

# Characterisation of Sugarcane Bagasse-Based Activated Carbon to Assess Its Suitability for Skincare Formulations

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DOI: <https://doi.org/10.51584/IJRIAS.2026.110400111>

Received: 23 April 2026; Accepted: 28 April 2026; Published: 12 May 2026

## ABSTRACT

The growing interest in natural and sustainable skincare products requires innovative strategies. This trend is driven by increasing consumer demand for products that are environmentally sustainable and skin-friendly. This study examines the characteristics of sugarcane bagasse-based activated carbon (SBAC) to evaluate its potential use in skincare formulations. Sugarcane bagasse was carbonised at 700°C and subsequently chemically activated with 30% (w/w) phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) to enhance its adsorptive properties. The activated carbon was analysed for its physicochemical properties, including carbon content, moisture content, ash content, sulphur content, pH value, adsorption capacity, and removal efficiency. The results revealed a carbon content of 97.07%, moisture at 1.77%, ash content at 2.93%, sulphur content at 0.25%, a neutral pH of 7.04, an adsorption capacity of 148.80 mg/g, and a removal efficiency of 98.35% for methylene blue. The characteristics suggest potential benefits in skincare products, including enhanced impurity removal, reduced skin irritation, and improved skin clarity. The neutral pH of 7.04 and the low sulphur content of 0.25% indicate that this formulation is suitable for use on sensitive skin. The SBAC demonstrated significant adsorption capacity (148.80 mg/g) and removal efficiency (98.35%) for methylene blue, highlighting its potential for detoxification and purification of the skin. The findings suggest that SBAC serves as a viable natural ingredient for skincare formulations, offering a sustainable and effective alternative for skincare applications.

**Keywords:** sugar cane bagasse, skin care, Activated carbon, Adsorption, Removal efficiency

## INTRODUCTION

Activated carbon (AC), renowned for its high porosity and adsorption capabilities, has been extensively utilized in various applications, including environmental remediation and, more recently, skincare formulations. The cosmetic industry has embraced activated charcoal for its ability to adsorb impurities, making it a popular ingredient in products like face masks, cleansers, and soaps. Sugarcane bagasse (SCB), the fibrous residue from sugarcane processing, presents a sustainable and cost-effective precursor for producing activated carbon. Sugar Cane Bagasse comprises approximately 50% cellulose, 25% hemicellulose, and 25% lignin, making it suitable for AC synthesis (Ekta et al., 2022). Charcoal is negatively-charged, so it attracts positively-charged compounds – such as deep-dwelling dirt and oil in the skin – to its surface.

Studies have demonstrated that sugarcane based-derived activated carbon exhibits a high surface area and porosity, which are essential characteristics for effective adsorption. In the realm of skincare, activated charcoal is acclaimed for its ability to extract dirt, toxins, and other impurities from the skin, owing to its porous structure. Products incorporating activated charcoal, such as facial masks, aim to balance the skin by absorbing impurities and excess oils, promoting a healthy complexion. Despite its popularity, comprehensive studies evaluating the efficacy and safety of activated charcoal in cosmetic applications remain scarce. This study aims to characterize sugarcane bagasse-based activated carbon and assess its potential suitability for skincare formulations. By analyzing its physicochemical properties, such as surface area, pore structure, and adsorption capacity, this research seeks to determine the feasibility of utilizing sugarcane based activated carbon (SBAC) as an effective and sustainable ingredient in cosmetic products.

One of the earliest studies on sugarcane bagasse derived activated carbon was conducted in the 1950's by researchers in India (Rasheed et al., 2023). They discovered that sugar bagasse could effectively be converted into activated carbon through a series of chemical and thermal treatments. This discovery sparked an interest to using sugarcane bagasse as raw material for activated carbon production

Suhesti et al., 2024 posits that Sugarcane bagasse is effective as an exfoliator and moisturizer. They maintain that Concentration and usage time significantly affect skin tone and moisture. Experimental results indicate that Sugarcane bagasse activated carbon-based exfoliating gels significantly improve skin tone, with increases observed at varying concentrations (1%, 3%, 5%). They also maintained that moisturizing gels formulated with SBAC also enhance skin hydration, although the effect is more pronounced with prolonged use rather than concentration alone.

Seixas et al., 2017 posits that activated carbon from sugarcane bagasse has microporous and hydrophilic characteristics that can improve skincare formulas by adsorbing pollutants and toxins.

The use of activated carbon in skincare formulations became prominent in the mid-20<sup>th</sup> century. Activated carbon has been used in the field of skincare for its ability to adsorb impurities and toxins from the skin making it a popular ingredient in facial masks and cleansers (Amirta et al. 2024). A study conducted found that activated carbon was effective in absorbing oil and dirt from the skin thereby making it an ideal ingredient for controlling excess oil production and preventing breakouts (Amirta et al., 2024).

Another study found that activated carbon aids in reducing the appearance of pores and also improves skin texture (Paramasivan., 2023). Activated Carbon can help to unclog pores, reduce excess oil and improve the overall clarity and appearance of the skin as well as absorb excess sebum, balance oil production, remove toxins and pollutants that can accumulate on the skin throughout the day thereby making it a beneficial ingredient for those with oily or acne prone skin (Nisreen et al., 2022). In skincare applications, activated carbon is often used in products such as cleansers, facial masks and scrubs to draw out dirt, oil and other impurities from the skin (Amirta et al., 2024). Additionally, a study published in the Journal of Cosmetic Dermatology highlighted the use of activated carbon in skincare formulations making it a popular ingredient in cleansing masks and exfoliators (Mahood et al., 2024).

Thuy, a student of the University of General Business Administration course won the first prize of the "Green Creative Ideas" contest in Tra Vinh province in 2021 maintaining that the activated carbon masks made from bagasse are environmentally friendly and easily degradable in the natural environment. Besides, this mask type can filter droplets containing a virus of little more than 100 nanometers. The mask makes it easy to breathe and not itchy, useful for those who have to wear masks for a long time or have underlying respiratory diseases. Moreover, this kind of mask from available natural materials does not carry any harmful substances, ensuring environmental friendliness and safety for users. (<https://en.tvu.edu.vn/>).

## METHODS

Preparation of Sugarcane-bagasse-based activated carbon via chemical activation method.

### Procedure

Sugarcane was procured from a reliable source and with the help of an electrical juicer, the juice was extracted from the sugarcane to obtain the sugarcane bagasse. The bagasse was dried in a drying oven at 135°C for 3 hours to obtain a moisture content between 5 - 6%. The dried sugarcane bagasse was ground into a uniform particle size (2mm or 10 mesh). The milled Sugarcane bagasse was then wrapped in a foil paper and carbonized in a muffle furnace at 700°C for 1 hour. The temperature, time and atmosphere were monitored to ensure complete carbonization and to avoid combustion, the windows were closed during this carbonization. 30% (w/w) phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) was mixed with the carbonized material in a ratio of 1:1 (that is, 100ml of phosphoric acid to 100g of carbonized material) in a beaker to ensure uniform impregnation. This mixture is then heated at a temperature of 105°C for 1 hour in a drying oven to remove excess moisture. The paste like mixture is then sent into a muffle furnace where it is heated at a temperature of 500°C for 1 hour in order for the phosphoric acid

to be deeply absorbed by the carbonized material. The activated material was then allowed cool to a room temperature. After that, the activated material is washed with 1M hydrochloric acid then distilled water until the pH of the activated material becomes neutral. The rinsed activated carbon was then dried in a drying oven at 105°C for 3 hours to remove moisture. The activated carbon obtained was then milled into a fine powder of 75um or 200 mesh and stored in an airtight bag. The activated carbon was then tested for moisture content, ash content, carbon content, adsorption capacity, removal efficiency, pH value and sulfur content in order to ensure that the produced activated carbon meets the standards and skincare formulation requirements as this will serve as a basis for ascertaining whether or not sugarcane bagasse -based activated carbon is suitable for use in skincare formulations.

$$\text{Yield (\%)} = \frac{\text{Mass of activated carbon}}{\text{Initial mass of sugarcane bagasse}} \times 100 \dots\dots\dots(1)$$

Characterization of sugarcane bagasse.

1. Determination of moisture content of the sugarcane bagasse using the traditional oven drying method (ASTM, 2019, E871-19).

**Procedures**

1. Weigh empty tray and record this weight as  $W_1$ .
2. Add 50g of sugarcane bagasse to this tray and record this weight as  $W_2$  (neglecting the weight of the tray).
3. Weigh the tray and the sugarcane bagasse (that is,  $W_1 + W_2$ ). Record this weight as  $W_3$ .
4. Put the tray containing the 50g of sugarcane bagasse in an oven to dry at 105°C. This procedure was repeated for temperature 125°C and 135°C until a moisture content between 5 – 6% was obtained.
5. After 3 hours, remove the tray containing sugarcane bagasse from the oven then weigh the tray and sugarcane bagasse. Record this weight as  $W_4$ .

**The moisture content can be calculated as:**

$$\text{Moisture content} = \frac{(W_3 - W_4)}{W_2} \times 100 \dots\dots\dots(2)$$

Where  $W_1$ = Weight of empty tray.

$W_2$ = Weight of sugarcane bagasse

$W_3$ = Weight of tray and sugarcane bagasse before drying.

$W_4$ = Weight of tray and sugarcane bagasse after drying.

$W_5$ = Weight of evaporated moisture.

6. Repeat the procedures with at least two more samples to ensure accurate and consistent results.
7. Calculate the average moisture content for the batch of each temperature.

Where  $W_5$ =  $W_3 - W_4$

Determination of ash content of the sugarcane bagasse using gravimetric analysis method (ASTM, 2019, D5832-19).

**Procedure**

1. Grind the sugarcane bagasse to a fine powder using a mortar and pestle.
2. Weigh a clean crucible and record the weight.
3. Place a portion of the powdered sugarcane bagasse into the crucible and weigh the crucible and the sample.

- Place the crucible in a muffle furnace and heat it to 550°C for about 3 hours until all the organic materials have been burnt off leaving behind only ash.
- Allow the crucible to cool in the silica gel desiccator for about 1 hour. Then weigh the crucible and ash. Record this weight.

The ash content can be calculated as:

$$\% \text{ Ash content} = \frac{(\text{Weight of ash residue} - \text{Weight of crucible})}{(\text{Weight of sample})} \times 100 \dots\dots\dots(3)$$

Repeat the procedures 1 – 5 for at least two more samples to ensure accurate and consistent results. Then calculate the average ash content for the batch

Determination of the carbon content of the sugarcane bagasse using the gravimetric analysis method (ASTM, 2019, D5832-19).

**Procedure**

- Grind the sugarcane bagasse to a fine powder using a mortar and pestle.
- Weigh a clean crucible and record the weight.
- Place a portion of the powdered sugarcane bagasse into the crucible and weigh the crucible and the sample.
- Place the crucible in a muffle furnace and heat it to 550°C for about 3 hours until all the organic materials have been burnt off leaving behind only ash.
- Allow the crucible containing the ash to cool then weigh the crucible and ash. Record this weight.

The ash content of the sugarcane bagasse can be calculated as:

$$\text{Ash content (\%)} = \frac{(\text{Weight of ash residue} - \text{Weight of crucible})}{(\text{Weight of sample})} \times 100 \dots\dots\dots(4)$$

- Repeat procedures 1 - 5 with at least two more samples to ensure accurate and consistent results. Then calculate the average ash content for the batch.

where

$$\% \text{ Carbon content} = 100\% - \text{Ash content (\%)} \dots\dots\dots(5)$$

Determination of the sulfur content of the Sugar Cane Bagasse-based activated carbon and industrial grade activated carbon (IGAC) by Barium chloride precipitation and UV-Vis spectrophotometry.

**Procedure**

- Weigh 2g of sugarcane bagasse-based activated carbon into a 100ml beaker.
- Add 30ml of distilled water to the 100ml beaker containing 2g of sugarcane bagasse-based activated carbon and stir the mixture.
- Add 10ml of 1M HCl into the mixture and stir.
- Heat the mixture at 90°C for 30 minutes and allow it to cool.
- Add 10ml of BaCl<sub>2</sub> solution and stir for about 5 minutes.
- Transfer the mixture to the cell of a UV-Vis spectrophotometer.
- Measure the absorbance value of the sample placed in the UV-Vis spectrophotometer at 220nm.
- Calculate the sulfur content using the formula;

$$\text{Sulfur content (\%)} = \frac{(\text{Absorbance value} \times \text{factor})}{(\text{Sample weight})} \dots\dots\dots(6)$$

- Repeat the procedures for the industrial grade activated carbon.

Determination of the adsorption capacity and removal efficiency of the sugarcane bagasse-based and industrial-grade activated carbon for methylene blue

**Procedure**

1. Prepare a 100ml MB solution (100mg/L) in a volumetric flask.
2. Weigh 2 grams of SCB-based activated carbon and add to the MB solution. Measure the absorbance of this mixture using a UV-Vis spectrophotometer at a wavelength of 665nm.
3. Stir the mixture for 2 hours.
4. Filter the mixture using filter paper.
5. Collect the filtrate and measure the residual MB concentration using a UV-Vis spectrophotometer (maximum wavelength= 665nm).
6. Calculate the concentration of methylene blue before and after adsorption using the absorbance value

$$C_0 = A_0/E$$

$$C = A/E$$

Where,

E= molar absorptivity of methylene blue (approximately 72000L/mol.cm)

A<sub>0</sub> = Absorbance of the initial methylene blue solution.

A = Absorbance of the filtrate.

7. Calculate the adsorption capacity using;

$$\text{Adsorption capacity (q)} = (C_0 - C_f) \times V/m \dots\dots\dots(7)$$

Where,

q = Adsorption capacity (mg/g)

C<sub>0</sub> = Initial concentration (mg/L)

C<sub>f</sub> = Final concentration (mg/L)

V = Volume of MB solution (L)

m = Mass of SCB-based activated carbon (g)

8. Calculate the removal efficiency using:

$$\% RE = \frac{C_0 - C_f}{C_0} \times 100 \dots\dots\dots(8)$$

9. Repeat procedures 1 -8 or the industrial-grade activated carbon.

**DISCUSSION**

**Characterization of Sugarcane Bagasse.**

**Moisture content analysis**

The moisture content analysis of the sugarcane bagasse which is a precursor for activated carbon production revealed significant reductions in moisture levels with increasing temperature. The results indicate that drying the sugarcane bagasse in the oven dryer at 135<sup>0</sup>C achieves the desired moisture content of 5 - 6% which aligns with the skincare industry standards. The initial moisture content was obtained to be 10.42% at 105<sup>0</sup>C which decreased to 7.74% at 125<sup>0</sup>C and further reduced to 5.56% at 135<sup>0</sup>C. Achieving this optimal moisture content of

5 - 6% ensures efficient activation process, better adsorption capacity, improved product quality, minimized risk of contamination or mold growth and reduced risk of moisture-related issues during activation.

### **Ash content analysis**

The ash content analysis of the sugarcane bagasse revealed an ash content of 3.91% which is considered to be low and meets the industry standards for biomass to be used in the production of activated carbon for skincare applications ( $\leq 5\%$ ). This ash content of 3.91% suggests minimal mineral content and very little amount of impurities which is suitable for skincare applications with low risk of skin irritation, pore clogging and inflammation.

### **Carbon content analysis**

The carbon content analysis of the sugarcane bagasse revealed a carbon content of 96.09% which indicates a high carbon content. This high carbon content value of 96.09% indicates sugarcane bagasse's potential for producing high-quality activated carbon for skincare formulations with excellent adsorption capacity.

## **Characterization of Sugercane Bagasse-Based-Activated-Carbon and Industrial-Grade Activated Carbon**

### **Moisture content analysis**

The moisture content of SCB-based activated carbon was obtained to be 1.77% which was slightly higher than that of the industrial-grade activated carbon which was obtained to be 1.67%. This difference is relatively small thereby indicating that the SCB-based activated carbon has similar moisture content properties as the industrial grade activated carbon. Both the sugarcane bagasse-based activated carbon and the industrial-grade activated carbon had relatively low moisture content, which is desirable for activated carbon to be used in skincare formulations. Low moisture content is important for activated carbon to be used in skincare formulations because it reduces the risk of microbial growth and contamination. Low moisture content also enhances the activated carbon shelf life and storage stability. A moisture content below 5%, preferably 3% is considered acceptable for activated carbon to be used in skincare formulations. The slight difference in moisture content between the SCB-based activated carbon and the industrial-grade activated carbon could be as a result of variations in the production process, raw materials, or drying conditions. However, it is unlikely to significantly impact the overall performance of the SCB-based activated carbon compared to the industrial grade activated carbon.

### **Ash content analysis**

The ash content analysis of the SCB-based activated carbon and industrial-grade activated carbon revealed ash contents of 2.93% and 1.84% respectively. The ash content results indicate that SCB-based activated carbon has a slightly higher ash content than the industrial-grade activated carbon. Both ash content values comply with regulatory requirements and meets the industry standards for skincare applications (ASTM D5742-13:  $\leq 5\%$ , ISO 1021: 2017:  $\leq 3\%$ ). A study by Razi et al 2016 revealed an ash content of 4.35 % and was said to be the lowest then, this current value indicates that this research is better because low ash content ensures a cleaner and more refined activated carbon, reducing the risk of skin irritation.

### **Carbon content analysis**

The carbon content analysis of the SCB-based activated carbon and industrial-grade activated carbon revealed carbon contents of 97.07% and 98.16% respectively. The carbon content value obtained for SCB-based activated carbon indicates high carbon content which ensures excellent adsorption capacity beneficial for removing impurities, toxins and excess oils from the skin. This high carbon content also indicates well developed pore structure and high purity (low ash content) which reduces the risks of skin irritation, redness and inflammation.

Overall, the carbon content of the SCB-based activated carbon demonstrates exceptional suitability for skincare formulations offering renewable and sustainable resource utilization, potential for cost-effective production and comparable quality to the industrial-grade activated carbon.

## Sulfur content analysis

The sulfur content analysis revealed that sugarcane bagasse-based activated carbon contains 0.25% sulfur which is slightly higher than the sulfur content of the industrial-grade activated carbon which is 0.17%. Although both the sugarcane bagasse-based activated carbon and the industrial-grade activated carbon meets the standards for cosmetics-grade activated carbon with sulfur content less than 0.5%, the sulfur content of the industrial-grade activated carbon indicates its potential suitability for sensitive skin applications or high-end cosmetics. On the other hand, the sulfur content of the sugarcane-bagasse-based activated carbon suggests its viability in skincare formulations that is, it can still be effectively used in skincare products without posing any significant risks of skin irritation or other adverse effects.

## pH analysis

The pH analysis of SCB-based activated carbon and industrial-grade activated carbon revealed pH values of 7.04 and 7.00 for SCB-based activated carbon and industrial grade activated carbon respectively using pH meter. Then the pH indicator strips revealed pH values of 7.00 and 7.00 for SCB-based activated carbon and industrial grade activated carbon respectively. The pH analysis also reveals consistency between the pH indicator strips and pH meter readings. From the values obtained from the pH analysis for SCB-based activated carbon and industrial-grade activated carbon using both pH indicator strips and pH meter, it is evident that pH of the SCB-based activated carbon and that of the industrial-grade activated carbon are remarkably similar with SCB-based activated carbon at 7.04 and industrial-grade at 7.00 which are near-neutral pH range making the SCB-based activated carbon ideal for skincare formulations. An activated carbon with a pH of 7.00 is less likely to cause severe skin irritation since it is neither acidic nor basic but rather neutral.

## Adsorption capacity and removal efficiency for methylene blue

Sugarcane bagasse-based activated carbon (SBAC) demonstrated an impressive adsorption capacity of 148.80 mg/g and removal efficiency of 98.35% for methylene blue (MB) which is a commonly used model pollutant. Methylene blue is a deep blue dye with high solubility in water thereby making it an ideal adsorbate for evaluating the performance of the sugarcane bagasse-based activated carbon. SBAC's performance was comparable to that of IGAC which had an adsorption capacity of 166.60 mg/g and removal efficiency of 99.91%. The minor differences between the adsorption capacities and removal efficiencies of the SBAC and IGAC may be attributed to variations in pore size, surface area and the activation methods. The comparable performance of the SBAC to the IGAC and its natural origin makes it an attractive alternative. SBAC's ability to effectively remove MB suggests its capability to remove impurities and contaminants from the skin. Also, SBAC's efficiency in removing MB's deep blue colour also indicates its potential to reduce skin discoloration and hyperpigmentation.

## Yield

The yield obtained is 46.65% which is a good yield for activated carbon production from sugarcane bagasse. A yield of 46.65% suggests that the activation process was relatively efficient and that a significant amount of the sugarcane bagasse was converted into activated carbon. Factors like temperature, time, and the chemical activator used during the activation process can influence the yield and quality of the activated carbon produced from the sugarcane bagasse. A yield above 45% is considered good and above 50%, it is considered excellent. Therefore, a yield of 46.65% is a respectable outcome, indicating a well-optimized activation process.

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