IJRESM
International Journal of Research in Engineering, Science and Management
Volume 5, Issue 8, August 2022
https://www.ijresm.com | ISSN (Online): 2581-5792

Thermally Treated Rice Husk Ash for Potential Application as Silica Source in Sodium Silicate Production

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***Abstract*: Due to the recent increase in solid waste management and environmental preservation demands, waste utilization as an alternative material to natural or traditional materials from non-renewable sources has increased. Rice husk ash (RHA) is a paddy industry waste product that is known to contain a high amount of SiO_2 and, as a result, can provide a low-cost alternative source of silica for the synthesis of many ceramic materials. Rice husk is thermally treated and characterized in this study to determine its potential as a silica source in the production of sodium silicate as a ceramic material. Standard procedures were used to evaluate microstructure, chemical composition, mineralogical composition, thermal behavior, and molecular bonding. The EDXRF results show that the thermally treated rice husk ashes contain 79.7 wt. percent SiO_2, which is supported by XRD analyses that show predominant peaks of amorphous SiO_2 phase. The FTIR results clearly showed Si - O - Si (SiO_2) bonding at 1069.7 cm^{-1} intense wavelength and 797.7 cm^{-1} weak wavelength. The SEM morphology features revealed that the RHA has an irregular and coarse granular morphology with few pores and a large surface area, which is typical of RHA, while the TGA/DTA curve revealed good thermal behavior.**

***Keywords*: Rice husk ash, thermal treatment, chemical analyses, morphology, sodium silicate.**

1. Introduction

According to the Food and Agriculture Organization [1] the world's annual rice production is estimated to be over half a billion tons, leaving behind over a hundred million tons of husks as waste products, which are frequently sent to landfills to be burned, causing environmental pollution [2]. Despite being an agricultural waste, rice husks have found use as combustibles in insulating bricks and pozzolanic materials [3], fillers in polymers [4], and effluent waste treatment [5]. When rice husks are burned as fuel to generate energy, residual ashes known as rice husk ash (RHA) are produced as a waste material containing more than 70% silica (SiO_2). Researchers have recently published several papers on the use of rice husk ash (RHA) as a new economic potential source of silica in the synthesis of silica-based ceramic products such as porcelain [6], zeolites [7], silicon carbide [8], silica gel [9], silicon nitride [10], and pure silica [11]. Despite its numerous applications, little research has been conducted on the use of rice husk ash in the synthesis of sodium silicate. The few studies that have looked into the use of rice husk ash (RHA) as a potential source of silica in the synthesis of sodium silicate [9], [11], [12] have failed to characterize this rice husk ash in order to determine why it is thought to be a suitable alternative to natural quartz or chemically synthesized silica.

In light of this, the purpose of this research is to characterize thermally treated rice husk ash (RHA) as a silica source for potential use in the production of sodium silicate. To assess its (RHA) suitability as an alternative silica source, the chemical and mineralogical composition, morphology characteristics, molecular bonding, and thermal behavior were determined.

2. Materials and Method

A. Material

The rice husks used in this study were obtained from a rice milling plant in Igbemo-Ekiti, Ekiti State (7.6838º N, 5.3812º E) in Nigeria. To remove dirt and unwanted residues adhered to the rice husks, they were thoroughly washed with distilled water. The thoroughly rinsed rice husks were then air dried at room temperature for 24 hours before being oven dried at 110oC for 24 hours in an electric oven. The dried rice husks were then placed inside a crucible and burned in a muffle furnace. The rice husks were gradually heated from room temperature to 700ºC for 1 hour and allowed to cool before being removed from the muffle furnace. The resulting rice husk ashes (RHAs) were sieved through a 75µm sieve to yield a fine white RHAs powder.

B. Characterization

Various analyses were performed using standard procedures to characterize the obtained rice husk ash. The chemical composition of the RHA was investigated using a high performance EDXRF, XSUPREME 8000, to quantify the concentrations of SiO2 and other oxides present. X-ray diffractometer BRUKER AXS with D8 Advanced diffractometer Cu K radiation XRD in the range of 2 tetha angle

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from 5 to 70 scanning range was used to determine phase identification. The morphology of a gold-coated sample was examined using a high-performance Phenom Prox scanning electron microscope (SEM) to assess its (RHA) microstructure characteristics. The RHA's molecular bonding was identified using Fourier-transform infrared spectroscopy (spectrum 100 FT-IR Spectrometer, Perkin Elmer). The thermal behavior of rice husk ash was investigated using thermo gravimetric and differential thermal analysis (TGA/DTA) in a simultaneous analyzer (Perkin Elmer - TGA 4000) heated from room temperature to 950oC at a rate of 10°C/min.

3. Results and Discussion

Table 1 displays the chemical composition of thermally treated rice husk ash (RHA) as determined by EDXRF in the form of stable oxides found in RHA. RHA has a high silica (SiO_2) content of approximately 80%, which is less than the SiO2 content obtained for synthetic silica [13], but is sufficient to serve as an alternative silica source for sodium silicate synthesis. Figure 1 depicts the X-ray diffractometer diffraction patterns of the RHA (XRD). Because of the predominant broad peaks typical of amorphous silica between 22° - 27° [14], the RHA diffractogram indicates amorphous silica. Because amorphous silica, unlike crystalline silica, is soluble [17], RHA is a viable candidate material for use as a silica source in sodium silicate, which is a soluble glass. According to Figure 2, which depicts the morphology features of RHA, the particles have irregular geometry but the coarse granular features have not fully developed, which could be due to the temperature (700°C) at which it was thermally treated. RHA coarse granular particles are known to be fully developed at higher temperatures [13]. In addition, few pores can be seen in the SE images of the RHA, indicating its typical nature and contributing to its solubility, making it a material of choice in sodium silicate solutions. Figure 3 depicts the outcome of the RHA's molecular bonding. FTIR was used to capture the IR spectrum at wavenumbers ranging from 500 to 4000 cm^{-1}. RHA transmittance peaks were found at 1069.7 cm^{-1} and 797.7 cm^{-1}. According to [13, 15], the predominant intensity peaks in RHA at wavenumber ranges of 900 - 1100 cm^{-1} could be due to Si - O - Si asymmetric bending and stretching vibration bonds indicating the presence of siloxane structural bonding. This is consistent with what has been observed for synthetic silica [13]. Weak peaks in the RHA spectra at wavenumber range 700 - 800 cm^{-1} can be attributed to stretching of the symmetric Si - O bond known as Silanol [16]. According to Figure 4, which depicts the TGA/DTA of the RHA, an initial mass loss of about 17.9 percent occurred in the TG curve between 45°C and 257.1°C, which can be attributed to moisture loss and the start of organic matter degradation [17], while quartz formation begins at 573.3°C. The DTA shows two endothermic peaks at 100°C and 350°C, indicating early carbonate decomposition, which is likely due to the higher carbon in the RHA. Overall, RHA demonstrated tolerable weight loss with temperature and thus may be suitable for heating in the synthesis of sodium silicate.

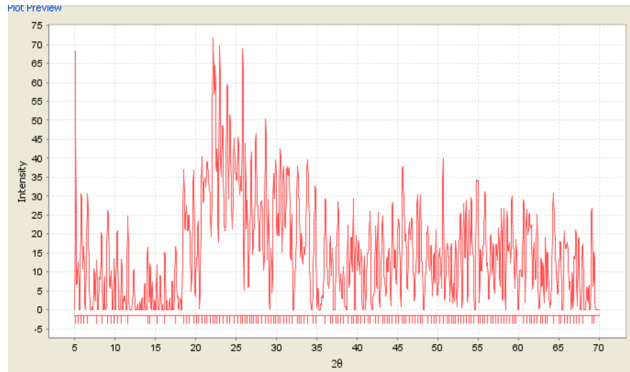

Fig. 1. X-ray diffraction pattern of the thermally treated rice husk ash (RHA)

Fig. 2. SE image of the thermally treated rice husk ash (RHA)

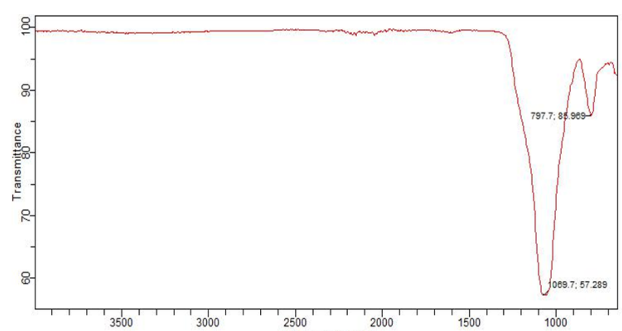

Fig. 3. FTIR spectrum of the thermally treated rice husk ash (RHA)

Table 1
Chemical composition of the rice husk ash using EDXRF

Oxides	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	Fe_2O_3	Cr_2O_3	Mn_2O_3	TiO_2
Wt. %	79.7	1.48	1.69	3.12	0.08	2.58	9.49	1.09	0.00	0.14	0.09

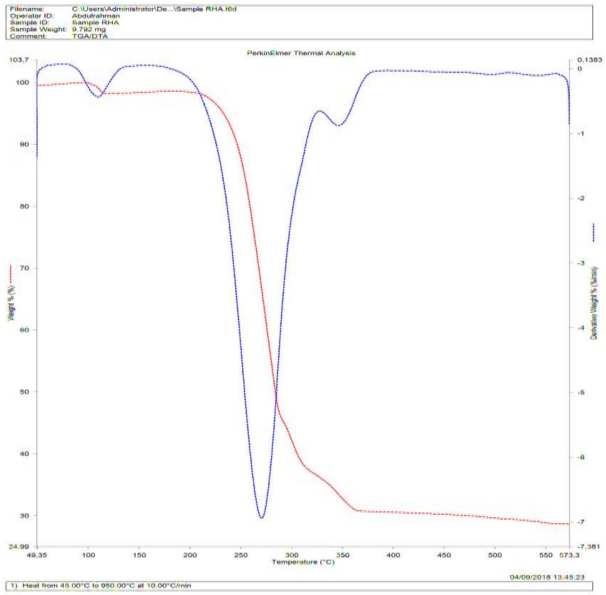
Fig. 4. Thermogravimetric curve of the thermally treated rice husk ash (RHA)

4. Conclusions

Thermally treated rice husk ash (RHA) has been successfully characterized in order to determine its potential application as a silica source in the synthesis of sodium silicate, thereby contributing to environmental preservation. The findings revealed:

- Rice husk ash contains silica content of approximately 80 percent, which is high enough to find application as potential silica source in the synthesis of sodium silicate
- Rice husk ash displayed a typical amorphous silica pattern as shown by the diffractogram and which makes it suitable for synthesis of sodium silicate as amorphous silica has been considered soluble unlike crystalline silica according to literature.
- The FTIR results showed that rice husk ash possessed typical Si – O – Si bonding and which justify their use as silica source in sodium silicate production while thermogravimetric results showed spots where weight loss, carbonates decomposition and quartz transformation occurred.
- Rice husk ash (RHA) displayed irregular geometry with the presence of coarse granular particles indicating the morphology of a typical irregular geometry of silica. However, the coarse granular features are yet to fully develop in RHA which is attributable to the level of phase crystallinity which is a function of the burning temperature of the RHA

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