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Use of Sugar Cane Fibers as Raw Material for the Production of Activated Carbon †

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Abstract: For years, activated carbon manufacturing has been based on coal. However, today, as coal mines in Eastern Europe are not accessible anymore, companies producing coal-based adsorptive materials need to search for new raw materials. Sugar cane fibers may provide an alternative solution. The sugar cane fibers tested were supplied from five different local sugar factories, and other soil, farming and harvesting conditions were maintained. In terms of cellulose and hemicelluloses, the chemical composition of sugar cane fibers is similar to wood; the differences are in the lignin content, with bagasse containing less lignin compared to wood. The research and production process included thermolysis, cooling, granulation, and then carbonization and activation. The final products were washed to remove ash and dried. In the new sugar cane fibers, it was shown that activated carbon has a well-developed porous structure and high adsorption capacity, especially for organic compounds with small particle sizes.

Keywords: activated carbon; sugar cane fibers; adsorption

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1. Introduction

Sugar cane pulp is a by-product of the production of the sugar plant. It is a fibrous substance that remains after the sap of the sugar cane plant has been harvested. Until recently, cane pulp was usually discarded or decomposed. However, today, it is used as a renewable raw material for fiber-based products, tar production and as an alternative fuel for factories [1,2].

For years, activated carbon manufacturing has been based on coal. However, today, as coal mines in Eastern Europe are not accessible anymore, companies producing coal-based adsorptive materials need to search for new raw materials. Sugar cane fibers may provide an alternative solution [3,4]. Similarly to coal, sugar root waste should firstly be dried and melted. Additives (binders, activators and others) are combined with the pulp, and it is then pressed into the desired shape in the granulation process, carbonized, activated, washed to remove ash and dried. The result may be a durable, safe product made from renewable plant resources [5,6].

2. Material and Methods

The sugar cane fibers tested were supplied from 5 different local sugar factories, and other soil, farming and harvesting conditions were maintained. The sugar cane fibers used in the experiments contained: 39.1–41.3% cellulose, 29.4–31.3% hemicellulose, 14.9–16.5% lignin and 11.4–14.4% other components presented in the Table 1. In terms of cellulose and hemicellulose, the chemical composition of sugar cane fibers is similar to wood, the differences are in the lignin content, with bagasse containing less lignin than wood.

Table 1. Sugar cane fibers' features.

Parameter	Different Sugar Cane Fibers				
	1	**2**	**3**	**4**	**5**
Moisture [%]	9.43	11.78	11.77	14.44	13.9
Ash [%]	1.24	2.13	2.86	2.40	2.76

Source: own experiments.

The research was conducted in the laboratory of Grand-Activated Ltd. The carbonization of the sugar straw was carried out in a steel retort placed in a muffle furnace. The temperature in the muffle furnace was maintained at a level that allowed the proper annealing of the coal and the release of residual volatile compounds. After thermolysis, the resulting carbon was kept in the retort without access to air until it had cooled completely, and then it was weighed. Next, it was processed using the granulation process, and then, carbonization and activation were carried out. The final products were washed to remove ash and dried.

The moisture content, ash content bulk density, volatile matter, iodine number, methylene number, specific surface area and mechanical strength of the raw and processed products were determined.

3. Obtained Results

The efficiency of the controlled carbonization products in relation to the dry post-sugar straw was as follows:

- Solid product—coal—33.2%;
- Liquid products—40.8%;
- Gaseous products—18.0%;
- Losses—8.0%.

Liquid products contained 9.3% sludge tar. The acidic water was characterized by 2.95% soluble tar and 8.68% acid content per acetic acid. The properties of the activated carbon in the sugar post-production obtained in the different carbonization tests are shown in Table 2.

Table 2. Activated carbon of sugar cane fibers features obtained using different processes.

	Parameter	Activated Carbon Features Obtained Using Different Processes				
		1	**2**	**3**	**4**	**5**
1.	Bulk density [g/dm^3]	82	80	74	78	81
2.	Volatile matter content [%]	20.65	15.51	13.06	12.76	13.15
3.	Ash [%]	13.7	13.75	10.64	9.85	11.05
4.	Elementary carbon in the sample [%]	62.8	73.7	65.1	71.8	68.31
	Iodine number [mg/g]	776	783	756	791	767
	Methylene number [cm]	39	52	45	42	49
	Specific surface area (SSA) [m^2/g]	649	925	675	721	880
	Mechanical strength [%]	58	97	78	75	91

Source: own experiments.

The activated carbon in the sugar fiber obtained in the five industrial tests had a developed specific surface area and high adsorption rates for iodine and methylene blue, corresponding to the best activated carbons. Good-quality activated carbon should be characterized by an SSA higher than 800 m^2/g. Only sample No.2 and 5 had such an SSA. Different results were obtained using manufacturing processes with various temperatures. Carbon No.1 and 3 had lower temperatures of carbonization and activation, and carbon

No.4 had higher temperatures. Samples No.2 and 5 were characterized by significantly higher ash contents than the charcoal activated carbon.

The main qualitative difference was in the mechanical strength of the activated carbons obtained, as in the first sample, a significant proportion of the granules was destroyed in the activation furnace, and the remaining granules had minimal mechanical strength, while the activated carbon obtained in the second sample had hard granules with a strength of 97.2%. The mechanical strength of the tested carbons followed the patterns on the SSA and was the best for samples No.2 and 5; sample No.1 had the poorest mechanical features.

The granular sugar cane fiber activated carbon obtained in the second sample had satisfactory mechanical properties and high adsorption capacities. In terms of granulation, mechanical strength and vapor and gas adsorption, it had similar ratios to domestic N-type activated carbon produced from hard coal [5].

To summarize the properties of activated carbon from sugar cane fibers, according to the technology used, the activated carbon had a well-developed porous structure and high adsorption capacity, especially of organic compounds with small particle sizes, which is in agreement with the findings of Ahmeda (2000) [6,7].

Garlock and others (2009) noted that activated carbon based on sugar fibers in the granular form can be used, among others, in wastewater treatment and water renewal processes [8]. The properties of the activated carbon in our experiments were similar to those of a material described by Cai (2019) and may be used for the adsorption of vapors and gases and the adsorption different of matter from the liquid phase in, inter alia, the chemical industry [5,8].

According to Chaiwon et al., 2017, as a new generation of adsorbent, sugar-cane-based carbon is an effective product for the manufacturing of chemisorbents and carbon catalysts. The main problem with this material may only appear during high temperature processing. Lower temperatures resulted in poor adsorption properties. On the other hand, overheating led to a decrease in mechanical strength [1,9,10].

4. Conclusions

Post-sugar straw is a ligno-cellulosic material that is a residue from the industrial use of sugar cane in the sugar industry. In terms of its chemical composition and fiber structure, it is a valuable raw material for the pulp and paper industry, the plate industry and in the production of activated carbons. Once processed, sugar straw can be used for many purposes. Once sugar cane has been harvested and liquid has been extracted, the residual substance is kept in a pulpy state and then mixed with water to form pulp. Experiences in the preparation of activated carbon from this substance indicate that it is relatively easy to obtain high sorption properties characterized by the degree of methylene blue (LM) decolorization or iodine (LJ) adsorption. Difficulties arise in obtaining good properties characterized by the decolorization of molasses (molasses number LMS). This phenomenon is not observed in the laboratory activation of post-sugar straw carbon alone without a binder. This applied carbon form requires an intensified activation process.

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