
PRODUCTION AND CHARACTERIZATION OF ACTIVATED CARBONS FROM SUGARCANE BAGASSE FROM CHEMELIL SUGAR FACTORY, COMPARED WITH COMMERCIAL ACTIVATED CARBONS

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doi: <https://doi.org/10.37017/jeae-volume6-no1.2020-3>

Publication Date: 30 June 2020

ABSTRACT

In Kenya activated carbon is imported yet we have enough bagasse that can be used in its production. The activated carbon from bagasse adds economic value to the bagasse and the processing excess bagasse provides for good utilization and management of the bagasse as a waste. The objective was to produce activated carbon from bagasse from Chemelil sugar factory on laboratory scale in a fabricated retort and furnace at selected conditions of temperature and time, characterize and give a comparison with the commercial activated carbons. Using molasses as a binder, ratio 1:1, the bagasse and molasses mixture was compressed into pellets in an extruder, heated to produce a char, and then activated using carbon dioxide, before finally being ground into powdered activated carbon. Carbonization was done in a retort, while the heating was done by two gas burners. Temperature, was controlled between 300 – 700 °C. The carbonized material (char) was cooled and ground to powder. Sample activation was conducted in an atmosphere of carbon dioxide passing through a chrome-nickel pipe with a gas distributor mounted in a furnace of porcelain cylinder with a metal sheet having one end closed. Air and nitrogen were used to control burning and the temperature of the furnace was controlled to between 300 – 600 °C. The activated carbons produced were characterized for their physical properties (bulk density, surface area, and micro pore volume and pore size), chemical properties (ash, pH, conductivity) and compared with selected two commercial activated carbons. The results showed that carbon materials activated from bagasse for 5 h at a temperature of 600 °C had similar characteristics with the commercial ones and therefore an inexpensive substitute with further process development on surface area.

Keywords: Sugarcane Bagasse, Activated Carbon, BET surface area, Adsorption

1.0 INTRODUCTION

Processing bagasse to produce activated carbon takes care of the potential hazard of fire outbreaks and also reduces on the cost of its disposal from

the sugar factories. The low cost and high availability of sugarcane bagasse make it attractive feedstock for activated carbon production and the subject of further research

efforts to create carbons with properties that equal or exceed those shown by commercial carbons and replace the expensive commercial adsorbents. Adsorption can be more economical than other processes when the adsorbent is cheap and easily available. Activated carbon is extensively used in sugar refining, bleaching of vegetable oils and chemical solutions, water purification, recovery of solvents and other vapors, in gas masks for protection against toxic gases and in filters for removing pollutants. Excess bagasse from sugar all companies in Kenya averages 700,000 tons per year an equivalent of 46% which is a large amount of biomass. The sugarcane bagasse is an underutilized waste material. Biomass such as bagasse, sugar cane fiber or solid waste from sugar cane (after juice extraction) can be used in

the production of activated carbon (AC) for adsorption applications [1- 4]. Bagasse in the sugar factories is mainly used as fuel in boilers to produce electricity and process steam, while the excess estimated at 46% is disposed from the factory to be used as manure in sugarcane farms or sometimes burnt. In Kenya, some bagasse is also used in the making of briquettes and match sticks. Bagasse production from sugar companies in Kenya averages about 2,000,000 tons per year [5]. The ninth row of Table 1(a) shows an initial decline and subsequent growth in the total amount of bagasse produced from Sugarcane in Kenya from 2009 – 2013, while Table 1(b) provides figures from 2014 – 2018 that indicate a decline in the year 2017 and recovery in 2018.

Table 1 (a): The amount of bagasse produced from sugarcane in Kenya from 2009 – 2013 (row 9).

Item	Production per annum (Year)				
	2009	2010	2011	2013	2014
Sugar Crushed (Tons)	5,622,175	5,591,678	5,385,224	5,830,058	6,810,338
Sugar Made (Tons)	549,598	522,499	501,473	502,563	602,151
Sugar Bagged (Tons)	548,207	523,652	490,210	493,937	600,179
Sugar Sold (Tons)	546,361	513,189	488,141	592,150	583
Ton Cane/Tons Sugar Ratio	10.23	10.70	10.74	11.60	11.31
Rendement Sugar (Sugar % Cane)	9.78	9.34	9.31	8.62	8.94
Molasses Produced (Tons)	198,061	185,074	199,811	222,836	241,561
Molasses % Cane	3.52	3.31	3.71	3.82	3.55
Bagasse Produced (Tons)	2,230,978	2,137,172	2,015,681	2,185,212	2,468,338
Bagasse % Cane	39.68	38.22	37.43	37.48	36.24

*Factory Performance of all Sugar Factories in Kenya 2009 – 2013.

[5] (Agriculture Food Authority - Sugar Directorate Kenya Year Book of 2018 C: 100.)

Item	Production per annum (Year)*				
	2014	2015	2016	2017	2018
Sugar Crushed (Tons)	6,596,994	7,266,023	7,411,303	4,640,771	5,383,759
Sugar Made (Tons)	590,150	642,278	638,653	375,012	440,805
Sugar Bagged (Tons)	592,668	635,674	639,742	376,111	491,097
Sugar Sold (Tons)	603,593	626,121	635,851	371,311	482,338
Ton Cane/Tons Sugar Ratio	11.18	11.31	11.60	12.37	12.21
Rendement Sugar (Sugar % Cane)	8.95	8.84	8.62	8.08	8.19
Molasses Produced (Tons)	227,135	251,642	264,732	192,717	211,064
Molasses % Cane	3.44	3.46	3.57	4.15	3.92
Bagasse Produced (Tons)	2,422,898	2,608,776	2,738,548	1,705,148	1,973,574
Bagasse % Cane	36.73	35.90	36.95	36.74	36.66

* Factory Performance of all Sugar Factories in Kenya 2014 – 2018.

[5] (Agriculture Food Authority - *Sugar Directorate Kenya Year Book of 2018 C: 100.*)

Due to high cost of commercial AC, various agricultural waste materials have been widely examined for the preparation of low cost activated carbon. Such raw materials include bagasse [6 -7], nutshell ([8], rice husks [9] [10], oil palm shell [11], sugar beet molasses [12], cotton stalk [13] tea industry waste [14], and Vetiver roots [15]. Data on the amount of trade in activated carbon in Kenya is not available, but the global activated carbon market revenue has been increasing and continues to increase. It is projected that it will increase from US\$ 367 M in 2018 to US\$ 584 M in 2028 [16]. In Kenya activated carbon is mainly used in wastewater treatment to remove dyes and colorants in wastewaters, which decrease light transmission and photosynthesis in aquatic environments [17-18]. In addition, the dyes have carcinogenic and mutagenic effects [19]. Treatment of wastewaters polluted with these compounds is very challenging since many of these dyes with aromatic compounds are non-biodegradable [20-21]. However, the activated carbon from bagasse is a low-cost, natural and available adsorbent, and, it has been applied for the removal of many

pollutants [22-23]. Activated carbon from bagasse has been used to remove Lead from wastewater [24-25]. Some activated carbon is used in hospitals for treatment of patients who have ingested poison.

Bagasse is composed largely of cellulose, pentosan, and lignin. Various studies indicate that sugarcane bagasse is a new alternative that can replace the existing products of activated carbon precursors like coal. [6, 26]. When comparing conventional and non-conventional adsorbents, activated carbon from sugarcane bagasse compares well in waste water treatment [27-28]. With improvement in the technology, the cost of activated carbon from bagasse would be US\$ 0.5/lb. compared to commercial activated carbons, which is in the range of US\$ 5 – 20/lb. in United states of America according to [6].

The adsorption capacity of an activated carbon is determined by: (i) its surface area, (ii) internal porous structure, and (iii) the functional groups at the carbon pore surface. Activated carbon materials are known to contain oxygen, hydrogen, chlorine and Sulphur atoms. These

atoms are derived from their starting material and become part of the chemical structure as a result of carbonization or being chemically bonded to the carbon during the activation process or during oxidation. The atoms get bound to the edges of the carbon layers and form surface groups that greatly affect the adsorption behavior of the activated carbon [29-31]. Activated carbons with equal surface areas, but having been prepared by various methods or different activation treatments contain a diversity of functional groups and hence exhibit different adsorption characteristics [32]. This is due to the formation of different types of surface oxides with a variation of concentrations on the carbon surfaces [33]. The carbon–oxygen surface structures are important in influencing the surface characteristics, which include the interaction with polar and non-polar adsorbates [29]. The most common functional groups, which influence surface activity are carboxyl, carbonyl, phenolic, hydroxyl, anhydride, ether-type, and lactone and lacteal groups. The presence of surface oxygen complexes imparts a polar character to the activated carbon surface, which causes enhanced adsorption of polar organic compounds [34-35].

The type and net charge of the functional groups bonded to the carbon surface elucidates the mechanism of adsorption between ionic adsorbates and the activated carbon [36]. The electrical charge of the surface groups plays some part in adsorption because if the adsorbate has the same electrical charge as that of the carbon surface, repulsion will occur thereby inhibiting the adsorption process. However, the adsorption will be enhanced if the adsorbate and the carbon surface have opposite charges. The physical, chemical and surface characteristics of activated carbon determine its efficiency in removing the targeted colorants. These properties of activated carbon include: Surface area [37-38] density [39] particle size [40-41] . Other properties are: porosity, wettability, dustiness, operation temperature, electrical conductivity, moisture, and pH [42], total ash ([6], and water extractable inorganics. There are also acid soluble inorganics

of Sulphur, sulphides, sulphates and phosphates together with chlorides of iron, copper, zinc, calcium, magnesium and silica in small proportions [43-44].

In the present study, the production of activated carbon from bagasse is seen as having potential to add value to the sugar industry as an extra income stream, besides the activated carbon produced being used in the sugar refining process as a decolorizing agent. Activated carbon is used as an ingredient in the making of cosmetics [45]. Processing excess bagasse to produce activated carbon can provide better solutions in the utilization and management of the waste in the sugar industry. This will take care of the potential hazard of fire outbreaks in addition to reducing the cost of its disposal. Therefore, the objective of this work was to (i) produce activated carbon from sugarcane bagasse of Chemelil Sugar Company at selected temperatures and times, (ii) evaluate and characterize the properties of the produced activated carbon, and (iii) compare the properties and performance of the produced activated carbons with commercial activated carbons.

2.0 MATERIALS AND METHODS

Materials Used

The materials used included: 1. Sugarcane bagasse (Chemilil Sugar Company, Kenya); 2. Cane molasses (Chemilil Sugar Company); 3. Nitrogen (Kenya Industrial Research & Development Institute); 4. Carbon dioxide (Kenya Industrial Research & Development Institute); and 5. Commercial activated carbons (Sutcliff Carbons England).

Experimental Methods

The bagasse sample was mixed with molasses in a mass ratio 1:1, compressed into pellets using an extruder, and then heated to produce char. The char was put through the activation stage and finally ground into powdered activated carbon. Carbonization was done in a retort, of capacity of 1.0 kg at a temperature range of 300 – 700 °C by heating using two gas burners, which were controlled by adjustment of the gas pressure until gas evolution ceased. A Chromel-Alumel thermocouple was placed through one end of the closed tube extended to the middle of the retort to control the temperature as illustrated in Fig. 1. The gas evolved was passed through an externally cooled condenser for the removal of tar and water. After cooling, the carbonized material (char), was removed from the retort, washed with hot water, then with dilute HCl to remove salts, and then finally washed with cold water until pH was neutral. The washed carbonized materials were dried in an oven at 120 °C for 2 h, then

ground to powder using an electrical driven laboratory mill, ready for activation. Experiments were performed to final temperatures of 300 – 700 °C with heating rates ranging from 5 to 30 °C/min with nitrogen sweep gas flow-rate of 350 ml/min. During activation, a furnace of porcelain cylinder with a metal sheet was used and one end closed with a distributor through which a Chrome-Nickel pipe passes for gas inlet as shown in Fig. 2. A Chrome-Alumel thermocouple was placed in the furnace. The temperature of the furnace was controlled by the rheostat during activation, which lasted between 2 – 5 h. The top of the furnace was closed to prevent any air leakage. Carbon dioxide gas was used as the activating agent. The furnace was first pre-heated to 300 °C before 100 g of the carbonized char was charged into it. Air and nitrogen were used to control burning. The temperature varied from 300 to 600 °C. The final product was again washed with hot water, then with dilute HCl to remove salts; then finally washed with cold water until neutral pH was attained, after which the sample was dried in an oven at 120 °C for 2 h

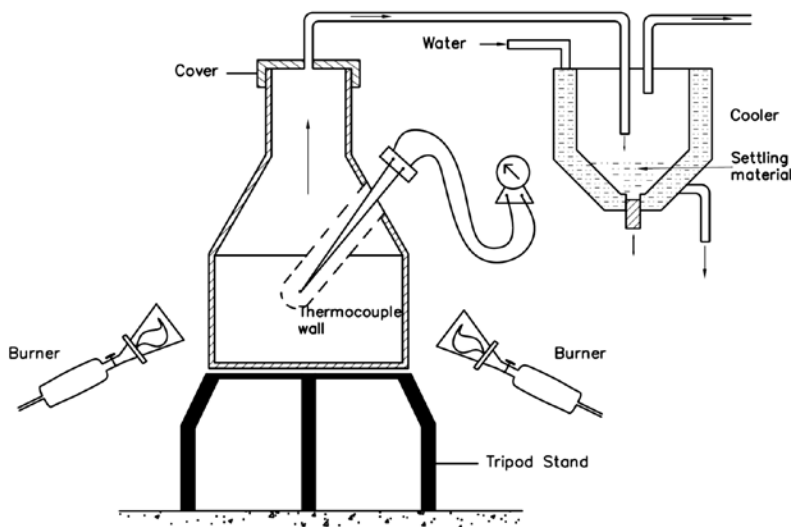


Figure 1: Sketched Experimental set up for the carbonization of bagasse materials.

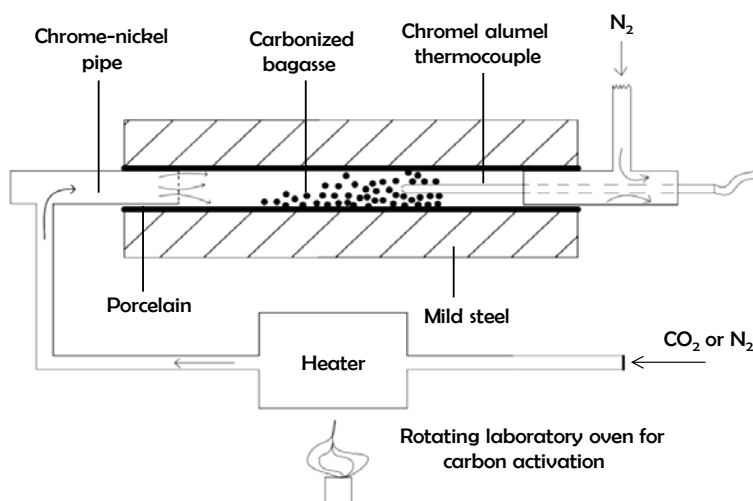


Figure 2: Sketch of a set up for the activation of carbonized bagasse.

The so-produced activated carbons were characterized for their physical properties (bulk density, yield, surface area, micro pore volume and pore size), and chemical properties (ash content, pH, conductivity) determined [46]. The Braunauer-Emmet-Teller (BET) specific surface areas of the samples were determined using the N₂ adsorption-desorption isotherms at 77 K in the relative pressure range of 0.05 to 0.25 as follows. The activated carbon samples were dried under vacuum at 100 °C for 3 h to remove moisture from the carbon pores. Samples were placed in an automatic Surface Area Analyzer (Micrometrics ASAP 2000), which measures the adsorption of nitrogen gas to the samples at 77 K with the help of the Micrometrics software. In the calculations, the cross-sectional area of the

nitrogen molecule was taken as 0.162 nm². The total volume pore volume of the adsorbed amount of N₂ was taken at the relative pressure greater than 0.98, assuming a liquid molar volume of N₂ to be 34.65 cm³/g at 77 K.

The average pore diameter, D is calculated from equation below

$$D = \frac{(4) \text{ (Pore volume)}}{\text{BET Area}}$$

The bagasse activated samples were coded before being characterized as in Table 3 shows the coding, activation temperature and time spent in the production of the AC materials.

Table 3: Coding system for the activated bagasse samples carbon.

Sample code	Activation	
	Temperature (°C)	Time (h)
500/C3	500	3
500/C4	500	4
500/C5	500	5
600/C3	600	3
600/C4	600	4
600/C5	600	5

Methods of characterization of the activated carbons

Bulk Density

Powdered activated carbon samples were placed in graduated cylinders, tapped several times until constant volume (10 mL) was obtained, and measuring the weight, the bulk density was calculated as the ratio of weight to volume

Moisture and Ash Contents

Moisture content was determined by the measurement of dry weight after bringing the sample (about 1g) to constant weight in an air circulation oven at 115 °C; and ash content was determined based on the weight of the residue obtained after 1.5 h in a furnace at 950 °C under air circulation.

pH

Suspensions of the samples (1% w/w) in distilled water were heated to 90 °C, subjected to continuous stirring for 20 min, cooled to room temperature and the pH of the solution was determined using a Leeds Northrup 7415 pH-meter (Ahmedna et al., 1997b).

Electrical Conductivity

Suspensions of the samples (1% w/w) in distilled water were subjected to continuous stirring for 20 min, and the electrical conductivity of the solution was measured (Ahmedna et al., 1997b) at 25.6 °C using a Jenway 4020 conductivity-meter.

Iodine test, molasses test and decolorization experiments

These experiments were all similar in the sense that an iodine solution, diluted cane molasses was contacted with the active carbon; the color of this sample was compared to that of a blank prepared and treated the same way without the activated carbon (Pendyal et al., 1999; Ahmedna et al., 1997a, 1997b). For the iodine test, 100 mL of

stock solution (2.7 g I₂ and 4.1 g KI in 1 L of solution) was added to 0.5 g activated carbon in 10 mL of 5% HCl solution, 5 min contact time was allowed, the sample was filtered through Whatman No. 110 filter paper and the percentage color removal was based on the volumes of 0.1 M sodium thiosulphate required (using starch as the indicator) for the sample and the blank filtrates. For the molasses test, the test solution was prepared by dissolving 10 g of sugar cane molasses and 15 g of Na₂HPO₄ in 500 mL of water and sufficient H₃PO₄ to make pH 6.5, diluting to 1 L and filtering through a thin layer of filter aid (diatomaceous earth). Fifty milliliters of this solution were added to 0.5 g of activated carbon; the mixture was well stirred, and was placed on a heating plate along with the blank and brought to boil. The percentage color removal was based on the absorbance readings taken 420 nm using a Hitachi U-3200 Spectrophotometer after the sample and the blank were filtered through Whatman No. 4 filter paper.

4.0 RESULTS AND DISCUSSION

Production and characterization of the activated carbons

The bagasse samples were first carbonized and summary of the results obtained is provided in Table 4, which indicates that the yields of carbonized bagasse ranged from 15 to 26%, with slight deviations from each other, due to the different activation temperatures applied. The bagasse carbon made at a temperature of 600 °C gave a yield of ~19% and it was the one used for subsequent activation with carbon dioxide. Activated carbons suitable for sugar decolorization can be obtained at yields of ~22% and higher. Maximum decolorization occurs at ~25% yield, which corresponds to the presence of macro-porosity as in [47-48]

Table 4: Carbonization of bagasse-based carbons with their yields at different synthesis temperatures. The yield values mean were obtained after taking an average of 3 (three) samples

Temperature of carbonization (°C)	Yield (%) Mean \pm 0.1 standard Deviation
300	25.4
400	21.6
500	21.9
600	19.4
700	15.2

The results in Table 4 show that as the carbonization temperature increased, the percentage yield of char decreased which agrees with conclusions from experiments done by ([49]. It was observed that the temperature of 700 °C was not conducive as some salts start to melt at temperatures above 700 °C leading to the roasting of the bagasse. Since the porosity and the pore structure is affected, this therefore results in poor adsorption [46, 50]. Table 5 provides a summary of the results obtained indicating the physical and chemical properties of the synthesized activated carbons, which were benchmarked against the commercial ones. It was observed that the low temperature char contains a larger quantity of volatile matter. Increasing activation temperature causes the evaporation of the volatile matter and it can be expected that there will be a high chance of macropore

development [51]. At lower temperatures, the carbon dioxide does not penetrate easily into the resulting macropores. The place near the entrance of the pores is eroded more easily by the reaction than the inner portions [52]. The erosion of the exterior portion of the char upon activation results in disappearance of exterior pores and this explains why both the surface area and the pore volume decrease with the degree of activation at higher burn off levels. The maximum values of surface area and pore volume were obtained within the temperature range of about 600 °C and activation time of 5h. Probably, this is the reason as to why during activation the high temperature of carbonized carbon shows a preferential development of the macropores in comparison to micropore formation, while the low temperature carbonized product develops micropores [53].

Table 5: Characteristics of the activated bagasse-based carbons compared to commercial ones.

Carbon type	BET surface area (m ² /g)	Pore volume (m ³ /g)	Pore size (Å)	Density (g/cm ³)	Ash (%)	Conductivity (µs) at 23°C	pH	Moisture (%)	Decolorization (%)	
									Iodine	Molasses
WP320*	1327.4	1.30	36.00	0.28	3.6	285.0	4.5	7.7	87.0	93.6
CS200*	858.5	0.54	25.60	0.35	16.8	17.1	6.7	5.3	93.5	93.8
600/C5	800.6	0.68	20.44	0.30	18.8	266.0	6.2	18.6	95.6	92.2
600/C4	771.5	0.51	23.26	0.33	19.0	245.7	6.1	20.1	82.6	85.6
600/C3	579.4	0.42	26.11	0.35	20.9	223.0	6.4	19.4	78.2	78.9
500/C5	654.0	0.50	33.22	0.32	21.7	235.8	6.2	19.8	63.7	53.3
500/C4	560.1	0.49	26.42	0.37	20.4	226.7	6.6	20.2	47.8	45.7
500/C3	437.5	0.39	26.50	0.36	22.1	237.2	6.7	21.4	34.8	31.3

* Commercial activated carbon samples

Increasing both the activation time and temperature may have a negative effect as it causes the widening of the existing pores leading to larger pore sizes occasioned by the complete burn-out of the walls between adjacent micro pores. This widening of pores does not produce the desired adsorption efficiency that is required. In order to produce an activated carbon with optimum properties, a high degree of uniformity in carbonization must occur, originating from the surface to the centre of the particle [54]. Besides the change in the pore sizes, continued activation may also impact on the crystalline structure. At lower activation temperatures, a fraction of each inner particles fails to undergo carbonization, and because of this unreacted and un-reacted region, the results obtained prove to be inferior in some cases. So, a carbonized char of fairly low quality

was obtained due to the non-homogenous effect by low heat treatment of 300 or 400 °C. Activation using CO₂ as the gasifying agent involves the C-H₂O and C-CO₂ reactions respectively, resulting in the removal of carbon atoms and causing the main weight loss of the resulting char [55-56]. In the laboratory preparation, 700 °C was not conducive for better results. According to [6] some salts start to melt at temperatures above 600 °C leading to roasting the bagasse and therefore the structure gets negatively affected. This leads to the formation of poor adsorption properties in the material. Porosity plots of the BET specific surface area and pore volume are provided in Fig. 3 and 4 respectively, and decolourization was found to be directly impacted by both the surface area and pore volume as illustrated in Fig. 5.

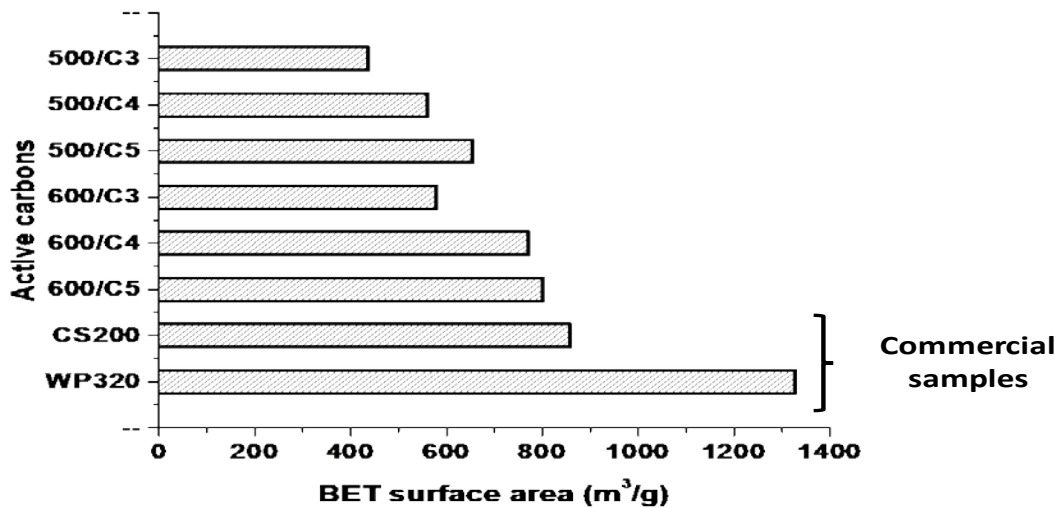


Figure 3: Plots showing the influence of synthesis time and temperature on the BET surface area of the activated carbons.

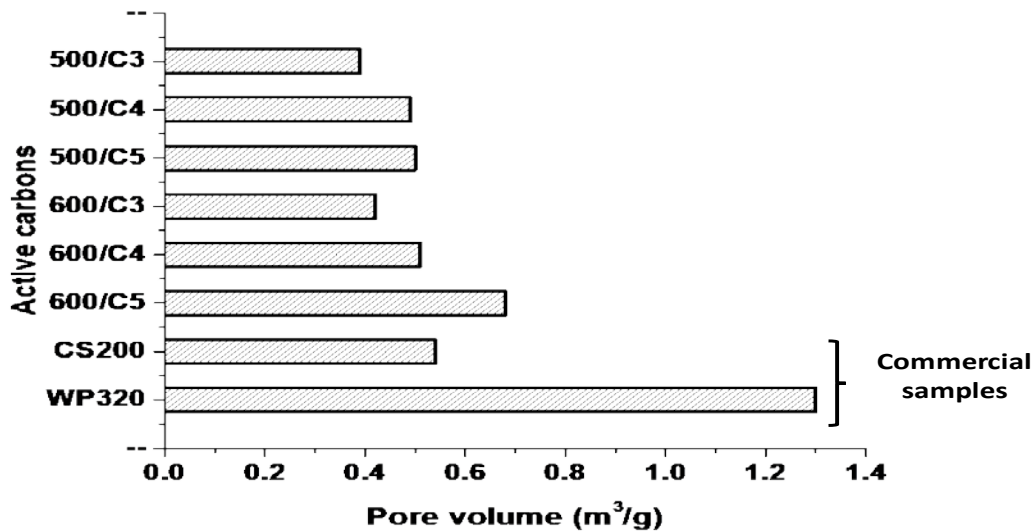


Figure 4: Effect of synthesis temperature and time on the pore volume of the activated carbons.

The BET surface area of the commercial and bagasse activated carbons are shown with the commercial activated carbons having better values over the bagasse ones. Both commercial carbons, WP320 and CS200 had high BET surface area values of 1327.4 m²/g and 858.5 m²/g, respectively. WP320 had low pH value of 4.5 due to activation by phosphoric acid, while the steam activated CS200 with pH of 6.7 had high ash content of 16.8% with a relatively higher density of 0.35 g/cm³. The bagasse carbons had lower BET surface area compared to the commercial carbons, with the highest being the 600/C5 sample with 800.6 m²/g followed by 600C4 (771.5 m²/g). This can be attributed to high carbon content and as a result they were volatilized to a less extent leading to a relatively lower surface area [57]. The lower volatilization capacity means that the carbons undergo less weight loss and are therefore relatively denser.

The ash content in CS200 (16.8%) which was slightly less than the ash content in the bagasse carbons, which ranged between 18% and 22%. In WS320 ash content was very low (3.6%). Since all the bagasse-based carbons were activated in carbon dioxide, it was observed that their pH values were less acidic, ranging from 6.1 to 6.7.

However, carbon dioxide activation produces an extensive surface area and a well developed microporosity [49]. H₃PO₄ is usually preferred as a chemical activation agent because it bubbles through the carbon matrix and gives a well-developed microporosity leading to a high surface area after opening up the cellulose structure. This structure once developed cannot shrink. The phosphoric acid controls the pyrolysis in such a way that formation of tar, which is an unwanted impurity together with volatilization, are kept to the minimum. The H₃PO₄ has an advantage, for example, in the case of WP320, which is a wood based carbon, and it leads to higher conversion of wood into carbon [58]. Nonetheless, the use of H₃PO₄ can be unfavourable due to the formation of phosphate residues and in the case of sugar refining, may add to the sugar color.

In the bagasse-activated carbons, 600/C5 (pH 6.2), and 600/C4 (pH 6.1), fit well into the pH range of good color removers. The inference here is that since carboxyls and lactones normally decompose between 600 – 800 °C, it gives them an advantage in sugar decolorization because with no carboxyls on the surface, the negative surface charge is decreased. In the case of

carboxylic acids, the fewer the number of these groups, the less the negative charge, which leads to increased adsorption.

Iodine and Molasses Decolorization

The last two columns of Table 4 show the decolorization efficiencies for the commercial and bagasse derived activated carbons on treatment with cane molasses. In commercial practice, the decolorization ability of active carbon is usually evaluated by two tests: the iodine decolorization test and Molasses decolorization test. The iodine and to an extent molasses decolorization test of an active carbon is an indicator of the ability to adsorb low molecular weight compounds [59-60].

In Fig. 5, it is shown that bagasse-carbon samples (600/C5 and 600/C4) comparatively had better

Iodine solution decolorization efficiency (95.6 and 93.4% respectively) due to their large surface area and pore volume. For example, 600/C5 sample (with pore volume 0.68 cm³/g) being high for advanced adsorption compared well with the commercial carbons of decolorization efficiency 87.0 and 93.5% in WS320 and CS200 respectively. The bagasse carbon with the least decolorization efficiency of 34.8% was the 500/C3 sample, which can be attributed to the low surface area (437.5 cm²/g) and the relatively small pore volume [61]. The disadvantage of all these types of carbons is that they have a high ash content, between 18 and 22%. The amount of color removed from molasses is regarded as the activated carbon's capacity to adsorb colored bodies especially sugar colorants since most of the impurities in the syrup during industrial sugar processing end up in the molasses.

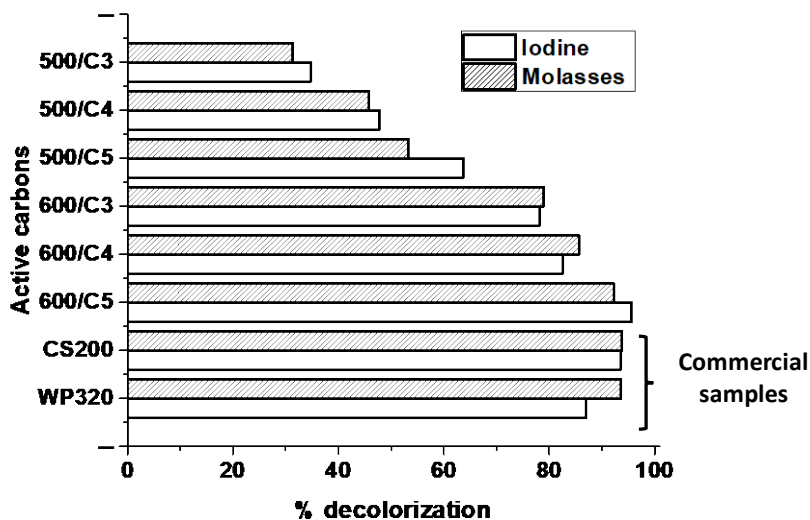


Figure 5: Comparison of percent decolorization in molasses and iodine samples.

Carbons with high capacity for color removal from molasses are potentially good sugar syrup decolorizers. The commercial carbons CS200 and WP320 show high decolorization values (93.8 and 93.6% respectively). The bagasse derived carbon, which achieved the best molasses decolorization efficiency, were 600/C5 (92.2%)

and 600/C4 (85.6%), with pore volumes of 0.68 cm³/g and 0.51 cm³/g respectively. The bagasse carbons with a decolorization percent above 90% gave a good indication that the carbons have a good capacity to remove high molecular weight sugar colorants [62]. Among the commercial carbons WP320 (93.6 %) came second after

CS200 (93.8 %). This is probably because the sample has a larger pore size diameter 36.0 Å to trap larger molecular colorants, which had been newly formed.

A look at other properties of 500/C5 with surface area 800.6 m²/g has a pore size of (20.44 Å), which is a good size for syrup decolorization, but its low density (0.30 g/cm³) and of course the high ash content (18.8%) are its drawback [63]. High ash content leads to higher electrical conductivity, and adds to the color. More electrical conductivity of the activated carbon means more ash content available for leaching into the sugar syrup. The leachable ash is undesirable and can be regarded as a colorant. Since the leached ash will act as a colorant, then it cancels the decolorization effect of the activated carbon [64].

5.0 CONCLUSIONS

The activated carbon obtained from sugarcane bagasse by direct carbonization for 5 h at 600 °C (600/5) under a stream of carbon dioxide has a decolorization performance that can compete with commercially used activated carbons. Among the studied physical characteristics of the activated carbons, iodine decolorization performance appears to be the best indicator of sugarcane molasses decolorization performance, followed by the molasses decolorization performances, electrical conductivities and their BET surface areas. This work has demonstrated that bagasse derived activated carbon 600/5 and commercial activated carbons WP320 possess similar characteristics. This is due to their physical, chemical, and adsorption properties, particularly their high surface area and pore volume accompanied by low production of ash content. A large surface area in the activated carbons is a key factor in their efficiency in absorbing coloring agents. The 600/5 is very close to the commercial WP320 sample, in surface area, and it satisfies commercial requirements and therefore presents potential as a low-cost alternative to the existing commercial ones. Bagasse therefore can be used as an

inexpensive substitute for activated carbon precursor, and will require further development while observing the processing parameters. This may be done by changing the conditions of temperature and time or addition of other lignocellulosic material that has beneficial effects on the carbon quality and the mixing ratio. Further research should aim for better surface charge to adsorb the sugar colorants and determine if it is possible to alter the surface charge or the functional groups in order to improve the adsorption capacity.

Acknowledgement

Chemilil Sugar Company for providing the bagasse and Cane molasses. Kenya Industrial Research & Development Institute for providing the Nitrogen and Carbon Dioxide and Sutcliff Carbons England for providing the Commercial activated carbons.

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