# Production of Activated Bio-Char from Sugarcane Bagasse and its Application in De-Colourising Sugar Melt

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**Abstract:** ***The sugar industry generates significant quantities of bagasse as a by-product. This bagasse has a potential to be converted as activated bio-char. At present, powdered or granular activated carbon is used in sugar refineries for the removal of colorants from sugar liquor and in general for treatment of industrial wastewater. Coal is a commercially used activated carbon, which is a limited non-renewable resource. There are different renewable resources such as sugarcane bagasse, almond nutshells, rice husk, rice straw, coconut shells, which can be used as alternatives. In this study bagasse, the by-product of sugar industry, was treated and converted into effective adsorbent using pyrolysis technology. The physical and chemical properties of the activated sample were analysed using standard methods. This bio-char was used as an adsorbent media to evaluate the effectiveness for percent colour removal from sugar liquors. Relative efficiency of de-colorization was compared with the commercial activated carbon and has been discussed herein.***

**Keywords:** Sugarcane bagasse, activated bio char, de-colourisation, sugar refining

## 1. Introduction

The sugar manufacturing industry is one of the thriving industries in India. Sugarcane bagasse is a by-product of sugarcane industry obtained after the extraction of juice which is used for the production of sugar. Sugar is obtained after the various processing stages which include: milling of the sugarcane, extracted juice clarification, concentration, crystallization and centrifugation. In India about 90-100 million metric tons of bagasse, which is majorly used as fuel for boilers and in small quantities it is used as raw material for the manufacturing of pulp, paper and particle board etc.

Sugarcane bagasse in its natural state is a poor adsorbent of organic compound such as sugar colorants and metal ions. Bagasse thus is to be modified physically and chemically to enhance its adsorptive properties towards organic molecules or metal ions, routinely found in water, wastewater other liquors. This is effectively accomplished by converting bagasse to an activated bio-char. Bagasse is reported as a suitable resource for preparation of activated bio-char.

The present work was focused on production of activated bio-char from sugarcane bagasse by activating at different temperatures using ortho phosphoric acid as an activating agent. The work was taken up to develop a low cost and environment friendly adsorbent to clarify the sugar syrup/melt.

## 2. Literature Survey

The literature mentions many precursors for activated carbon such as sugarcane bagasse, rice husk, corncob, hazelnut shells, rice bran, apple waste etc. Activated Carbon can be manufactured from any material that has reasonable elemental carbon content, any lignocellulosic material can be converted to an activated carbon (Qureshi, K. et al., 2008). Compare to other adsorbent, Activated carbon has several advantages, which includes its simplicity in operation and design of equipment, compatibility in removing large gamma of pollutants, low cost of its production since the raw material are abundantly available at little or no cost (C.S Ajinomoh et al.,). Sugarcane bagasse is a good raw material for bio-char production, produced bio-char had good porosity and surface area which makes it useful as a effective bio adsorbent(M. M. Manyuchi et al.,2020).Activated Carbon from sugarcane bagasse (SCBAC) showed best potential with physical as well as chemical properties making it a good sugar de-colorizer (Qureshi, K. et al., 2008).

## 3. Methods

**Materials**
Sugarcane bagasse sample were collected from various sugar factories of UP for the season of 2020-21 and 2021-22.

**Analysis**
For determining the efficiency of activated bio-char various analysis were conducted.

**Surface area, total pore volume and average pore size**– The Brunauer-Emmett-Teller (BET) analysis of prepared activated bio-char was determined using Quanta-chrome Autosorb Automated Gas Sorption System.

**Micro-pore volume and pore size distribution**– both were analysed by t-method micropore analysisand Density Functional Theory (DFT) method, respectively.

**Apparent density** – was observed by Gravimetric method as per standard Indian protocol.

**Ash percentage and moisture percentag e** – were determined by BIS IS 877: 1989 method.

**Iodine Number**– was determined by BIS IS: 2752 (1995) (RA 2010) method.

Analysis of raw and treated sugar melt for various parameters was conducted as per standard protocol i.e.

**Colour**- was determined by ICUMSA method using double beam spectrophotometer, refractive index of the solution and absorption at 420 nm were measured in the UV/VIS region.

**pH** – was determined by pH analysis method using micro-processed based pH meter, Systronic Type 361.

**Preparation of Activated Bio-char**
In this study, the activated bio-char was produced through the chemical activation process. Sugarcane bagasse, collected from different sugar factories, was washed with double distilled water to remove any trace of sugar or any other impurities in the material. Then it was dried at $110^0$C in hot-air oven for 48 hrs and finely grinded. After grinding, the powder was sieved using a 35-mesh size sieve. To transform the sieved sugarcane bagasse into carbon it ignited in a muffle furnace at the temperature of $550^0$ C and $700^0$C for 60 minutes and for 30 minutes respectively.

By carbonization, most of the non-carbon elements viz. hydrogen and oxygen etc. are removed in gaseous form and the remaining carbon atoms are grouped into organized crystallographic formation. The carbonization step usually results in an inactive material with a specific surface area and low adsorption capacity. Produced carbon was then impregnated with 50% aqueous solution of phosphoric acid ($H_3PO_4$) in a weight ration 1:10 for 24 hrs and then washed with double distilled water several times. It was then dried and weighed. Yields of both derived bio-char were calculated from weight differences. Besides, the ash content as well as moisture content of the bio-char arising from pyrolysis of the acid- treated charred sugarcane by-product was also determined.

Textural properties of the bio-char samples generated from the sugarcane bagasse were evaluated from $N_2$ adsorption isotherms (BET Analysis), which gives information about the surface area, total pore volume and micro-pore volume. BET assumes that physical adsorption resulting in the formation of multi-layers, is the true picture of adsorption and solid surface possesses uniform, localized sites i.e. adsorption at one site does not affects adsorption at neighbouring site. Bio-char samples obtained from raw sugarcane bagasse charred at 550˚C and 700˚C are designated as SCBAB550 and SCBAB700 respectively else wherein the paper.

## 4. Results and Discussion

**Characterization of the activated bio-char**
A highly porous charred bio-char was produced after pyrolysis followed by activation by an acid. The bagasse based bio-char had characteristics indicated in following tables, which made it efficient as an adsorbent for sugar syrup clarification.

The specific surface area was determined using BET method which employs adsorption of adsorbate (Nitrogen gas) on the surface of the adsorbent (activated bio-char) using BET theory. The resulting BET equation is expressed by the given equation,

$$\frac{P/P_0}{V_a(1-P/P_0)} = \frac{1}{V_mC} + \frac{C-1}{V_mC}\left(\frac{P}{P_0}\right)$$

where, P is the partial vapour pressure of adsorbate gas in equilibrium with the surface at -195.85°C (b.p of liquid nitrogen) in pascals, $P_0$ the saturated pressure of adsorbate gas, in pascal, $V_a$is the volume of gas (Nitrogen gas)at the pressure P, $V_m$ is the volume of gas adsorbed when the surface of the solid (Bio-char) is covered completely with the monolayer of the adsorbed molecules of the gas and C is a constant depending upon the nature of the gas which approximately given by,

$$C = e^{\left(\frac{E_1 - E_L}{RT}\right)}$$

where $E_1$ is the heat of adsorption in the first layer and $E_L$ is the heat of liquification of the gas.

Micro-pore analysis and pore size distribution were determined by "*t*-method" of de-Boer micro-pore analysis method and Density functional theory (DFT) method respectively.

Characterization of the activated bio-char prepared at 550°C

Figure 1 shows $N_2$ adsorption-desorption isotherms of sugarcane bagasse based activated bio-char prepared at 550°C (SCBAB550) at -195°C. Both of the isotherms are type I, this means SCBAB550 contained micropores and adsorption of gas on microporous solids whose pore size are not much larger than the molecular diameter of the adsorbate. Complete filling of these narrow pores corresponds to the completion of a molecular monolayer formation.

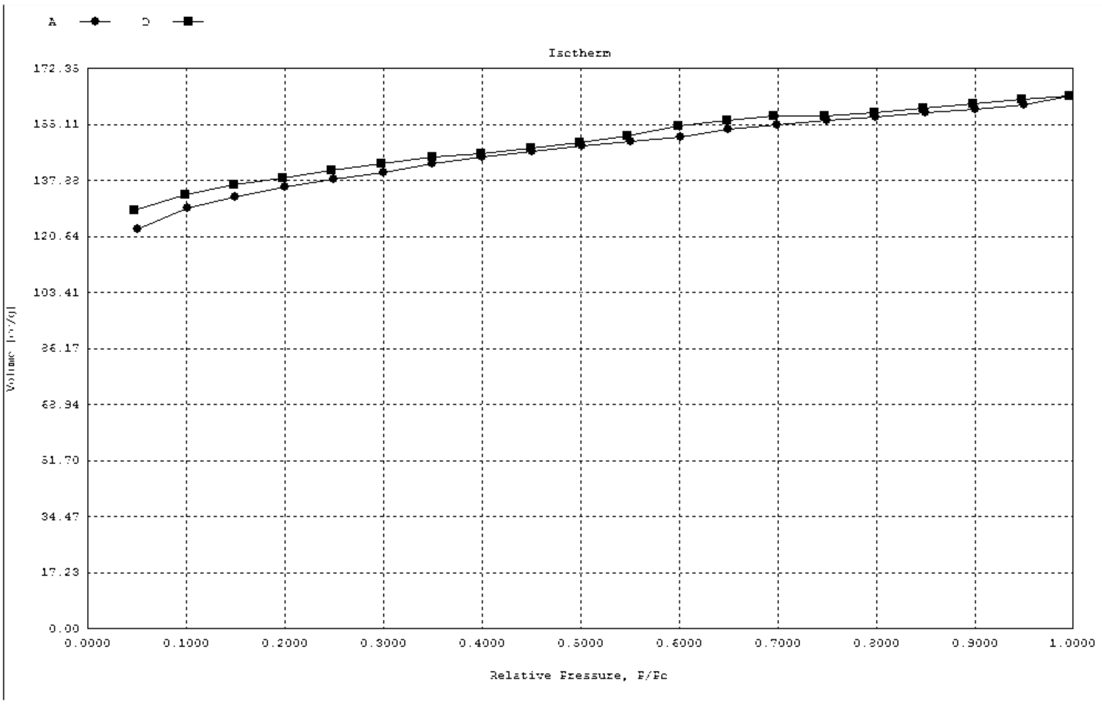


**Figure 1:** Adsorption-desorption isotherm of $N_2$ of the prepared Activated bio-char

The BET surface area of the prepared SCBAB550 was 403 $m^2/g$. The high surface area of the bio-char makes it usable adsorbent for sugar syrup/melt liquor clarification. The other characteristics indicated inTable 1.

**Table 1:** Activated Bio-char characteristics

| Characteristics | Value |
|---|---|
| Surface Area | 403 $m^2/g$ |
| Average pore size | 2.5 nm |
| Pore width | 1.68 nm |
| Total pore volume | 0.254 cc/g |
| Micro-pore volume | 0.227 cc/g |
| Apparent density | 0.3814 $g/cm^3$ |
| Ash percentage | 7.1 % |
| Moisture percentage | 13.60 % |
| Iodine number | 433 mg/g |
| Yield | 10 % |

Characterization of the Activated Bio-char prepared at 700°C

Similarly, Figure 2 shows $N_2$ adsorption-desorption isotherms of sugarcane bagasse based activated bio-char, one prepared at 700°C (SCBAB700) at -195°C. Both of the isotherms are type I, this means that the SCBAB700 contained micro-poressame as the previous one.

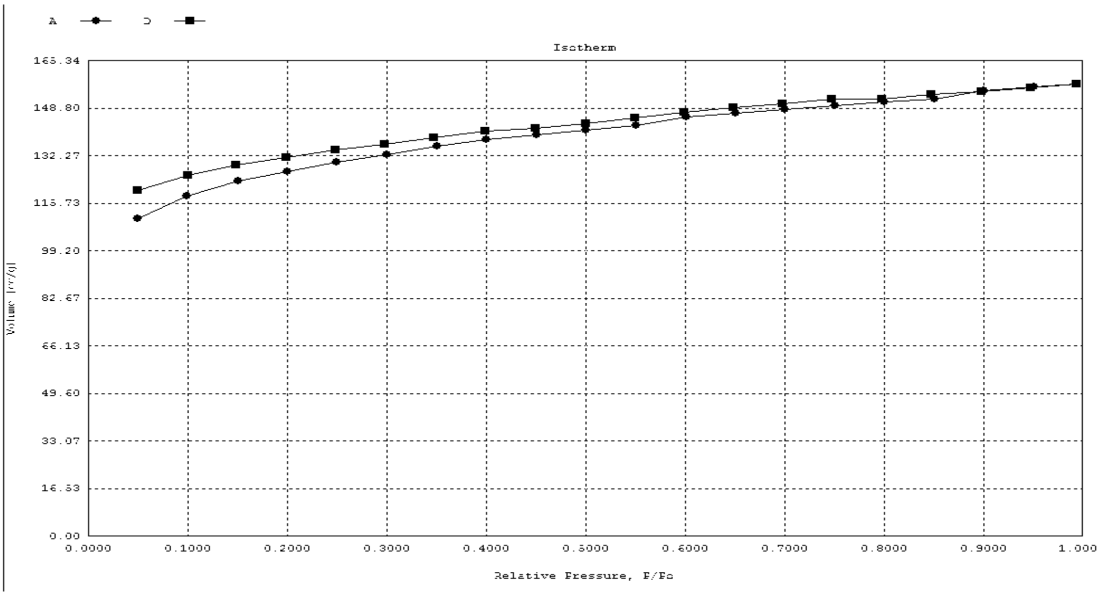


**Figure 2:** Adsorption-desorption isotherm of $N_2$ of the prepared Activated bio-char

The BET surface area of the prepared SCBAB700 was 383 $m^2/g$, and this BET is much smaller than majority of commercial activated carbon. The other characteristics indicated in Table 2.

**Table 2:** Activated Bio-char characteristics

| Characteristics | Value |
|---|---|
| Surface Area | 383 $m^2/g$ |
| Average pore size | 2.5 nm |
| Pore width | 1.68 nm |
| Total pore volume | 0.244 cc/g |
| Micro-pore volume | 0.218 cc/g |
| Apparent density | 0.075 $g/cm^3$ |
| Ash percentage | 7.9 % |
| Moisture percentage | 11.65 % |
| Iodine number | 400 mg/g |
| Yield | 10 % |

On the basis of comparison between above mentioned characteristics tables of both Bio-chars, it was found that activated bio-char prepared at 550°C showed 5.2% more total surface area than prepared at 700°C and hence was preferred. The average pore size and pore width for both the bio-chars were equal but the total pore volume in case of bio-char developed at 550°C was bit higher which was complimented by the value of Iodine no. which is 433mg/g (for SCBAC550) in comparison to 400mg/g for SCBAC700. This clearly indicates that the SCBAC550 was comparatively better than SCBAC700.

**Sugar Melt Clarification**

The principles of UV/VIS spectroscopy are described by The Lambert-Beer law: absorbance ($A_\lambda$) maintains a linear relationship with the path length 'b', the concentration of the analyte 'c', and the molar extinction coefficient of the analyte (aλ). The subscript λ denotes wavelength dependence. This relationship is mathematically expressed as,

$$A_\lambda = a_\lambda * b * c$$

$a_\lambda$ is also known as absorbancy index of the analyte. The value of the absorbancy index (extinction index) at the wavelength of 420 nm is multiplied by 1000, and is subsequently reported as ICUMSA colour. The resulting values are designated as ICUMSA Units (IU). Initially the refractive index of the dry substance (RDS) of the solution, using refractometer was measured. Used the RDS to obtain the density 'ρ' of the prepared sugar syrup, in kg/L.

A double beam spectrophotometer is used to determine absorbance ($A_{420nm}$) of the sample with distilled water serving as reference standard for zero absorbance (blank).

$$ICUMSA\ Colour = \frac{Absorbance_{(420nm)} * 1000}{b * c}$$

Where, $c = \frac{RDS * \rho}{10^5}$

The amount of colorants that can be removed from a sugar liquor solution by activated bio-char depends on factors such as contact time, carbon dosage, temperature, concentration, viscosity of the solution and the intrinsic features of carbon itself. A study was conducted to evaluate the effect of activated bio-char on the percent colour removal from a sugar melt of 65˚ brix. For the optimization of effective colour removal, treatment of sugar syrup/melt liquor of 65˚ brix at 80˚C with various dosage of activated bio-chars i.e SCBAC550 and SCBAC700 was carried out followed by the absorbance determination and the observations are given as follows-

**Table 3:** Activated Bio-char De-colorization Efficiency

| Type of bio-char | Dosage of Activated bio-char gm/200ml | Raw sugar syrup/melt | | Treated sugar Syrup/melt | | Percentage Reduction in Colour (ICUMSA value) |
|---|---|---|---|---|---|---|
| | | ICUMSA Colour | pH | ICUMSA Colour | pH | |
| SCBAB550 | 0.5 g | 2077 IU | 6.01 | 1664 IU | 5.55 | 19.8 |
| | 1.0 g | 2223 IU | 6.34 | 1790 IU | 5.38 | 19.7 |
| | 2.0 g | 1954 IU | 6.24 | 1456 IU | 5.90 | 25.4 |
| | 3.0 g | 1931 IU | 5.70 | 1333 IU | 4.93 | 30.9 |
| | 4.0 g | 1350 IU | 6.42 | 717 IU | 5.80 | 46.8 |
| SCBAB700 | 1.0 g | 1812 IU | 5.78 | 1608 IU | 5.39 | 14.2 |
| | 2.0 g | 2024 IU | 5.75 | 1632 IU | 4.99 | 19.3 |
| | 2.5 g | 1964 IU | 5.72 | 1537 IU | 4.79 | 21.7 |
| | 3.0 g | 1931 IU | 5.71 | 1645 IU | 4.84 | 14.8 |
| | 3.5 g | 1971 IU | 5.92 | 1612 IU | 4.55 | 18.2 |
| | 4.0 g | 2123 IU | 5.75 | 1493 IU | 5.11 | 29.6 |

Table 1 and Table 2 depict results from proximate elemental analysis for the sugarcane bagasse-based bio-char samples at both temperatures. Sugarcane bagasse possesses high volatile matter content and low fixed carbon. As expected, pyrolysis promoted substantial changes in the bagasse composition that depend on temperature and are reflected in chemical characteristics of bio-char (SCBAB). Release of volatile matter leads to enhancements in carbon percentage and in the inorganic material of the resulting bio-char, even though the bio-char samples obtained at both temperatures had almost same ash amount.

For the assessment of effective colour removal by above mentioned bio-char, it was observed that 4g of bio-char prepared by charring at 550°C for 60 minutes (SCBAB550) gave higher percentage of colour removal i.e. 46%-47% from 65° brix of sugar syrup/melt liquor, whereas similar quantity of SCBAB700 gave 29%-30% of colour removal only. The pH values of various sugar syrup/melt liquors were generally slightly acidic with the acidity increasing with dose of activated bio-char.

## 5. Conclusion

This research work proved the effectiveness of activated bio-char produced from sugarcane bagasse raw material. The bio-char produced had enough surface area and total pore volume which makes it useful as a low-cost bio adsorbent. Application of the bagasse based bio-char in sugar syrup/melt de-colorization resulted in significant removal of colour value as it had good adsorption properties. The bio-char from the acid-treated sugarcane agricultural by-product is found potentially appropriate as substitute of conventional activated carbons extensively used in the sugar factories and related industries for sugar syrup/melt de-colorization.

## 6. Future Scope

Production of Bio-char shall open new dose for application as colour adsorbent in sugar factories or sugar refineries. Further studies shall be required to improvise the characteristics so as to have lower cost of operation.

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## Author Profile

**"Ambition is the path to success, persistence is the vehicle you arrive in" Prof. Narendra Mohan**, an inspiring teacher, admirable research worker and an esteemed government official having a long and distinguished career of working in sugar industry and at the institute. An author of 6 books and more than 130 papers been published in various reputed journals which reflect his passion for innovative work to covert "Waste to Resource". He is a visiting speaker and expert who travelled to many countries.

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