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Obtención y caracterización de carbón activado granular a partir de semilla de aguacate

Tesis que, para completar los requisitos del Programa de Honores presentan los estudiantes

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OBTENTION AND CHARACTERIZATION OF GRANULAR ACTIVATED CARBON FROM AVOCADO SEED

OBTENCIÓN Y CARACTERIZACIÓN DE CARBÓN ACTIVADO GRANULAR A PARTIR DE SEMILLA DE AGUACATE

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Abstract:

Activated carbon (AC) can be obtained from different types of organic residue, which generally does not have a second use. Avocado being one of the most successful products within the agri-food sector and with a high production of seed residue was chosen to obtain AC. To activate the AC, phosphoric acid (85%) was used at different impregnation ratios (0.5, 1.0, 1.5, and 2.0). In order to characterize and prove the efficiency of the AC, different parameters were measure. The characterization was tested according to ASTM D4607-14 to determine the iodine number and D3838-05 to determine the pH number. Isotherms of Methylene Blue (AM) were measured to prove the adsorption capacity. The Brunauer-Emmett-Teller (BET) equipment was used to calculate the specific surface area, including the pore size distribution. Field emission scanning electron microscope (SEM) was used to determine the elemental analysis of the synthesized AC and obtain images of the pores. According to the results obtained from the different tests, it was found that AC with an impregnation radios of R = 2 was the most efficient. The maximum adsorption capacity of MB 2 from de Langmuir's equation, produced by the AC with an R=2, was 357.14mg/g, although the best iodine number of 504.344 was obtained from the AC R=1.5. The characterization of the surface area (BET) for R=2 was 549.66 m^2/g and the adsorption/desorption graphic are classified as type IV according to the IUPAC classification of the adsorption isotherms.

Keywords: activated carbon, adsorption, pore size, superficial area, avocado seed.

Resumen:

El carbón activado (AC) se puede obtener de diferentes tipos de residuos orgánicos, que generalmente no tienen un segundo uso. El aguacate, uno de los productos más exitosos dentro del sector agroalimentario y con una alta producción de residuos de semillas, fue elegido para obtener AC. Para activar el AC, se usó ácido fosfórico (85%) a diferentes relaciones de impregnación (0.5, 1.0, 1.5 y 2.0). Para caracterizar y demostrar la eficiencia de la CA, se midieron diferentes parámetros. La caracterización se probó de acuerdo con ASTM D4607-14 para determinar el número de yodo y D3838-05 para determinar el número de pH. Se midieron las isotermas de azul de metileno (AM) para demostrar la capacidad de

adsorción. El equipo Brunauer-Emmett-Teller (BET) se utilizó para calcular el área de superficie específica, incluida la distribución del tamaño de poro. Se usó Scanning Electron Microscopye (SEM) para determinar el análisis elemental del AC sintetizado y obtener imágenes de los poros. De acuerdo con los resultados obtenidos de las diferentes pruebas, se descubrió que la CA con radios de impregnación de R = 2 era la más eficiente. La capacidad de adsorción máxima de MB 2 de la ecuación de de Langmuir, producida por el AC con un R = 2, fue de 357.14 mg/g, aunque el mejor número de yodo de 504.344 se obtuvo del AC R = 1.5. La caracterización del área de superficie (BET) para R = 2 fue de 549,66 m^2/g y el gráfico de adsorción / desorción se clasifica como tipo IV según la clasificación IUPAC de las isotermas de adsorción.

Palabras clave: carbón activado, adsorción, tamaño de poros, área superficial, semilla de aguacate.

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1. Introduction

Activated carbon (AC) is considered a carbonaceous material, with a structure and properties similar to pure coal, such as graphite and diamond; it is strong, permeable and is classified as basic carbon, because of the lack of contaminants and an oxygenated surface [1]. The main characteristics of the activated carbon are the organic groups in their surface, which are generated by oxidation; and, the property to adsorb, due to its high surface area, where the surface of a solid (adsorbent), retains molecules (adsorbates) contained in a liquid or gas [2].

The structure and atom arrangement of AC depend on the type of activation; thermal/physical or chemical activation. Both types of activation generate a porous surface. The chemical activation has two stages: first an impregnation of a chemical must be made on the raw material; afterwards, the material must be carbonized at high temperatures in order to obtain the porous structure. Carbonization is a type of pyrolysis [3].

The atom arrangement is combined as graphite plates, which tend to have single or double bonds, having a thickness of 0.35 nm. The plates present separations between them, which are known as pores, these will define the superficial area of the carbon and subsequently the adsorption capacity. The common superficial area of commercial AC is between 500-1500 m^2/g [2].

During the carbonization, the three main variables are the temperature, heating speed and time; these have an impact on the enrichment of the carbon. The ideal temperatures are 450-900°C and slow speed of heating is recommended to obtain low volatilization and high yield. The time of carbonization depends of the precursor, usually is between 1-3 hours, depending of the temperature of carbonization [4].

The adsorption can eliminate organic compounds and aqueous metals, because of the high efficiency and easy handling; AC is one of the most versatile and common adsorbents, since their great superficial area and pore size [5]. The International Union of Pure and Applied Chemists (IUPAC), classified the porosity of the carbon according to their sizes, taking in consideration the diameter of the pore. The micropores have a size minor than 2nm, these

retain small molecules responsible of odor, taste and solvents. The mesopores have a size between 2-50 nm. The macropores have a size bigger than 50 and 100,000 nm, these works as a "mean of transport" for the adsorbed particles to reach the mesopores [1].

The configuration of the carbon has a relevance, because the application is based on its classification and particle size. The carbon can have the form of irregular granules (granular), dust, pellets or fibers [2]. The granular carbon has different sizes (mesh), which are defined by the ranges of the sieves used; the most common sieve size is the standard American (U.S. Std. Sieve). Commercially, the particle mesh available are: 8x16, 8x30, 10x30, 12x40 14x40 and 20x40, the range of diameter goes from 0.55 until 1.35mm [6]. The speed of the carbon will depend on the particle size, small particles will work faster, yet a higher-pressure fall will be caused on the treated fluid [2]. The mesh of 8x30 is usually used for water and liquid treatment in an industrial or municipal level [6].

Among the years, Mexico has increased the import of activated carbon. The numbers in 2005 were from 5,141 tons, by 2014 were 12,574 tons. The national production has grown as well, since the export numbers increased during the same years: 2,466 tons (2005) and 7,955 (2014) [7]. The increasing numbers of import and export AC show the importance of this product in the market. Even though the export number have increased, these are lower than the imports, therefore more alternatives must be generated to cover the national demand.

Activated carbon can be obtained from different types of organic wastes: coconut shell [8], orange skin [9], wood [10], and cacao [11], among others. The objective is to obtain activated carbon from a residue, which generally does not have a second use.

The avocado is one of the most successful products inside the agri-food sector of Mexico, bringing 4.39% of the national agricultural GDP. The Secretary of Agriculture, Livestock, Rural Development, Fishing and Food (*SAGARPA*, by their initials in Spanish), calculates that in 2016 the production was 1.89 millions of tons, which from 1.02 were designated to exportation (2,227.25 millions of dollars); despite of designating 50% of the production to this sector, the national demand was fully covered. In advance, according to the SAGARPA the production projection in millions of tons for the following years are: 2.05 (2018), 2.61 (2024) & 3.18 (2030) [12]

The seed inside the avocado has a considerable weight of the fruit in general, since the 15% of total weight corresponds only to this component [13]. Due to the avocado is used to produced oils, guacamole, pure, among others [14]; consequently, the seed is wasted before having a second use. According the Food & Agricultural Organization (FAO), the production of avocado in Mexico in 2011 was 1,264,141 tons, while the reported production of the seed residue was 2,700 tons [15]. Comparing the last data, a projection of the seed waste can be made for the 2016; where the residue production was around 4,035.35 tons.

Most of the raw material used for the AC synthesis has a similar characteristic: a strong and raw structure (i.e. coconut shell [8] and wood [10]). The avocado seed presents these two characteristics, and since it is abundant in Mexico [12], it has been considered as a good option to produce AC.

2. Methodology

2.1. Preparation of the raw material

Avocado was opened in order to extract the pulp. The seed was washed with distilled water, to take away all the possible pulp. This was dehydrated during 12 hours at 110°C, to eliminate the humidity from the seed. After the dehydration process, these were crushed to obtain small pieces of the dried material.

2.2. Impregnation

First, the mass was defined as a constant variable, 4.5g were weight for each sample. The samples were classified according their impregnation ratio and then places into a beaker of 250ml. Four impregnation ratios were defined for the phosphoric acid (85%): 0.5, 1, 1.5, and 2. To define the quantity of acid to be added, the mass was multiplied with each impregnation ratio to obtain the mass solute and then calculate the volume of the solution. The corresponding volumes for each impregnation ratio are presented in the following table.

Table 1. Ratios of phosphoric acid impregnation

R	H_3PO_4, g_{solute}	H_3PO_4, ml_{solute}	H_3PO_4, $ml_{solution}$
0.5	2.25	1.34	1.57
1	4.50	2.67	3.14
1.5	6.75	4.01	4.71
2	9.00	5.34	6.28

The solutions were dissolved in 25 ml of distilled water, heated at 85°C and stirred at 150 rpm for 4 hours to rise acid penetration. At the end of the stirring, the flasks were introduced into an oven at 110°C for 12 hours to eliminate to excess of humidity.

2.3. Carbonization

After the flasks were taken from the oven, the mixture was placed into a melting pot. A furnace was used to carbonize mixture at 600°C, with a heating rate of 30°C/min with an inert atmosphere and oxygen free. Important to note, that the carbonization process was made with individual samples, to avoid contamination from adjacent samples. The furnace ran for 4 hours, from this, approximately 20 minutes was the time taken to reach the desired temperature and the rest of the time the furnace remained at constant temperature. At the end of the procedure, the furnace was left to cool down for about 2 hours and then the melting pots were placed into a desiccator. The mixture is from now on classified as activated carbon (AC).

2.4. Washing

The AC was returned to their respected beaker. From each sample 0.2g was obtained and was washed individually with 25ml of NaOH (0.1M) for 30 minutes, with a stirring of 150 rpm. Afterwards, the solution was filtrated (Whatman-1 or equivalent) carefully. Then 175ml of distilled water were added to the beaker to wash the AC, which was filtrated subsequently under the same filtration procedure. Another 200ml of distilled water were added and then filtrated with the identical technique. The pH of the last filtrated solution was measured, until it reached a pH near 7. If the pH was not reached with one wash, a second should be done. Important to note, when washing more sample at the same time, the equivalent volumes for the desired weight should be obtained. Following the wash and reaching the desired range of pH, the AC was dried in an oven under 110°C for 12 hours, to eliminate the humidity.

2.5. Granulometry

The desired mesh for the AC was 8x30 [6], therefore, each sample of carbon was crushed carefully with the help of a mortar. To classify the AC with the selected mesh, a tower of sieves was used. Eight sieves were selected, were the AC had to go through the first sieve and avoid going through the last one. The AC smaller than the last sieve, was classified in percentage; the desired maximum of this percentage was 10%. After this point, the activated carbon can be classified as granular, consequently, granular activated carbon (GAC).

2.6. Experimental design

After obtaining the GAC, different measures were made in order to characterize the material and prove its contaminant removal efficiency. The characterization was tested according to ASTM D4607-14 to determine the iodine number and D3838-05 to determine the pH number. The Brunauer-Emmett-Teller (BET) equipment from Microtrac model BELSORP-mini II was used to calculate the specific surface area, including the pore size distribution. A Morphological analysis was performed using a MAIA (Tescan, Czech) field emission scanning electron microscope (SEM) working at 20kV and equipped with a Bruker Quantax energy dispersive spectrometry (EDS) detector. Used to make an elemental analysis and obtain images of the pores. The test to remove contaminants was made with methylene blue (MB).

2.7. Adsorption isotherm determination for Methylene Blue

For this test the procedure described by J.H. Potgieter [18] in 1991 and Raposo, F., et al. [19] were used as reference. A solution of 25 mg/L of MB was used. To test the maximum absorbency of the solution, the Spectrophotometer HACH model DR6000 was used with a wavelength of 630nm. A curve of calibration was made using concentrations ≥ 25 mg/L, this needs to be used before plotting the adsorption isotherms.

To calculate the isotherms, different carbon weights were used: 1, 10, 20, 30, 40 and 50 mg. Each weighted sample was introduced into an Erlenmeyer flask, and 100 mL of the 25mg/L MB solution was added to the different flasks. A plug was put on in each flask and covered with aluminum to avoid photodegradation. These were left 72 hours with a stirring of 150rpm to reach the equilibrium. At the end of this time, a sample of each flask was taken and then, with the help of the spectrophotometer, the absorbency and concentration (mg/L) was measured. Each run included a control (MB without GAC) and a replicate. To determine the Langmuir and Freundlich isotherms the equations 1 and 2, were used.

$$q_e = \frac{q_{max} \cdot b \cdot C_e}{1 + b \cdot C_e} \quad (1)$$

$$\log x = \log K + {}^{1}/_{n} \log c \quad (2)$$

2.8. SEM analysis of the avocado seed and activated carbons

SEM images were obtained using the field emission SEM. Small samples were taken from each different GAC, then these were placed on a thin layer of platinum and covered with a thin layer of graphite. The samples were observed at an accelerating voltage of 15kV and a working expansion between 4.5-4.7 mm.

2.9. BET analysis of the activated carbons

The surface area of the carbon was characterized by adsorption of N_2 by a Beisorp II mini. A pretreatment was applied at 150°C in a vacuum condition for a period of at least 30 minutes. Adsorption isotherms of the N_2 were measured over a relative pressure (P/P_0) range from 0 to 0.815, with a temperature of 77K. The BET surface area, the pore volume and the mean pore diameter were obtained with this technic; using the range mentioned above.

3. Results & discussion

Before beginning with the analysis of the results, it is important to mention, that the GAC obtained with the impregnation ratios of 0.5 and 1, will not be analyzed since the used procedure was not favorable for both. An important part of the samples was lost during the wash, since the structure broke up. With the small samples left, the analysis was made, yet the results were obsolete compared with the ones obtained with the impregnation ratios of 1.5 and 2, which will be analyzed onward.

3.1. Carbonization yield

The initial weight was equal for all the samples: 4.5g. After the carbonization, the samples were weighted again to determine how much mass was lost during this process. Yet, most of the samples were humid, because of the phosphoric acid. Therefore, the washing of the samples was made and after reaching the desired pH, these were dried and afterwards weighted, recording the respected results, shown in table 2.

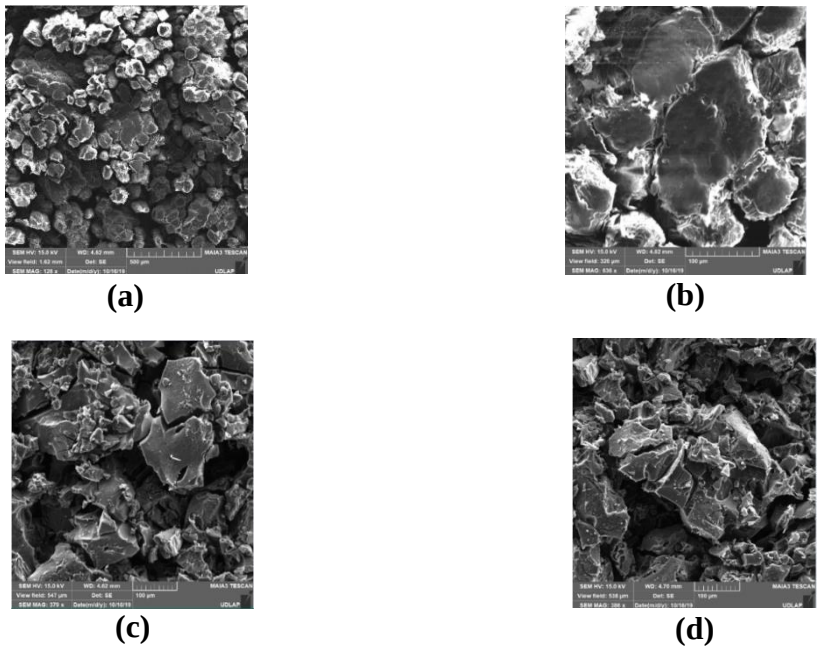
Table 2. Carbonization yield of the R=1.5 & R=2 CAG

R	M_i, g	M_f (avg.), g	Yield, %
1.5	4.50	1.12	25
2	4.50	1.23	27

The yields are 25% for R=1.5 and 27% for R=2, which are relatively low. The reason for obtaining such a low yield, rely on the carbonization temperature and heating rate, since the increase of these two variables decrease the yield of organic carbons [20]. On the other hand, the yield was affected as well by the washing, since the filters used retained particles of the GAC during the process.

3.2. SEM analysis of the avocado seed and activated carbon

SEM images were made of the raw material (a-b) and the activated carbon (c-d), to see the difference between surface structures. The surface of the raw material presents a round and smooth configuration (a-b). On the other hand, the surface of the activated carbon, looks solid and organized (c-d). The raw material surface is more attached, comparing to the AC, which is full of cracks and open pores.



(a) **(b)** **(c)** **(d)**

Image 1. SEM of: (a) & (b) avocado seed and (c) & (d) GAC (R=1.5)

Afterwards, an element analysis was made to each sample, to obtain their composition. The raw material has 49.65% of carbon (Table 3), which is essential to obtain a carbon material subsequently. In tables 4 and 5, it is clearly shown that the percentage of carbon increased after the activation, indicating the presence of a more carbonaceous material; 83.33% for the R=1.5 and 77.93% for the R=2 GAC. The removal of the acid impregnation was successful, since the percentage of phosphorus is low for both cases; 0.7% (R=1.5) and 2.11% (R=2).

The result is higher for R=2, since the beginning more acid is applied to this sample, and therefore, the washing is less effective to this sample.

Table 3. Elemental Analysis of the avocado seed before impregnation.

Element	At. No.	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)	rel. Error [%] (1 sigma)
Carbon	6	49.65	49.65	56.95	5.52	11.12
Oxygen	8	46.15	46.15	39.74	5.28	11.44
Nitrogen	7	2.83	2.83	2.79	0.58	20.34
Potassium	19	1.04	1.04	0.37	0.06	5.77
Phosphorus	15	0.24	0.24	0.11	0.04	15.19
	Sum	100.00	100.00	100.00		

Table 4. Elemental Analysis of the GAC (R=1.5).

Element	At. No.	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)	rel. Error [%] (1 sigma)
Carbon	6	83.33	83.33	87.35	10.64	12.77
Oxygen	8	15.16	15.16	11.93	3.18	20.95
Sodium	11	0.81	0.81	0.44	0.10	11.97
Phosphorus	15	0.70	0.70	0.29	0.08	11.33
	Sum	100.00	100.00	100.00		

Table 5. Elemental Analysis of the GAC (R=2).

Element	At. No.	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)	rel. Error [%] (1 sigma)
Carbon	6	77.93	77.93	87.47	8.66	11.12
Oxygen	8	18.78	18.78	15.10	2.53	13.49
Sodium	11	0.71	0.71	0.40	0.07	10.15
Phosphorus	15	2.11	2.11	0.88	0.11	5.20
Calcium	20	0.47	0.47	0.15	0.05	11.03
	Sum	100.00	100.00	100.00		

3.3. Determination of GAC pH (T=50°C)

It can be seen in table 6 the average of pH, for R=1.5 GAC was 8.7 and for R=2 GAC was 6.6. It was desired to obtain the most neutral pH possible, since having a low pH implicates difficulties with the handling, since it would be more corrosive. Alkaline and acid effects on the other tests can be neglected, when having a neutral pH. The average pH for R=1.5 is 6.56 and 6.60 for R=2, having similar results indicates, that the washing procedure was successful in both cases, obtaining almost a neutral pH material.

Table 6. GAC pH determination

	R=1.5		R=2	
m, g	pH	Stand. Dev.	pH	Stand. Dev
0.3	6.17		6.50	
0.3	6.79	0.342	6.79	0.165
0.3	6.73		6.51	
Avg. pH	6.56		6.60	

3.4. Determination of iodine number

The iodine number helps to determine the surface area and porosity of the activated carbons [21]. It is determined using the standard method of the ASTM D4607-14. The average iodine number for the sample of R=1.5 is 504.3 and for R=2 is 501.8 mg/g (Table 7). There is practically no change in the result between the two impregnation ratios. The typical iodine number of an activated carbon, range is 500-1200 mg/g [22]. Thus, even though there is no increment of the iodine number, both samples enter in the range.

Table 7. Iodine number from GAC (R=1.5)

R=1.5				R=2			
C, N	X/M, mg/g	log (c)	log (X/M)	C, N	X/M, mg/g	log (c)	log (X/M)
0.064	2373.568	-1.197	3.375	0.066	2373.084	-1.180	3.375
0.066	1977.570	-1.181	3.296	0.062	1978.267	-1.209	3.296
0.063	1695.500	-1.201	3.229	0.065	1695.233	-1.188	3.229
Avg. Iodine Number			504.344	Avg. Iodine Number			501.809

In table 8 a comparison of iodine number using different organic waste material was listed. The result obtained in this work relates well with the other adsorbents. The reason of the small value may be due to the low amount of carbon used for this analysis.

Table 8. Comparison of Iodine Number on GAC with different organic waste

Reference Raw material	mg/g	Reference
Avocado seed	501.81	This work (R=2)
Acorn Shell	372	[23]
Rubber Wood Sawdust	958	[24]
Olive stone	574	[25]

3.5. Adsorption isotherm determination for MB

The methylene blue adsorption isotherm determination was analyzed and compared between the two different AC's. The results of the R=1.5 GAC were neglected, since the correlation coefficient was lower than 0.86. The results obtained are displayed in equation 3 and 4.

$$\frac{C_e}{q_e} = 0.0024C_e + 0.0116\ ;\ R^2 = 0.869 \quad (3)$$

$$\log q_e = 0.6079C_e + 1.8193\ ;\ R^2 = 0.7779 \quad (4)$$

The best results were obtained from the R=2 GAC, as the Lambert-Beer's law is fulfilled. The graphics from the equation 1 (a) and 2 (b) are displayed in figure 3. The best correlation coefficient obtained, was from the Langmuir's equation compared to Freundlich's equation. According to this result, the GAC will adsorb all substrate molecules, even though the surrounding fluid concentration suddenly changes [26]. Afterwards, the adsorption isotherm for MB was plotted (Figure 3. c), in order to determine the type of isotherm according to the IUPAC (Brunauer classification): Type I; this reversible type of isotherm can be obtained for microporous solids with relatively small external surfaces [27].

The values obtained of the maximum adsorption of MB (q_{max}) and the Langmuir constant (K) for the R=2 GAC were 249.12 mg/g and 0.07. According to these results, an efficient presence of macropores is notable.

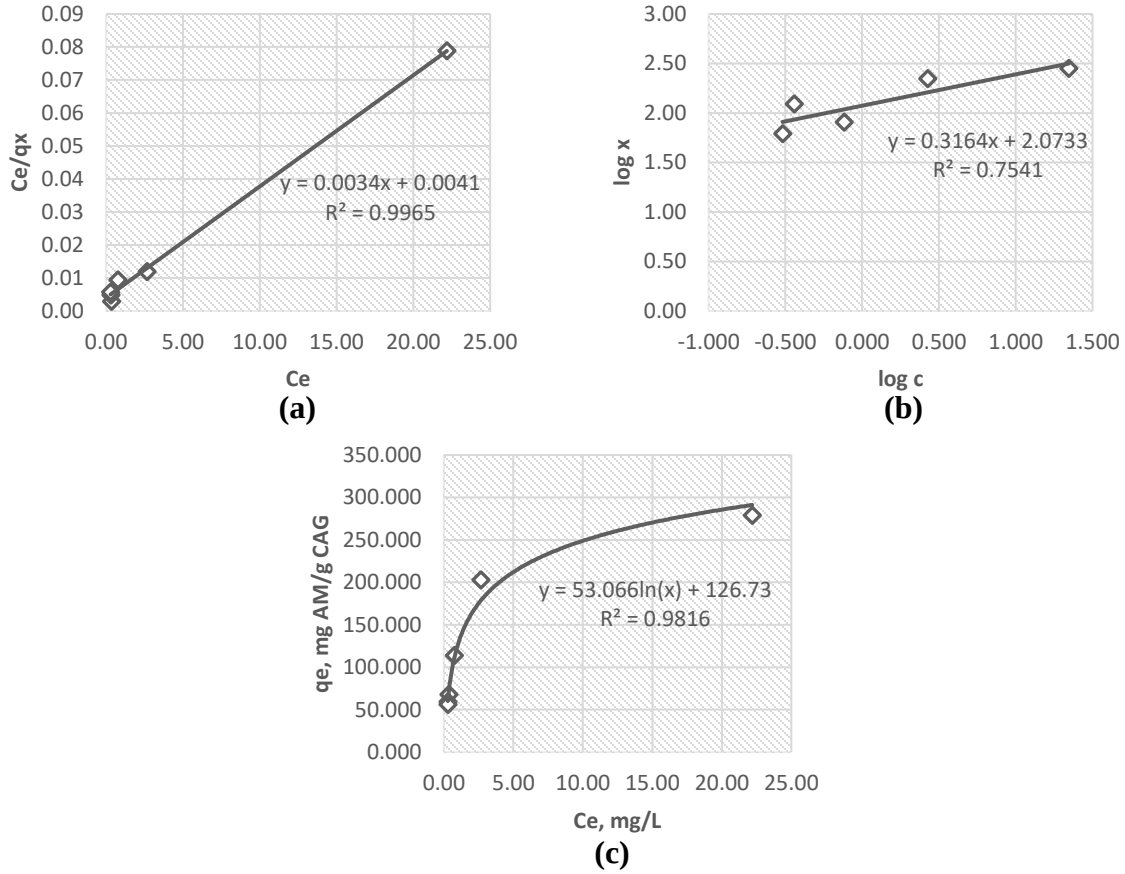


Figure 3. Linear transformation of the adsorption isotherm for MB (R=2) to Langmuir's (a) and Freundlich's model (b), and adsorption isotherm for MB (c).

Table 9. Comparison of Langmuir constants for MB adsorption on GAC with different organic waste

Reference Raw material	q_{max}, mg/g	K_L	Reference
Avocado seed	357.14	0.07	This work R=2
Bamboo based	549.66	0.56	[28]
Pecan Nutshell	400	0.625	[29]
Cherry stone	321	0.04	[30]

A comparison of the methylene blue adsorption on GAC is registered in Table 9 with different types of organic waste material. The maximum adsorption with avocado seed is lower compared to bamboo and pecan nut, but higher compared to the cherry stone, done with a similar procedure using a lower temperature in the activation.

3.6. BET analysis of the activated carbons

In the following table, the results obtained with the BET equipment are shown. The results show, that the CAG of R=2 has greater surface area, pore volume and pore diameter than the one of R=1.5. According to the pore classifications, both GAC's enter in the mesopores range (2nm < d < 50nm) [31].

Table 10. BET analysis results for the different CAG's

R	$a_{s,BET}$, m^2/g	Pore Volume, cm^3/g	Pore diameter, nm
1.5	516.72	0.49	3.80
2	549.66	0.56	4.06

Table 11. BET analysis Comparison of different organic CAG

Raw Material	$a_{s,BET}$, m^2/g	Pore Volume, cm^3/g	Pore diameter, nm	Reference
Acorn Shell	535	0.236	2.28	[23]
Olive Stone	1200	-	-	[25]
Rise husk	750	0.38	2.04	[30]

In table 11, a comparison with different surface areas, pure volume and pore diameter was made. The surface area obtained in this work shows a more favorable result compared with the acorn shell, but not a better result compared with the olive stone and rise husk even though the impregnation ratio is lower than 2. Also, the pore diameter and pore volume of the avocado seed GAC with both impregnation ratios, is greater compared with the other examples.

According to the IUPAC, there are six different types of adsorption isotherms. Figure 4, obtained with the BET equipment, shows the adsorption/desorption isotherm for the CAG of

R=2, which is classified as type IV. This type of isotherm is characteristic of mesoporous solids, presenting a hysteresis loop, related to the vacating of mesopores by capillary condensation. This type is a combination of type I and II; which are typical for microporous- and macroporous adsorbents respectively, being both reversible isotherms [27].

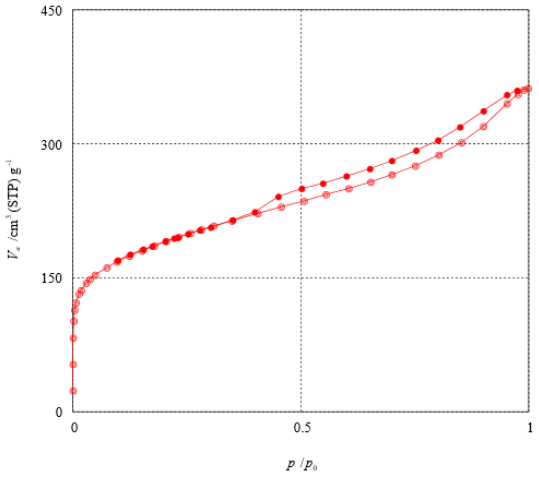


Figure 4. Adsorption / desorption isotherm for the R=2 CAG.

4. Conclusion

In conclusion, the results obtained with the different test methods show that the best ones were from the GAC with the ratio of impregnation 2. This demonstrates, that the quantity of phosphoric acid applied to the raw material had an influence on the activation of the carbon. The results of methylene blue, iodine number and BET analysis were compared with different types of organic granular activated carbons. The results from the GAC obtained from the raw material, avocado seed, presented a similar behavior compared to the other examples taken from the literature.

Regarding to the MB-analysis, the results were like the ones from the cherry stone [30] GAC, possibly due to the synthesis process used for both GAC, since it was a similar one. For the iodine number analysis, the result of the R=2 GAC can be compared with the olive stone [25] data, since is the most alike result in the comparison table. For both processes, the impregnation was made with phosphoric acid, the ratio was 1.75 for the olive stone and 2 for this case; the impregnation ratio can be a reason of the similar results. Lastly, the BET surface area for both impregnation ratios (1.5 and 2), exhibited a similar result to acorn shell, yet, the pore volume and diameter are relatively smaller than the avocado seed GAC; although the similar results, acorn shell got zinc chloride as chemical activator.

The results and comparison obtained in this article, tells us, that granular activated carbon obtained from avocado seed is a viable option since its characteristic are alike to other GAC's prepared with different raw materials. Despite of the positive results, the process can be

improved, which furthermore could be centralized in the carbonization process, were the yield for this case was low. An economic analysis can be made as well, to obtain the process cost and optimization, then verify the viability of it. Finally, the great number of avocado residues can be reutilized and even generate economical profit. The raw materials synthesis to obtain granular activated carbon is a possible option.

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