Production of Activated Carbon from Oil Palm Shells via Physical Activation with H_2O and its Characterization for Use in Aqueous Phase

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Abstract

Oil palm shells (OPS) are a solid residue of the extraction of palm oil having excellent characteristics for production of activated carbon. OPS worldwide production amounts to 17.214 ton (2018) from which Colombia participates with 364 ton. Oil palm shells were first carbonized in a horizontal oven under N_2 atmosphere until 850 °C for 30 min. Carbonized samples were than submitted to physical activation with steam in the same horizontal oven. A variation of process parameters was performed. Activation temperatures of 750, 800, 850 and 900 °C were studied. Residence time varied between 60 and 400 minutes. H_2O flow rates between 1 a 5 ml / min were used. 50 g of carbonized oil palm shells were used for each experiment. The influence of the process conditions on pH, soluble water content, extractable acid content, methylene blue index, BET surface area from N_2 adsorption and density were determined. Visual inspection through scanning electron microscopy and determination of surface functional groups through infrared spectroscopy were performed. The obtained activated carbons show suitable characteristics for its use in aqueous phase. Results obtained were useful to determine its optimal production conditions.

Keywords: Oil palm shells, activated carbons, physical activation, adsorption.

1. Introduction

The pollution generated by human activities alters the soil, air and water, introducing chemical compounds conceivably harmful to planet´s ecosystem. There is a large amount of organic and inorganic waste coming from farming, industry and urban facilities.

Among the methods developed for removing contaminants from liquid and gaseous phases, the adsorption with porous solids has been used since ancient years. Particularly, carbonaceous materials were applied as filters for air and water, because of its chemical and physical properties. Previously the adsorbents utilized were coal and carbonized biomass, then the implementation of activation processes with reaction agents such as chemicals and gases, originated the activated carbons. The activation stage consists of developing the porous structure, releasing atoms from the surface of the solid, through chemical reactions propelled by heating and interaction with selected reagents.

In Colombia more than 500.000 hectares are used for oil palm crops (Fedepalma, 2017), their waste have been recognized as good precursor for activated carbon production (Rashidi, 2017). Characteristics as the empty space within the particles, known as porosity, the particle´s surface area value and the groups of atoms attached on surface, are important for the capture of pollutants in the adsorption process.

2. Materials and Methods

2.1. Raw material

Oil palm shells (OPS) obtained from the oil palm extraction process are used as raw material for production of activated carbon. These shells contain high percentage of carbon and lignin (González-García, 2018), granting good qualities to develop the porous structures. A commercial activated carbon based on coconut shells was included to compare results.

2.2. Preparation of activated carbon from OPS

OPS were ground using a cutting mill SM100 – Retsch, and then were sieved. The fraction of particle size around 2 mm was used. Carbonization and activation were performed in a horizontal fixed bed furnace. First OPS were carbonized at 850 °C for 30 minutes, at a mean heating rate of 4 °C/min, under N_2 flow rate of 0.9 L/min. The char obtained was divided into batches of 50 g, then these were physically activated at temperatures of 750, 800, 850 and 900 °C, changing the N_2 flow to steam flow after reaching the activation temperature. Activation time was between 60 and 400 min.

2.3. Characterization

The carbonized OPS (char), the obtained activated carbons (AC) and the commercial activated carbon (AC-C), were characterized following the standards presented in Table 1. Additionally methylene blue index, scanning electron microscopy and infrared spectroscopy tests were performed.

Table 1. Standard test methods applied

Standard test	Description
ASTM D2854	Bulk density
ASTM D2862	Particle size
ASTM D2866	Ash content
ASTM D2867	Moisture content
ASTM D3838	pH measurement
ASTM D5832	Volatile matter content
ISO 9277:2010(E)	BET surface area

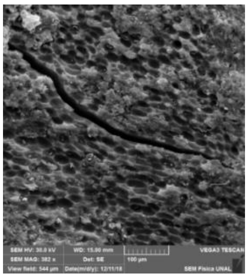
3. Results and Discussion

The results of the characterization of the char and the activated carbons are presented in Table 2. The bulk density of the char is 625 kg/m^3, of AC-OPS is 500 kg/m^3 and of AC-C was 555 kg/m^3. The most representative mass fraction of the particle size distribution of char and AC-OPS was found in the sieve of 1 mm aperture mesh, while for AC-C was in the 1.7 mm aperture mesh.

Table 2. Values obtained for carbons tested

	A %	M %	VM %	MB ml/g	BET m^2/g	pH
Char	4.8	2.6	2.7	10	29	6.27
AC750D38	6.7	1.6	3.3	89	973	6.70
AC800D43	7.6	1.3	2.7	157	1074	7.28
AC850D24	7.4	2.8	0.6	48	884	5.55
AC850D46	7.7	1.7	1.9	188	1135	8.27
AC850D64	12.2	11.8	2.7	215	1214	6.07
AC900D40	6.6	3.0	1.8	159	1027	7.62
AC-C	1.3	3.4	5.6	195	1140	5.81

The obtained activated carbon showed a well-developed surface area with values as high as 1214 m^2/g. The greater the value of BET surface area the greater adsorption capacity for methylene blue. The carbons studied showed a high thermal stability and were predominantly of a slightly acid character. Sample AC850D46 showed similar BET surface area and methylene blue number as the commercial activated carbon (AC-C). Contrary to the tendency of the activated carbons to have an acidic character this sample show basic character. The AC-OPS have a rough surface with fixed heteroatoms, as shows Figure 1. Phenol and carboxyl groups can be found attached to the surface of carbons, taking into account, that peaks attributed to their presence (Figueiredo, 1999) are in the spectrum in Figure 2.



a)

C	88.22
O	9.38
Si	1.43
K	0.73
Mg	0.24

b)

Figure 1. *a)* SEM image and *b)* chemical composition (%) by EDS of AC850D64.

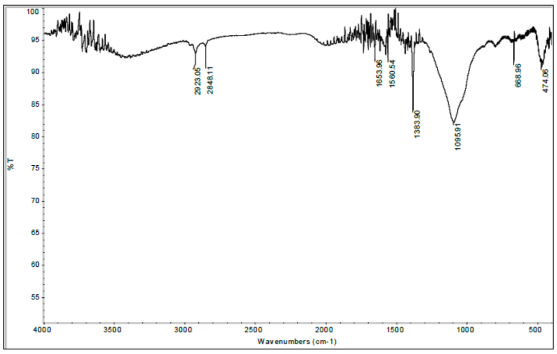


Figure 2. FTIR spectrum of AC850D64.

4. Conclusions

AC-OPS show appropriate characteristics to be used in adsorption processes. BET surface areas and methylene blue numbers similar to that of the commercial activated carbon could be obtained. By increasing conversion degree, the adsorption properties of the activated carbons are enhanced. On the surface of the activated carbons phenol and carboxyl groups are presented.

References

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