European Journal of Science, Innovation and Technology
ISSN: 2786-4936
www.ejsit-journal.com
Volume 5 | Number 3 | 2025

Biochemical Synthesis and Characterization of Hybrid Groundnut Shell Powder and Coconut Husk Ash as Corrosion Inhibitor on Mild Steel in Acidic Environment

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ABSTRACT

There is an increase in demand for environmentally friendly and cost-effective corrosion inhibitor materials, notably in the development of corrosion inhibitors produced from natural resources. However, the composition of natural inhibitors appropriate for effective control of corrosion has yet to be extensively studied. This work attempts to synthesize and characterize an environmentally friendly corrosion inhibitor from groundnut shell powder (GSP) and coconut husk ash (CHA) and examines the inhibitory potential of GSP-CHA on mild steel under 1M HCl environment, using SEM-EDX. It was observed that the CHA-GSP contains an appropriate amount of polyphenolic, carbon and active silica components present in its constituents. These active ingredients could make the GSP-CHA blend a good candidate for a corrosion inhibitive material.

Keywords: Corrosion Inhibitor, Coconut Husk Ash (CHA), Groundnut Shell Powder (GSP), SEM-EDX

INTRODUCTION

Degradation of engineering materials especially corrosion of ferrous metal under severe environmental conditions has huge economic costs to industries. Using corrosion inhibitors is one practical way to prevent corrosion in some circumstances (Abdallah et al., 2017). Corrosion inhibition slows down the pace at which metals erode in hostile conditions. Most manufacturing and processing sectors utilize corrosion inhibitors as a corrosion preventive method. Over the years, the Oil and gas, manufacturing and processing sector have employed inorganic and synthetic chemical-based inhibitors, such as chromate and nitrate-based, Cobalt-based, etc., which are not environmentally friendly (Oreko & Samuel, 2022; Odili et al., 2024; Samuel et al., 2025). The need for corrosion inhibitors that are both economical and environmentally friendly has grown significantly. Equally too, synthetic compounds employed as inhibitors are costly and, for the most part, constitute a considerable environmental hazard (Pyun, 2021; Okuma & Oreko, 2024). Current research inclinations are tending towards ecologically friendlier materials, which are non-toxic and biodegradable (Jyothi et al., 2019; Saeed, 2023). Agro-particles appear as better source of natural-based candidate with a variety of uses (Ranga & Sanghavi, 2017; Sivakumar et al., 2021; Sukyeung et al., 2022). There several corrosion inhibitors made from natural materials like rice husk waste, Cocos nucifera coir, coconut shell ash, groundnut shell, corn cob, fruit seeds and peels, wheat bran, etc., which are generally less harmful, available, less expensive to manufacture, and ecologically acceptable (Chigondo & Chigondo, 2016). Numerous natural agricultural

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wastes have been the subject of in-depth research, and the results have shown that they are rich in components such as silicon and magnesium oxide. The characteristics of blended groundnut shell powder and coconut husk ash (CHA-GSP) on mild steel in the presence of 1M hydrochloric acid as a corrosion inhibitor has rarely been studied. Hence, this work aims to synthesize and characterize GSP-CHA blend as surface inhibitors on mild steel in 1M hydrochloric acid.

MATERIALS AND METHODS

The materials used for the research include reagents, testing samples, and corrosion testing tools. These are Mild steel, Coconut husk, Groundnut shell, Hydrochloric acid, Distilled water, Acetone Ethanol, Filter paper, Sieve, Sandpaper, Brush, Paper tape, sponge, Detergent and bath.

Source of Materials

The reagents used were obtained from the Department of Chemical Engineering, Federal University of Petroleum Resources, Effurun. The mild steel used to prepare the coupon was obtained from Rizhao Steel Holding Group Co., Ltd., and the source materials for the agro particulates namely coconut husk and groundnut shell were obtained from Effurun Main market, Warri, Delta State Nigeria.

Equipment and Laboratories Used

The equipment used includes a hotplate magnetic stirrer, crucible, ice bath, digital weighing balance, petri dish, test tube, reagents bottles, beakers, conical flask, scapula, electrochemical testing electrodes and other necessary laboratory equipment. The synthesis was conducted at the Federal University of Petroleum Resources' Chemical Engineering Laboratory in Effurun, Nigeria. The mechanical engineering department laboratory at Bells University Ota in Ogun State, Nigeria, is where the electrochemical corrosion test was conducted. The Department of Chemical Engineering at ABU, Zaria, is where the material characterization was completed.

Synthesis of Coconut Husk Particulates

After being purchased from Effurun market, the coconut husk was dried at 125 degrees Celsius in an electrical oven to eliminate moisture and contaminants. To keep contaminants and moisture out of the environment, the fiber was taken out of the coconut's outer layer and kept in a dry container. To produce the coconut husk ash (CHA), the cleaned fibers were put in an aluminum crucible and heated for 2.5 hours at 500, 600, and 700 degrees Celsius at a rate of 11 degrees Celsius per minute in an electric furnace.

Figure 1: Muffle Furnace for the calcination of Coconut Husk

Chemical treatment of coconut husk ash

CHA was added to 25 mL of 5 N sulphuric acid in a beaker. The solution was heated up to 50 °C and stirred continuously for 1 h by using magnetic stirrer. After the leaching process, the solution was filtered, and the residue was rinsed for a few times with distilled water. This is to remove excess sulphuric acid content in the ash. The ash residue was dried at about 75 °C for 2 hours in the oven to obtain white powdered silica

Synthesis of Groundnut Shell Particulates

The Groundnut Shells was washed with distilled water to remove impurities and dried under sun. The dried sample was crushed into powder form using a mortar and sieved through 150 µm mesh screen sieve. 70 g of the sieved powder sample was refluxed in 350 mL of distilled water for three hours. The refluxed solution was filtered to remove any contamination and then dried under the sun. From the dried sample obtained, inhibitor solutions were prepared in different concentrations of Groundnut Shell (GS) extract ranging from 100- 2500 mg/L (w/v).

Figure 2: Samples of dried groundnut shell

Formulation of Coconut Husk Ash-Groundnut Shell Blend

The blend of groundnut shell particulate (GSP) and Coconut husk ash (CHA) was prepared in the ratios of 50:50 weight %. The composite was stirred and dissolved in 100ml of the Corrosive medium.

Preparation of the Metal Coupon

The coupons used for this research were prepared from a mild steel plate. The mild steel plate was obtained from Rizhao Steel Holding Group Co Limited China as hot hot-rolled steel plate. The steel plate was taken to the mechanical laboratory at the Federal University of Petroleum Resources, Effurun, where it was machined into the appropriate coupon sizes. The preparation of the coupon will involve marking out different pieces of 40 x 20 x 5 mm square size from the plate. Then, each size was carefully cut and machined to obtain a very smooth metal piece. A tiny hole was drilled in each of the metal pieces with the aid of a drilling machine. The coupons were polished mechanically with sandpaper. It was then washed with ethanol, and finally with Acetone to ensure proper degreasing and cleaning.

Figure 3: Mild steel Coupon

Preparation of the Corrosion Medium

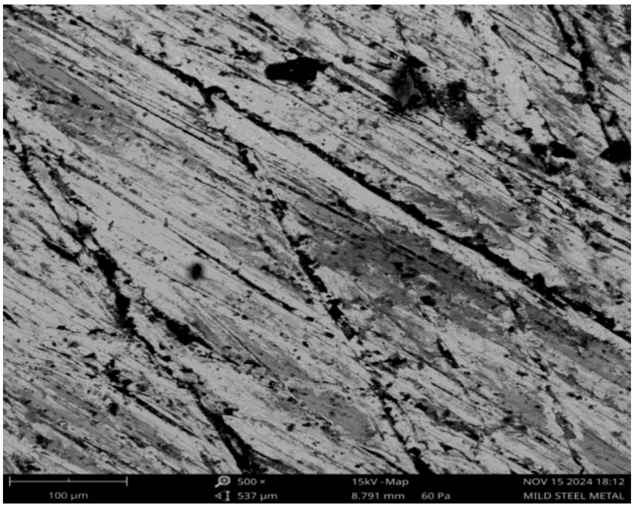
The environment to be used for this test was concentrated hydrochloric acid. The solution is 1 molar of hydrochloric acid.

Characterization using Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS)

Characterization was carried out to study the effect of groundnut shell particulate (GSP) and Coconut husk ash (CHA) on the mild steel. Characterization was done on the synthesized coconut husk shell and the groundnut shell powder, which were used as inhibitors to study the core properties and relate their properties to their corrosion resistance performance on the metal. The Scanning Electron Microscope and Energy Dispersive X-ray Spectroscopy. The samples were examined with a JEOL-JSM-7600F Scanning Electron Microscope (SEM) interfaced with Energy Dispersive X-ray (EDS) analysis system. At an accelerating voltage of 15kV, the SEM micrograph was obtained at system magnifications of 8000x, 9000x, and 10000x. The energy dispersive X-ray spectroscopy was used to examine the chemical characteristics of the sample and the elements present and their various compositions would then be determined. This was a result of the interaction of the X-ray with the sample.

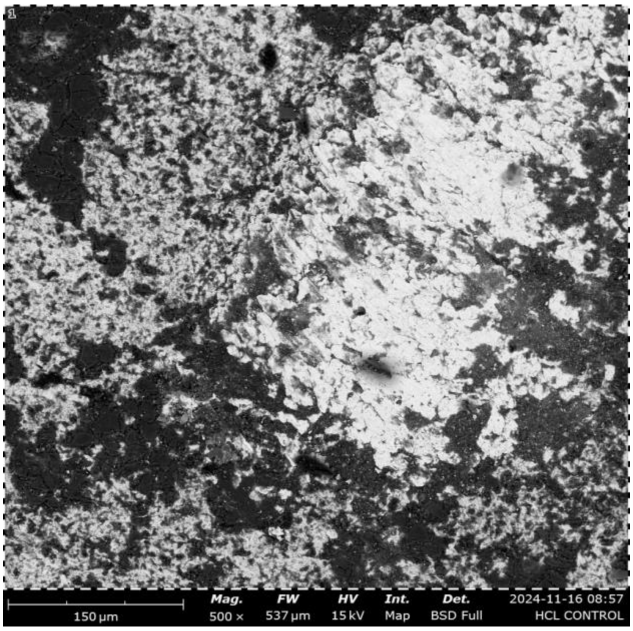
RESULTS AND DISCUSSION

Figure 4 is the surface morphology using SEM-EDX. It describes the visual details of the mild steel in the absence of Corrosion. Likewise, Figure 5 shows the surface morphology using SEM-EDX. The SEM reveals the surface morphology of metal samples exposed to corrosive media, clearly distinguishing between unprotected surfaces experiencing severe pitting and cracks while those treated with the CHA-GSP inhibitor displaying a smooth, uniform protective layer. This morphological improvement directly correlates with the high inhibition efficiency. For instance, a dense, defect-free surface observed via SEM confirms the formation of an effective barrier, while Energy-Dispersive X-ray Spectroscopy (EDX) maps the elemental distribution, detecting key components like silicon (Si) from CHA and carbon (C) from GSP, which are absent in non-inhibitive samples. EDX further quantifies composition of the protective mechanism of inhibitor-derived elements (e.g., Si, C, and O) on the metal surface. This elemental analysis validates the adsorption of GSP-CHA blend. The combined SEM-EDX data not only reinforces the electrochemical findings but also identifies areas for blend optimization, such as improving film homogeneity or adhesion. Evaluation of the visual, chemical, and electrochemical insights using SEM-EDX offers the potentials of GSP-CHA blend as good corrosion inhibitor.



Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
26	Fe	Iron	91.47	97.03
6	C	Carbon	6.42	1.46
20	Ca	Calcium	0.67	0.51
19	K	Potassium	0.45	0.33
17	Cl	Chlorine	0.48	0.32
16	S	Sulfur	0.35	0.21
25	Mn	Manganese	0.07	0.07
15	P	Phosphorus	0.08	0.05

Figure 4: SEM-EDX for Polished mild steel in the absence of inhibitor GSP-CHA



Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
26	Fe	Iron	70.07	84.71
13	Al	Aluminium	14.41	8.42
6	C	Carbon	9.29	2.41
14	Si	Silicon	2.53	1.54
17	Cl	Chlorine	1.35	1.04
19	K	Potassium	1.00	0.84
20	Ca	Calcium	0.57	0.50
16	S	Sulfur	0.39	0.27
15	P	Phosphorus	0.40	0.27
12	Mg	Magnesium	0.00	0.00
11	Na	Sodium	0.00	0.00

Figure 5: SEM-EDX for mild steel in the presence of GSP-CHA inhibitor blend

CONCLUSION

This work has synthesized and characterized a groundnut shell powder (GSP) and coconut husk ash (CHA) blend and applied same to a mild steel coupon under 1M HCl environment. It was noticed that GSP-CHA blend is effective as a sustainable corrosion inhibitor for mild steel in acidic environments. Observation from GSP-CHA characterization (SEM-EDX) confirmed the formation of a protective surface film rich in silica and polyphenolic compounds that could block corrosive agents. The study has shown that the GSP-CHA is a good candidate for corrosion inhibitive materials.

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