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ASSESSMENT OF THE IMPACT OF HYDROCHLORIC ACID ON METAL IMPURITIES AND SILICA CONTENT OF RICE HUSK ASH

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Abstract: Rice is the main staple food of Nigeria, recent government policy on local content in agriculture has led to a boom in the cultivation of rice in the country. Rice husk which is a by–product of rice production is being considered for industrial applications as it has very little value in the food value chain. This study investigates the effect of hydrochloric acid in the leaching of rice husk to remove metal impurities and improvement of the percentage of silica content in the composition of rice husk ash. Rice husk was collected from a milling plant and washed to remove sand particles and dust. The cleaned rice husk was then leached with 1M of Hydrochloric acid (HCl) by heating it in an oven at 70°C for 3 hours. Thereafter, it was washed thoroughly with distilled water and air dry. The sample was calcined in a furnace at about 700°C for six hours and thereafter analysed using X–ray fluorescence technique. It was found that the leaching process with HCl had increased the Silica content of the rice husk ash from about 79.3% to about 92.8%. Likewise, the metal impurities in the rice husk ash had significantly reduced. It can be concluded that leaching rice husk ash with HCl makes it more suitable for industrial application.
Keywords: biosilica, rice husk, rice husk ash, XRF

INTRODUCTION

Rice is the number one staple food in Nigeria, the Federal Government's policy that banned the importation of rice has spurred an astronomical rise in the local production of rice in the country so much that Nigeria has now overtaken Egypt as the highest producer of rice on the continent – Nigeria now produces about 8 million tonnes of out of the Africa average of 14.6 million tonnes of rice annually [1]. The boom in the cultivation of rice in the country has resulted in a commensurate rise in the number of rice mills in the country and consequently the production of large quantities of agricultural waste – rice husk to be specific.

Rice husks (RH) are the hard protective coverings of rice grains that are separated from the grains during the milling process. RH which is the major by–product of rice milling and agro–based biomass industry is a cellulose–based fibre that contains approximately 20% silica in amorphous form and is usually produced in large quantities [2].

Rice husk is not edible as such it cannot be used as animal feed like other agricultural wastes/residues, thus, in most places in Nigeria, it is burnt or used for landfilling. The low economic value of RH and the problems associated with its disposal has prompted researchers and environmentalist to seek alternative usage for it.

One of such is the usage of rice husk ash (RHA) to partially replace cement in the preparation of cement concrete as an additive, it equally enhances the corrosion resistance and durability of concrete [3], [4].

RHA is produced from the burning of rice husk, upon burning, RH yields 14–20% ash, which is rich in Silica (about 60%) with trace amounts of metallic impurities and can be an economically valuable raw material for the production of biosilica [5].

Biosilica from RHA are used in various industrial applications such as; Chemical Industry, Electronic Industry, Glass industry and Building. Bansal, Ahmad, & Sastry [6] reported that nanocrystalline silica obtained from RH is used in commercial applications such as catalyst support, resins, fillers in polymers as well in biomedical applications.

Zamani, Mohajerani, & Ataie [7] also reported that silica gotten from RH is being considered as a possible raw material for the production of semiconductors due to its unique property of being highly reactive due to fine particles having large porosity and surface area. Biosilica is also used as pozzolone in cement when Portland cement is partially replaced by rice husk.

Despite the aforementioned industrial applications of biosilica and its huge prospects for wider industrial applications, its usefulness is limited by the level of metal impurities present in it. The higher the silica content of RHA and the fewer metal impurities it contains, the more desirable it becomes.

Therefore, for RHA to be suitable for industrial usage, there is a need for it to undergo a purification process to reduce its impurities and improve its silica content. This research explores the role hydrochloric acid (HCl) plays in the improvement of silica content and reduction in mineral impurities content of RHA.

MATERIALS AND METHODS

— Materials and Equipment Used

The materials used for this experiment include rice husk which was sourced from a local mill in Kura, Kura Local Government Area of Kano State, Nigeria. Tap water, 1M dilutes hydrochloric (HCl) acid and distilled water. The equipment used includes a digital weighing balance, a 2000 cm^3 aluminium pan, a muffle furnace (Carbolite Technology with model number CWF and capacity of 1100°C), an electric oven with a capacity of reaching 900°C, a measuring cylinder of 2000 ml capacity, X–Ray Fluorescence and a spectrometer (Epsilon panalytical Model DY1055).

— Sample Preparation and Calcination

Rice husk weighing 500 grammes without rice grains and sand particles was washed thoroughly with tap water to remove dust and other possible impurities.

The washed sample was then air–dried. This was done because impurities could influence the properties and composition of the rice husk ash.

The cleaned RH was leached with 1M HCl, the leaching process was carried out by heating the mixture of rice husk and HCl in the ratio of 1:10 in an oven at 70°C for 3 hours. Thereafter, the mixture of rice husk and HCl was washed with distilled water and air–dried.

The leached rice husk was calcined by putting the RH sample in a crucible and placed inside the furnace. The furnace was switched on and set at a temperature of 700°C and allowed for six hours. White RHA was obtained as shown in Figure 1.

Figure 1: White RHA obtained from Calcination

— Sample Characterization

An X–ray Fluorescence (XRF) analysis of the RHA sample was undertaken by first weighing 5 gramme of the sample using a macular balance. A binder (cellulose powder) was added to it and a pellet was produced using a manual compression machine.

The pellet produced was loaded into the sample chamber of the spectrometer, the machine was then set to a voltage of 30 kV and current of 1mA, these are required to produce the x–ray to excite the sample for 10 minutes.

Five gramme of unleached RHA was mixed with the binder and pellet of similar size as the previous was produced using the manual compression machine. This pellet was equally loaded into the sample chamber of the spectrometer and the machine was set at the same voltage and current as in the first case. This sample is meant to serve as a control for the experiment.

RESULTS AND DISCUSSIONS

It was observed that the ash produce after the calcination of RH is white, indicating the complete combustion of carbon. The result of the chemical analysis of rice husk ash which was carried out using X–Ray Fluorescence (XRF) is shown in Table 1.

Table 1: Chemical Analysis of Rice Husk Ash

Components (Oxide Element)	Composition by Weight (%)	
	Control	Leached Sample
SiO_2	79.30	92.80
P_2O_5	6.98	0.001
K_2O	5.64	1.43
CaO	3.06	1.40
Al_2O_3	2.54	0.002
MgO	0.06	0.001
Fe_2O_3	1.00	0.8
TiO_2	0.44	0.12
MnO	0.33	0.21
SO_3	0.24	2.40
BaO	0.20	0.0098
ZnO	0.15	0.055
Cr_2O_3	0.024	0.23
CuO	0.02	0.058
V_2O_5	0.01	0.008

It can be seen from the table that the result of the chemical analysis showed that RHA contains a high percentage of silica ($SiO_{2)}$ along with thirteen (13) oxides components as impurities. The oxides of Phosphorus (P), Potassium (K) and Calcium (Ca) and Aluminium exist in a considerably higher percentage than other elements which are less than one percent, this could be because these elements are essential nutrient uptake by the plants as such exist in larger quantities than other metals [8].

It can also be seen from the table that the Silica content of the unleached rice content was 79.3%. However, on treatment with HCl acid, the content increased to 92.8%. Though this is not the purest form of silica in RHA as others researchers have found higher values using other methods, for example, Ma et al., [9] used NH_4F to extract silica from RHA and was able to obtain Silica with purity levels of 94.6%.

Likewise, Bakar, Yahya, & Gan [10] who used hydrochloric acid and sulphuric acid to pre–treat RHA before heating in an oven found out that the Silica content of the RHA had increased to up to 99.6%. In the same vein, Liou & Yang [11] found out that the silica content of RHA could be enhanced to up to 99.48% by extracting the silica from a leached RHA using NaOH. Reports on the varying composition of rice husk ash and silica content is largely dependent on many factors such as the type of fertilisers employed, variety of rice paddy and climatic or geographical factors [12]. These findings notwithstanding, it can be said that the silicate content of RHA in this study has been found to increase by up to 13.5% by leaching with HCl acid.

Leaching RHA with HCl acid has also been found to affect the percentage of metal impurities, as can be seen in Table 1, the content of phosphate (P_2O_5) which have been found to reduce the strength of Portland cement (when RHA is used as cement additive) [13], [14] has reduced from 6.98% to 0.001%. This reduction is quite significant, it shows that the potentials for use of RHA as cement additive can be greatly improved by leaching with HCl acid.

The Potassium Oxide (K_2O) content of the RHA was found to have dropped from 5.64% to 1.43% upon leaching with HCl acid. This enhances the viability for the industrial application of RHA especially as cement additive as potassium oxide is undesirable in cement as it causes damage to kiln and attacks reinforced concrete [15].

It was also found that the leaching process with HCl acid reduced the Calcium Oxide (CaO) content of the RHA from 3.06% to 1.40%, this makes the usage of the RHA for the production of glass more suitable as higher CaO content in glass makes it more prone to devitrification thus making it less desirable for usage especially at elevated temperatures [16]. The brittleness of components produced using RHA can equally be significantly reduced when the Al_2O_3 content of the RHA additive is leached with HCl acid thus reducing its presence from about 2.54% to about 0.002% as seen in Table 1. The percentage content of all metal impurities in the RHA was found to have been reduced except for Cr_2O_3 and CuO which were found to have increased from 0.024 to 0.23 and 0.02 to 0.058 respectively.

Without a doubt, the leaching of RHA with HCl acid greatly improves its usability and desirability for industrial application as the silica content is enhanced and the content of undesirable metal oxides present in the ash is largely diminished.

CONCLUSIONS

This study reveals that biosilica with a high percent purity of 92.8% with minimal impurities can be produced from RHA by simple leaching with HCl acid. This suggests that HCl acid has proved to be effective in removing mineral contaminants, thereby improving the purity of silica content in RHA composition and making it more suitable for industrial applications.

Other researchers can vary the concentration of the HCl acid to see if it has any effect on the purity level of the biosilica produced and the mineral oxide impurities.

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