the adsorption capacity (Hasan and By, 2019).

Fig. 2: Microwave pyrolysis process unit.

The product from this process is the solid charcoal with high carbon content (25-50%) which depends on the process parameters and the biomass used (Bergna, Varila, Romar and Lassi, 2018).

Physical activation of charcoal

Physical activation comprises carbonization of the biomass to eliminate the bulk of volatile matter then

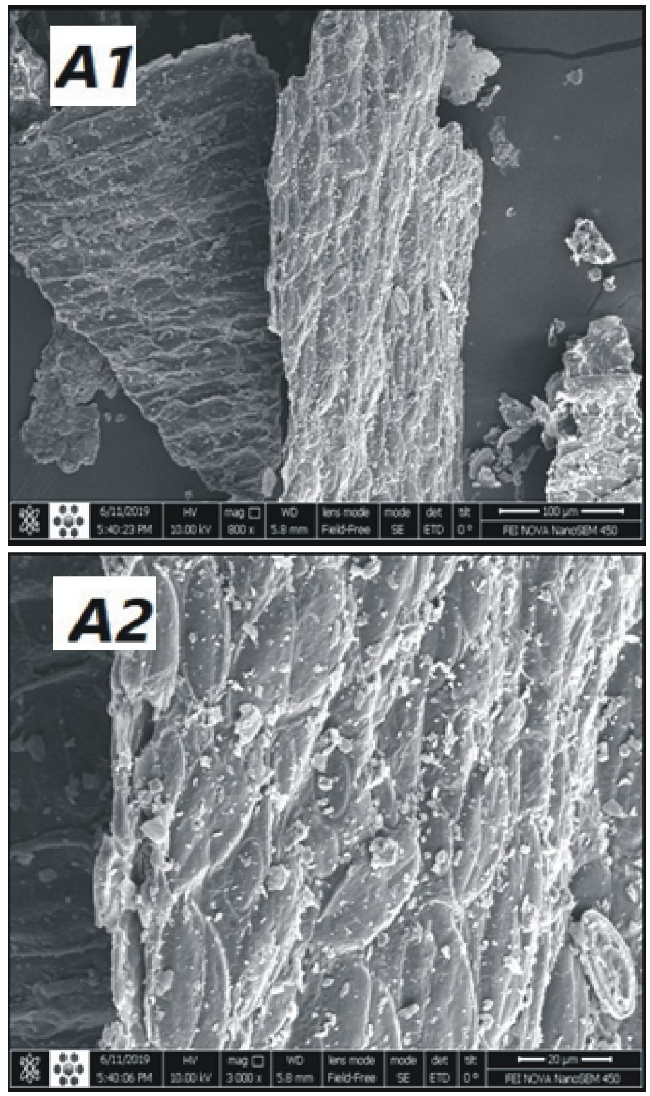

Fig. 3: A1 and A2 FESEM images for *Ceratophyllum demersum.*

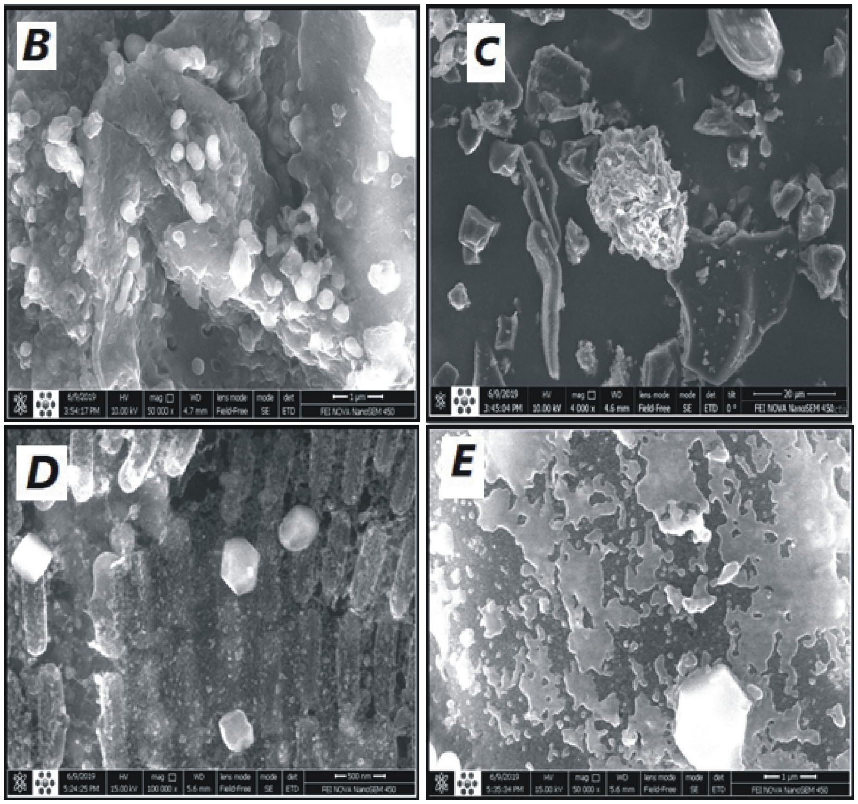

Fig. 4: FESEM images for A: *C.d* and for activated Characol B: Run1, C: Run6, D: Run11, E: Run16.

followed by the activation of the resulting product (Zhou, Luo and Zhao, 2018). The physical activation is generally occurred by using an oxidizing agent like steam, air, carbon dioxide, or the mixture of these gases at elevated temperature 750°C-1100°C (Hasan and By, 2019). The activated agent influences the morphology of the charcoal such as specific surface areas, pore volumes and pore size distributions (Bergna *et al*., 2018).

Results and Discussion

The physicochemical properties of *Ceratophyllum demersum*

The physicochemical properties of *Ceratophyllum demersum* are tabulated in table 2. The chemical composition was calculated based on 12.4% dry weight. It can be observed that the lignocellulosic composition of the biomass arranged in the following order Cellulose> Hemicelluloses > Lignin.

Characterization of activated charcoal

• Field Emission Scanning Electron Microscope (FESEM):

The morphology and the mean size of the charcoal were examined by field emission scanning electron microscopy (FESEM).

At first, from the FESEM image shown in fig. 3, the raw material *Ceratophyllum demersum* before pyrolysis and activation It appears that the surface morphology with no pores and with a disordered structure.

When the process starts and produced charcoal with increasing temperature, the temperature will have caused substantial changes in the surface morphology and generates the wear of the thin walls of the charcoal channels. After pyrolysis, the charcoal undergoes to the

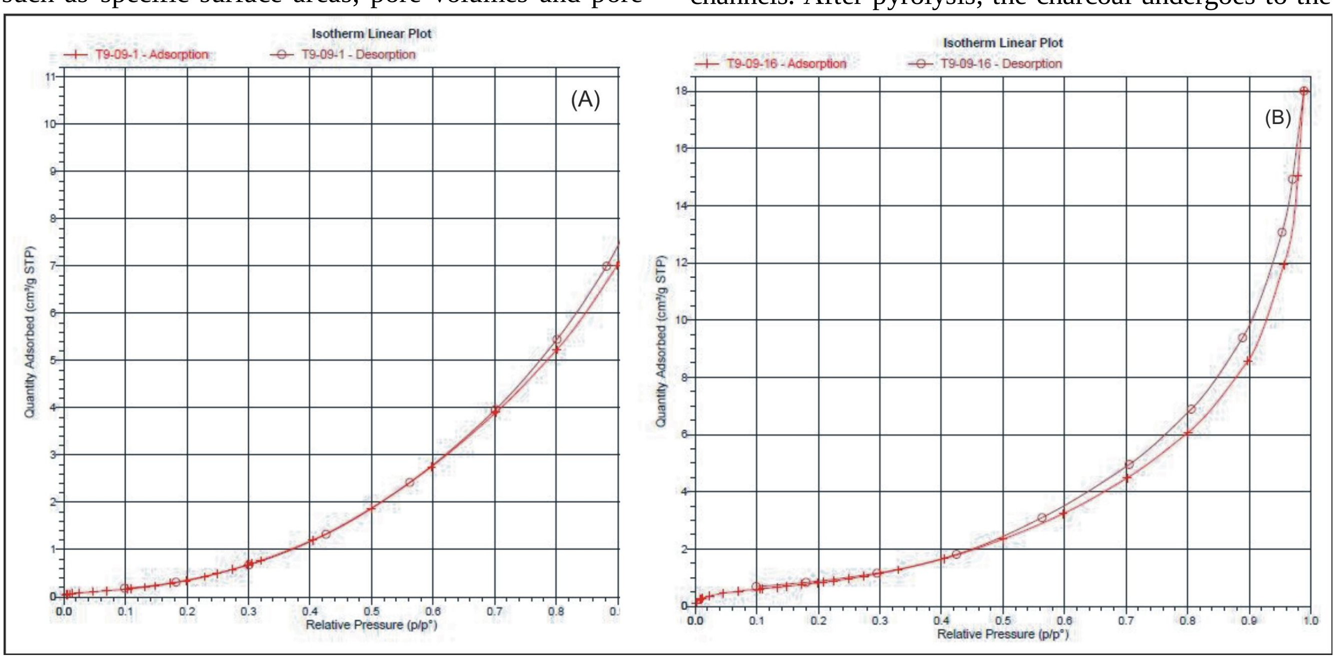

Fig. 5: Isotherm linear plot of activated charcoal a: Run1and b: Run16.

activation step, the carbon backbone is restructured and the volatile matter released to form the graphite structure that causes the pore volume to rise, thereby increasing the specific surface area (Ahmad Zaini and Mohamad, 2015).

The images presented in fig. 4, show the evidence that the variation of the porous activated charcoal structure and with increasing pyrolysis temperature, the charcoal surface and pore size decreased gradually and become more porous. However, when the charcoal produced with small particle size and high internal porosity becomes more effective for adsorption which allows charcoal to adsorb high concentrations of toxic substances when used for medical applications.

Brunauer-Emmett-Teller surface area (BET)

The morphological characteristics and physical properties of charcoal were determined by the Brunauer-Emmett-Teller (BET) method by nitrogen gas, the results of surface area, bet surface area, pore volume and pore size of experiment runs 1, 6, 11 and 16 shown in table 3.

With increasing the process temperature from 350°C to 650°C, the BET surface area will increase and the charcoal produced with higher surface area. Besides, the development of pores in charcoal samples enhanced with increasing temperature may result in significant improvement in the pore properties of it. These results agree with (Suárez-Hernández, Ardila-A. and Barrera-Zapata, 2017). Fig. 5 shows the isotherm linear plot of activated charcoal.

Conclusions

The above results confirm that charcoal can be produced from the biomass *Ceratophyllum demersum* and activated can be prepared via physical activation way to become effective in adsorbing the toxic substance from the body.

Finally, porosity and surface area are the most important properties of activated carbon which affect its absorbing capacity of the toxic substances from the stomach to the body.

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