



ORIGINAL RESEARCH PAPER



EXTRACTION OF SILICA FROM BAGASSE (CANE SUGAR HUSK)

USING INCINERATION AND CHEMICAL TREATMENT

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Abstract:

Bagasse, or cane sugar husk (CSH), is an abundant agricultural by-product, and its controlled combustion produces cane sugar husk ash (CSHA), a rich source of amorphous silica (SiO_2). This study focuses on the extraction of high-purity silica from CSHA through optimized chemical and thermal treatments. Unprocessed CSH was subjected to controlled incineration at various temperatures (400–850 °C) to obtain silica-rich ash. Acid pretreatment was carried out to remove metallic impurities, followed by alkali leaching using sodium hydroxide (NaOH) or potassium hydroxide (KOH), which converted silica into soluble silicates. The resulting silicate solution was then subjected to acid precipitation using sulfuric acid (H_2SO_4) or hydrochloric acid (HCl), leading to the formation of silica gel. The gel was purified through repeated washing, drying, and calcination to obtain fine silica powder. Characterization was performed using X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and thermogravimetric analysis (TGA), confirming the amorphous nature, surface morphology, functional groups, and thermal stability of the extracted silica. The obtained material was evaluated for potential applications in adsorbents, catalyst supports, cementitious materials, and nanocomposites. The findings demonstrate the economic significance of CSHA-derived silica and highlight its potential as a sustainable raw material within the framework of waste valorization and green chemistry.

Keywords: Bagasse ash, Silica extraction, Waste valorization, Chemical treatment, Nanocomposite.

Introduction

Silica (SiO_2) is a flexible fabric with applications across industries consisting of production, electronics, and biomedicine (1). Traditional methods for silica production rely on quartz and sand, which are power-in depth and environmentally unsustainable.

Cane Sugar husk (CSH), an agricultural by-product, has emerged as a promising alternative because of its excessive silicon content material and availability (2).

Whilst burned under managed situations, CSH produces cane sugar husk ash (CSHA) containing up to 68–78% amorphous silica (3). The valorization of CSH now not best offers a renewable source of silica but additionally mitigates environmental issues associated with agricultural waste disposal.

Moreover, CSHA-derived silica can be used to synthesize superior substances along with silicon carbide, silicon nitride, and SiO_2 nanoparticles (1-3).

Materials and Strategies

Sample Collection and Preparation

Cane Sugar husk was obtained from agricultural farms, cleaned thoroughly, dried at 150 °C, and ground into fine powder. The powdered husk was stored at room temperature to prevent deprivation.

Extraction Process

- **Pre-treatment:** 100 g of CSH was soaked in 1 M HCl for 6 h to eradicate metal oxides and other materials. The husk was then cleansed until neutral pH and dehydrated at 150 °C.
- **Incineration:** The pre-treated husk was incinerated in a muffle furnace at 850 °C for 6 h, producing excellent white CSHA.
- **Alkali Leaching:** 5 g of CSHA was dissolved in 20 mL of 1 M NaOH at 980 °C and stirred for 2 h to form sodium silicate (Na_2SiO_3). The solution was filtered using Watmman filter paper.
- **Acid Precipitation:** The sodium silicate solution was titrated with H_2SO_4 or HCl until gelation transpired. The silica gel was washed, dried, and calcined to obtain fine silica powder.

Fourier-transform Infrared Spectroscopic Evaluation

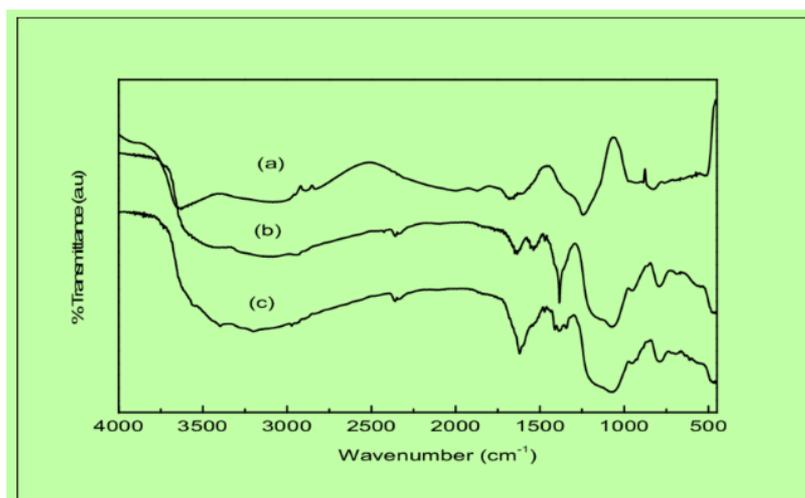


Figure 1: Spectrum FTIR sample (a) Pure silica and silica prepared using acid (b) HCl (c) H_2SO_4

The structural traits of the polysaccharide samples were analyzed the use of a Fourier-remodel infrared

spectrophotometer (IR Affinity-1, Shimadzu, Japan). Every pattern changed into combined with spectroscopic-grade KBr powder, ground, and compressed into 1 mm pellets for measurement (4-7).

FTIR spectra have been recorded in the frequency variety of $400\text{--}4000\text{ cm}^{-1}$ at a spectral resolution of 0.5 cm^{-1} , averaging 64 scans in step with spectrum. Each local and pretreated samples have been examined. Baseline correction and normalization were executed using the IR solution software, and absorption bands at 1427 cm^{-1} and 898 cm^{-1} have been used to calculate the crystallinity index (8-10).

To make certain the consistency with microscopy observations, samples were analyzed without homogenization prior to FTIR measurement. The potential restriction of this loom was that surface cells of native CSH might not represent the bulk material. To verify this, some untreated samples were finely ground and analyzed; negligible differences were observed between homogenized and non-homogenized spectra.

Thermogravimetric Analysis (TGA)

TGA was performed beneath a nitrogen (N_2) ecosystem at a flow rate of a hundred and 40 mL/min.

CSH and coconut pulp samples weighing among 0.5 and 1.0 g have been pyrolyzed as much as a most temperature of $800\text{ }^\circ\text{C}$. To begin with, the samples had been heated to $100\text{ }^\circ\text{C}$ and maintained at this temperature for half-hour to take away moisture.

In the end, heating was carried out at two different heating quotes, $50\text{ }^\circ\text{C}/\text{min}$ and $80\text{ }^\circ\text{C}/\text{min}$, till the very last temperature changed into reached. The experiments were repeated for each biomass type using particle length degrees:

$dp_1 < 0.30\text{ mm}$ and $0.30 \leq dp_2 < 0.50\text{ mm}$

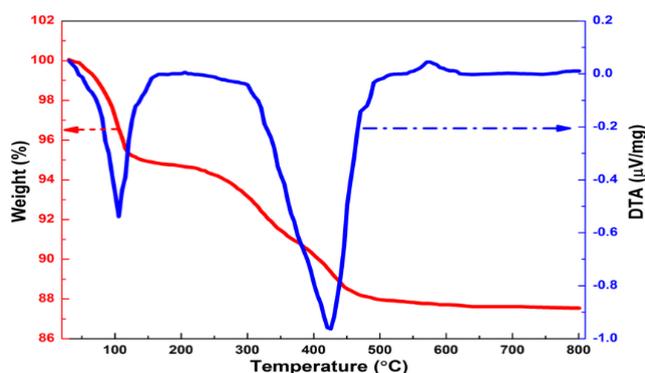


Fig.2 Differential thermal-thermogravimetric (DTA-TGA) analysis of silica nanoparticles (NPs)

Figure 2: SEM of Pure Silica (SiO_2)

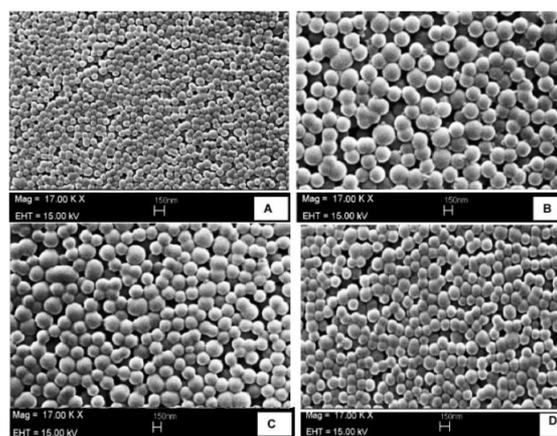


Figure 3: SEM Micrographs of Pure Silica Extracted from CSHA

Scanning Electron Microscopy (SEM) is widely used to study the surface morphology, particle size, and texture of pure silica. What you observe in SEM depends strongly on the form of silica (amorphous, crystalline, mesoporous, fumed, etc.) and the synthesis route.

Typical SEM Morphology of Pure Silica

1. Amorphous silica

- Shape: Irregular or near-spherical particles
- Surface: Smooth to slightly rough
- Agglomeration: Strong (due to high surface energy)

- Particle size: ~20 nm to a few micrometers (often agglomerated)

2. Fumed silica

- Shape: Chain-like aggregates of nano-sized spheres
- Primary particle size: ~5–50 nm
- Feature: Highly porous, fluffy structure

3. Mesoporous silica (e.g., MCM-41, SBA-15, COK-12)

- Shape: Spherical or rod-like particles
- Surface: Uniform, smooth external morphology

4. Crystalline silica (Quartz)

- Shape: Angular, sharp-edged particles
- Surface: Rough, fractured appearance
- Size: Micron-scale

SEM operating conditions (Typical)

- Accelerating voltage: 5–20 kV
- Magnification: 5,000× – 100,000×

Sample preparation:

- Gold/Pt coating (for insulating silica)
- Dry, powder mounted on carbon tape

Example: SEM interpretation

“The SEM micrograph of pure silica reveals irregularly shaped, agglomerated particles with a relatively smooth surface. The aggregation is attributed to strong inter-particle hydrogen bonding between surface silanol (Si–OH) groups. No distinct crystalline facets are observed, confirming the amorphous nature of silica.”

SEM description of pure silica (General / amorphous silica)

The surface morphology of pure silica was examined using scanning electron microscopy (SEM). The SEM micrographs reveal that the silica particles possess an irregular morphology with a strong tendency toward agglomeration.

The individual primary particles are not distinctly separated, forming clusters due to strong inter-particle interactions and hydrogen bonding among surface silanol (Si–OH) groups. The particle surfaces appear relatively smooth, indicating the amorphous nature of the synthesized silica.

No well-defined crystalline facets or sharp edges are observed, further confirming the non-crystalline structure of silica. The agglomerated particle size is found to be in the micron range, while the primary particle size is expected to be in the nanometer scale.

The observed morphology is consistent with previously reported amorphous silica materials.

SEM Description of pure silica (CSHA-Derived / Sol-Gel Silica)

SEM analysis of the synthesized pure silica reveals irregularly shaped particles with significant agglomeration. The micrographs show a porous and loosely packed morphology, which is characteristic of silica obtained via sol-gel processing.

The particle aggregation can be attributed to the high surface energy and the presence of silanol groups on the silica surface. The absence of sharp crystalline features suggests the amorphous nature of the silica framework.

Such morphology is advantageous for applications involving adsorption and catalysis due to the increased surface exposure and accessibility of active sites.

Results and Discussion

Phytochemical screening of CSH showed the presence of several bioactive compounds, which include alkaloids, flavonoids, tannins, terpenoids, saponins, steroids, phenols, and glycosides, contributing to its antioxidant and antimicrobial properties.

Biochemical estimations also found out the presence of carbohydrates and proteins, highlighting the dietary and medicinal fee of CSH. The chemical remedy yielded high-purity silica, with XRD styles confirming its amorphous shape (11, 12).

FTIR analysis diagnosed Si–O–Si stretching vibrations, at the same time as SEM confirmed porous floor morphology appropriate for adsorption and nanocomposite programs. TGA proven thermal balance, confirming its suitability for business processing.

Extraction silica through incineration

CSH consists of a high quantity of silica. To extract it, the husk is first cleaned and dried to do away with moisture and impurities. The dried husk is then subjected to govern heating (pyrolysis) at excessive temperatures, normally at 850°C.

At some point of heating, the organic matter (which includes cellulose, hemi-cellulose, and lignin) burns off, leaving behind CSHA that is rich in silica. The ensuing ash specifically includes amorphous silica that can later be purified the use of chemical treatment if required.

Extraction silica through chemical procedure

Inside the chemical extraction method, CSH is first washed very well to put off dust and soluble impurities, after which dried. The dried husk is handled with acid answers consisting of hydrochloric acid (HCl) or sulfuric acid (H₂SO₄) to eliminate metallic impurities like iron, calcium, and potassium.

After acid leaching, the husk is rinsed with distilled water and dried again. The dealt with husk is then subjected to manipulate burning at 850°C, producing CSHA rich in silica.

To extract pure silica, the ash is similarly dissolved in sodium hydroxide (NaOH) solution, forming sodium silicate. On acidifying this solution with sulfuric acid (H₂SO₄) or hydrochloric acid (HCl), silica precipitates out. The prompted silica is washed, filtered, and dried to reap excessive-purity amorphous silica.

Conclusion

This study demonstrates that CSH, an agricultural by-product, can be effectively transformed into excessive-purity amorphous silica the usage of blended thermal and chemical extraction techniques.

The controlled combustion and alkali-acid remedy produced silica with appropriate structural, morphological, and thermal properties, showed via XRD, FTIR, SEM, and TGA analyses. In addition to being a sustainable supply of silica, CSH carries bioactive phytochemicals with medicinal potential, similarly enhancing its value.

The extracted silica suggests promise for applications in adsorbents, catalyst helps, cementations composites, and nanomaterial's, aligning with inexperienced chemistry ideas and waste valorization strategies. The findings spotlight the twin advantage of environmental waste discount and material restoration, supplying enormous ability for business and biomedical applications.

Highlights

- Cane Sugar husk ash (CSHA) is a sustainable supply of excessive-purity amorphous silica.
- Controlled combustion (850°C) yields silica-wealthy ash with minimum carbon.
- Alkali leaching and acid precipitation enable green silica extraction.
- Extracted silica showed by way of XRD, FTIR, SEM, and TGA characterization.
- Silica shows capability in adsorbents, catalyst supports, cement, and Nano composites.
- CSH phytochemicals provide additional medicinal and nutraceutical Value.
- Procedure supports inexperienced chemistry and agricultural waste valorization.

References

1. Kumari, M., Mikhlesh, et al. (2023). Sustainable green approach of silica nanoparticle synthesis using an agro-waste rice husk. *Nature Environment & Pollution Technology*, 22(1).
2. Sankar, S., et al. (2018). Rapid sonochemical synthesis of spherical silica nanoparticles derived from brown rice husk. *Ceramics International*, 44(7), 8720–8724.
3. Beidaghy Dizaji, H., et al. (2019). Generation of high quality biogenic silica by combustion of rice husk and rice straw combined with pre- and post-treatment strategies: A review. *Applied Sciences*, 9(6), 1083.
4. Barnes, R. J., Dhanoa, M. S., & Lister, S. J. (1989). Standard normal variate transformation and de-trending of near-infrared diffuse reflectance spectra. *Applied Spectroscopy*, 43(5), 772–777.
5. Bose, D. N., Halder, A. R., & Chaudhuri, T. K. (2015). Preparation of polysilicon from rice-husk. *Current Science*, 108(7), 1214–1216.
6. Senthamilselvan, P., Velavan, S., Sagunthala, P., & Shyam, S. (2015). Anti-hyperlipidemic activity of the bark extract of *Terminalia arjuna* in caffeine-induced mice. *Indian Journal of Applied Research*, 5, 310–313.
7. Della, V. P., Kühn, I., & Hotza, D. (2002). Rice husk ash as an alternate source for active silica production. *Materials Letters*, 57(4), 818–821.
8. Agidew, M. G. (2022). Phytochemical analysis of some selected traditional medicinal plants in Ethiopia. *Bulletin of the National Research Centre*, 46(1), 87.
9. Mirahmadi, K., Kabir, M. M., Jeahanipour, A., Karimi, K., & Taherzadeh, M. J. (2010). Alkaline pretreatment of spruce and birch to improve bioethanol and biogas production. *BioResources*, 5(2), 928–938.
10. Selvan, P. S., Vellavan, S., Sagunthala, P., Prakash, N., & Subramanian, S. (2015). Analysis of phytochemical component and nutrients component in ethanol extracted *Oldenlandia corymbosa*. *World Journal of Pharmaceutical Research*, 4(7).
11. Agidew, M. G. (2022). Phytochemical analysis of some selected traditional medicinal plants in Ethiopia. *Bulletin of the National Research Centre*, 46(1), 87.
12. Selvan, P. S., Vellavan, S., Sagunthala, P., Prakash, N., & Subramanian, S. (2015). Analysis of phytochemical component and nutrient component in ethanol extracted *Oldenlandia corymbosa*. *World Journal of Pharmaceutical Research*, 4(7), 1015–1023.