

ANALYSIS AND CHARACTERIZATION OF SILICA OF PALM STARCH WASTE (*ARENGA PINNATA*) WITH COPRECIPITATION METHOD

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Abstract

Palm starch waste obtained from the Aci Kawung vermicelli flour factory in Ciamis, Indonesia, poses an environmental problem that also impacts the health of the surrounding community, thus requiring an effective treatment method. Silica synthesis from sago starch waste was performed using a coprecipitation method with 2M HCl. This study aimed to characterize the silica from sago starch waste using X-ray fluorescence (XRF) analysis to determine the elements, scanning electron microscopy (SEM) to determine the morphology, and a particle size analyzer (PSA) to determine the particle size of the silica. Sample preparation involved determining the weight of the raw material, washing the raw material, followed by physical and chemical activation through burning, calcination, mixing, and grinding, as well as chemical activation by washing with 2M HCl. XRF results showed that the main phase of the sample was SiO₂ at 68.90%. The silica itself can be utilized in wastewater adsorption. SEM analysis clearly shows numerous pores distributed evenly, which are beneficial for wastewater treatment; these evenly distributed pores are useful for adsorbing heavy metals such as Pb, Zn, Mn, and Fe. Additionally, PSA results indicate a particle size of 2.46 μm. This study holds potential for the development of bionanoadsorbent raw materials for water treatment.

Keywords: *Coprecipitation Method, HCl, Silica*

INTRODUCTION

Arenga pinnata is a tropical tree that grows naturally in Southeast Asian countries such as Indonesia, Malaysia, the Philippines, and China (Rahayu et al., 2025). In Indonesia, it is estimated that there are 64,025 hectares of sago palm plantations spread across 29 provinces (D. Gartina & L. L. Sukriya (Eds.), 2021). When the sago palm matures, it is harvested and no longer produces sugar or fruit; its trunk can be processed to produce starch. This sago starch is widely used in the food industry to make sago flour and rice vermicelli (Ratnaningsih & Arovah, 2025). Several studies have utilized parts of the sago palm as raw materials; waste from sago palm fruit husks (*Arenga pinnata* Merr) produces activated carbon with a high number of pores and active adsorption sites (Said et al., 2023) and activated carbon from sago palm bunches is used in applications to adsorb lead, copper, and chromium in solutions (Adrianto et al., 2019), sugar palm fiber ash as a natural silica source in industrial applications, with a silica content of 66.03%, holds potential as a raw material for composites, adsorbents, and construction materials. This study utilizes sago starch waste as a natural source of silica for raw materials in composites, adsorbents, and construction materials (Aliyu et al., 2023). And a source of natural silica for composite raw materials. Additionally, this study utilizes biomass waste to produce natural silica for various industrial applications.

One method for obtaining high-purity SiO₂ involves synthesizing SiO₂ from sago palm starch waste using the coprecipitation method (Nurdin, 2022), (Bukit et al., 2025). This method has advantages over conventional methods, as the coprecipitation method yields high purity, a very simple precipitation process with relatively fast processing times, and requires simple equipment and relatively low costs. This study also examined the effect of base activation using HCl and distilled water on the resulting SiO₂, which was subsequently processed via the coprecipitation method. In this study, the synthesized product underwent XRF characterization to identify the elements present in the material, and SEM characterization to observe changes in surface morphology (Nurdin, 2022). A study by Susilawati et al. (2024) synthesized silica from rice husk ash using a coprecipitation technique that can be incorporated into composites (Susilawati et al., 2024). Khairiah et al. (2021) used banana peels as a raw material for an adsorbent capable of absorbing the metals Mn, Pb, Zn, and Fe (Khairiah et al., 2021) and research by Enda et al. (2024) an adsorbent using *Hydrilla verticillata* activated carbon to absorb the heavy metal chromium ((Tarigan et al., 2024). Based on the above

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explanation, this study aims to synthesize silica from sago palm starch waste, which has potential for the development of bioadsorbent raw materials for waste treatment and lead metal adsorption.

METHOD

The materials used are palm strach waste ash, aquadest, and HCl 2M. The materials were weighed based on the compositions given in Table 1.

Table 1. Material Composition.

Ingredients	Mass
Palm Strach Waste Ash	38,75 g
Aquadest	70 ml
HCl 2M	155 ml

To synthesize silica from palm strach waste ash from a vermicelli factory was calcined at 300°C for 4 hours. The sugar palm starch waste ash was washed with a 2M HCl solution in a 1:4 ratio and stirred at 500 rpm for 2 hours to remove metal impurities. Next, the palm starch waste ash was washed with distilled water until it reached a neutral pH and dried at 105°C for 24 hours. Then, the carbon from the sago starch waste ash was ground and sieved to prevent agglomeration. The carbon was sonicated using a bath sonicator at 70°C for 1 hour. Furthermore, the carbon active was characterized using X-ray Fluorescence (XRF), Scanning Electron Microscopy/Energy Dispersive Spectroscopy (SEM-EDX), and Particle Size Analyzer (PSA)

RESULTS AND DISCUSSION

3.1. XRF Analysis

Table 2. XRF Results Before and After Coprecipitation

Elements and Compounds	Concentration Before Co-precipitation (%)	Concentration After Co-precipitation (%)
SiO ₂	0.00	68.90
CaO	45.78	3.13
MgO	21.61	0.16
K ₂ O	15.89	11.74
Fe ₂ O ₃	5.45	3.95
P ₂ O ₅	2.33	6.49
Cl	2.13	1.12
MnO	1.17	0.39
ZnO	0.55	0.39
TiO ₂	0.51	0.00
SrO	0.48	0.00
Rb ₂ O	0.24	0.15
Sc ₂ O ₃	0.22	0.00
CuO	0.17	0.00
Rh ₂ O ₃	0.05	0.06
SO ₃	3.42	3.49
Br	0.00	0.17

The results of the XRF analysis show that the coprecipitation method successfully extracted SiO₂ from the palm strach waste ash samples before and after extraction, with values of 0.00% and 68.90%, respectively. This overall increase indicates that the application of this method is appropriate and effective in enhancing the high purity of silica in palm strach waste ash, where the silica undergoes re-precipitation to form amorphous SiO₂, and is capable of removing impurities present in the initial material, thereby increasing the concentration of SiO₂ to a more dominant level. This indicates that this method is effective at removing metal impurities and improving the purity of silica (Al-Saad et al., 2024; Guo et al., 2021; Kristanti et al., 2024).

3.2. SEM Analysis

Analyze the surface morphology of palm strach waste ash with characterization SEM as seen in Figure 2.

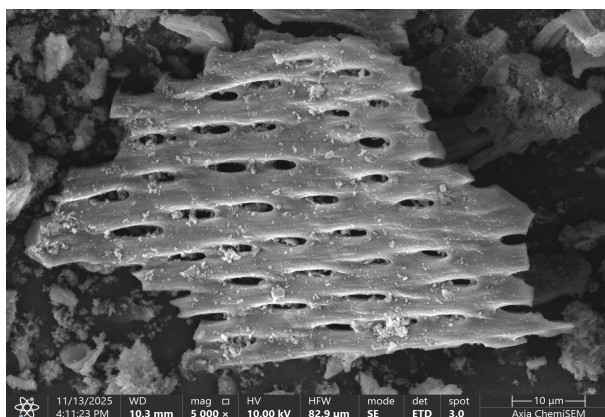


Figure 2. Morphology images and chemical compositions of Carbon Active from palm strach waste ash with 5000x magnification.

As can be seen in Figure 2, the sample has porous structure that appears as a hollow sheet. A characteristic feature of biomass is its surface structure, which is similar to a sheet and porous. The surface structure of sugar palm starch waste ash appears porous due to chemical activation and the activator compounds used in producing the adsorbent (Kristanti et al., 2024), (Erdiwansyah et al., 2024).

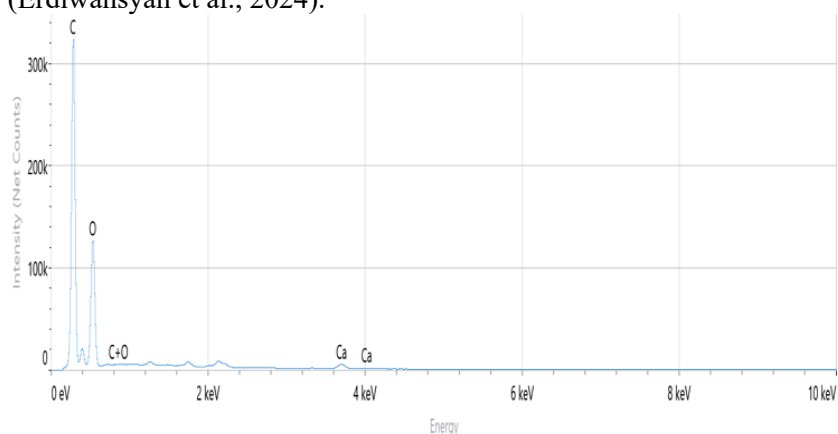


Figure 3. EDX Graph of Palm Strach Waste Ash

As shown in Figure 3, the percentage of the C and O mass elements were 54,2% and 42,7% respectively. These percentages are sufficiently high and tend to be evenly distributed.

Table 3. Elemental Composition Data from Palm Strach Waste Ash

Elemen	Baris	At. %	Wt. %	Jumlah Bersih
C	K	54.2	45.0	734 769
O	K	42.7	47.2	687 859
Si	K	0.9	1.8	48 711
Ca	K	2.2	6.0	56 401

EDX test results indicate that the material's dominant elements are carbon (C) and oxygen (O). High-carbon components can adsorb heavy metals due to their specific surface area, pore structure and surface modification capabilities, all of which contribute to high adsorption efficiency (Darminto, 2018; Togibasa et al., 2021). In addition to the main elements, carbon (C) and oxygen (O), silicon (Si) was detected at 0.9% and calcium (Ca) at 2.2%. The presence of Si and Ca is usually due to natural mineral residues in the biomass or inorganic ash resulting from carbonisation. The low Si and Ca content indicates that the activation process effectively reduces mineral impurities. Nevertheless, small amounts of Si and Ca can contribute to the stability of the adsorbent structure.

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3.3. PSA Analysis

Analyze the surface size of palm strach waste ash with characterization PSA as seen in Figure 4

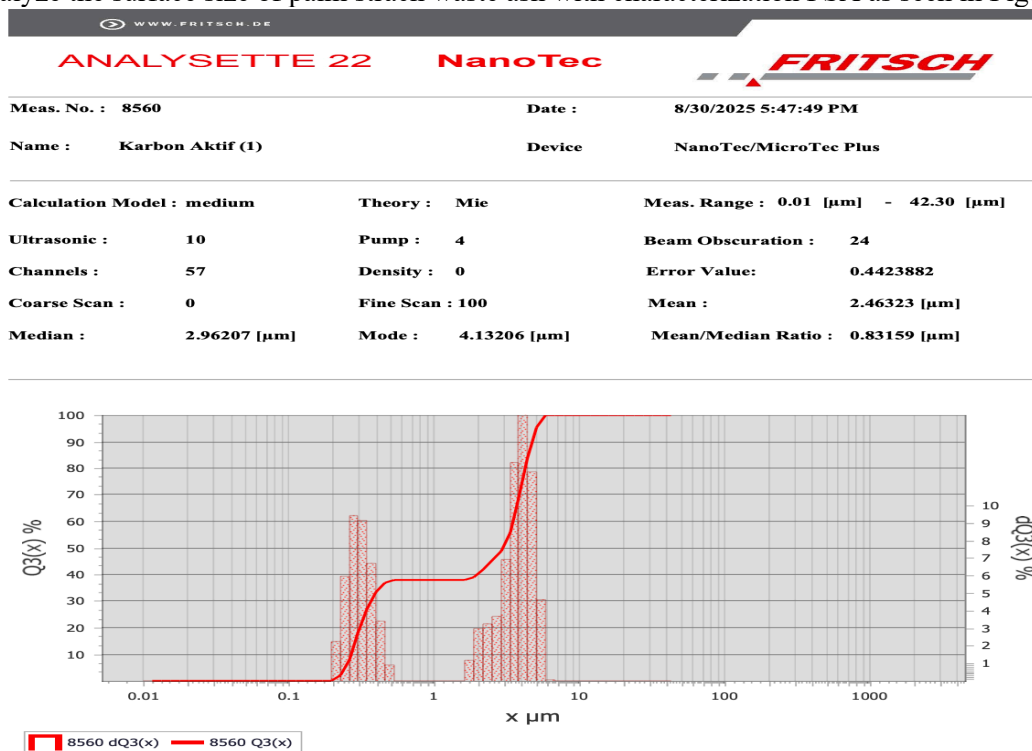


Figure 4. Differential Graph (%) vs diameter of palm starch waste ash samples

Based on the PSA results obtained using the FRITTSCH Analysette 22 NanoTec/MicroTec instrument, the particle size was 2.46 µm. This particle size offers advantages in adsorbent applications, as it increases the adsorbent's surface area. Wael (2025) explains in his study that silica synthesized from rice husk ash effectively removes heavy metals from synthetic wastewater. The removal efficiency was 94% for Pb²⁺ and 76% for Cd²⁺ (El-Nazer et al., 2025)

CONCLUSION

Silica has been successfully produced using the coprecipitation method. The XRF pattern indicates a high silica content and a reduction in impurity levels. SEM analysis clearly shows numerous pores distributed evenly, and SEM-EDS mapping clearly reveals that the carbon distribution is uniform. The high carbon content indicates that the material is dominated by an amorphous carbon matrix structure, which plays a crucial role in the adsorption process. The higher the carbon content in the adsorbent, the greater the formation of pores and specific surface area, which supports the adsorption of heavy metal ions.

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