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EFFECTS OF *CARICA PAPAYA* SEED EXTRACT ON THE ELECTRICAL AND MICROSTRUCTURAL PROPERTIES OF MILD STEEL IN 0.1M NITRIC ACID

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ABSTRACT

The impact of Carica papaya seed extract on mild steel's electrical and microstructural characteristics in an acidic media (HNO_3) is examined using a weight loss technique at room temperature. Based on the results obtained, coupons with18ml extract immersion in an acidic environment yielded an efficiency of 58.38%. Also, the micrographs displayedprimarily pearlite (dark) and ferrite (light) structures, with more ferrite on the first day that gradually reducing with time and more pearlite from the seventh dayupwards. Finally, there was also a drop in the mild steel's electrical conductivity after immersion and increased in electrical resistance with an increasein inhibitor concentration, at the same time impedance remained the same before and after the immersion.

Keywords: *Carica papaya*; Corrosion; Inhibition; Mild steel; Pearlite; Ferrite; Nitric acid

INTRODUCTION

In the modern day, corrosion is a formidable foe to humanity due to the enormous annual costs associated with damage and upkeep, which amount to trillions of dollars worldwide. In industries such as the pulp and paper industry, power generation, underground structures, chemical and oil industries, metals are used in over 90% of the construction process (Osarolube et al., 2004).Metals continue to be essential to the technological growth of modern civilization as seen by their use in the building and construction industry, the manufacturing of tools and automobiles, agriculture, healthcare, telecommunications, and the generation and distribution of energy (Zehra et al., 2022). A metal is subjected to a variety of environmental circumstances during its working life, which increases its susceptibility to corrosion (Oyebanjo and Ayotamuno, 2023).

The main focus of this study is the corrosion of mild steel in 0.1M Nitric acid (HNO_3). Due to the tendency of mild steel corrosion to revert the material to its most stable oxide state or original form, known as its ore, and the contentious corrosive properties of HNO_3, the corrosion of mild steel poses a significant challenge in various industrial operations. Thus, it is crucial to acknowledge and address this specific corrosion occurrence to guarantee safety, maintain the economic viability of assets andinfrastructure, and preserve the structural soundness of industries that are exposed to acidic environments, including nitric acid. The need to develop corrosion inhibitors that are environmentally friendly and with specific actions on the substrate has led to a wide – ranging study on natural inhibitors (Avwiri and Igho, 2003).

Using natural inhibitors obtained from plant sources offers a viable way to successfully reduce corrosion while reducing the negative effects on the environment. The primary goals of the research are to analyze the extract's chemical makeup, determine how well it inhibits corrosion, and determine how the extract affects the mild steel's electrical and microstructural characteristics.

This research is to enhance our understanding of the interactions between natural inhibitors and metal surfaces in acidic environments and contribute to the development of sustainable corrosion mitigation techniques through methodical experimentation and analysis.

Compared to other well-known inhibitors like chromates and molybdates, research on Carica papaya extract as a viable corrosion inhibitor is comparatively sparse.

MATERIALS AND METHODS

Collection and processing of *Carica papaya* seed extract

Ripe fresh *carica papaya* fruit seeds were harvested from farms in the Rumuowha hamletin Eneka community of the Obio/Akpor Local Government area of Rivers State. Using distilled water, the *carica papaya* seeds were properly cleansed to ensure no dirt or impurities remained. The cleaned papaya seeds were arranged in a tray, sun-dried and thenfurther dried in an oven set at a low temperature (around 40–50°C or 104–122°F) until they were totally dry. The dried papaya seeds were then ground into a fine powder using a machine grinder.

Ninety (90) grams of the grinded material were weighed and added to a volumetric flask that contained 300 millilitres of N-hexane. The solution was kept in a controlled area for twenty-four (24) hours before to filtering. Then, in order to extract the active ingredients, the powdered papaya material was refluxed with the proper solvent (N-Hexane). After which the *Carica papaya* seed was extracted, leaving behind a clear liquid extract. Since N-hexane can evaporate at temperatures lower than 65 °C, the extract was subjected to an additional room temperature evaporation step to produce a stronger solution.

Phytochemical Screening of *Carica papaya* Seed Extract

The dried *Carica papaya* seed sample extract was subjected to phytochemical screening at the University of Port Harcourt's Phytotherapy Laboratory and the Department of Pharmacognosy. The analysis showed the presence of carbohydrates, glycosides, terpenoids, alkaloids, tannins, and flavonoids.

Preparation of Mild Steel Specimens

In the University of Port Harcourt's engineering workshop, mild steel coupons with dimensions of 40 mm by 40 mm and a thickness of 1.5 mm were cut into regular shapes. To enable threading through for the insertion and suspension of the coupons into the corrosive medium, a 2 mm drilling beat was utilized to create a hole near the top of each coupon. The spark analysis of the mild steel grades was C-4120(1.29), C-4140(1.53) and with the elemental composition of Cr (0.63%), Mn (2.25%), Fe (90.50%), Co (4.50%), Ag (0.61%) and Pb (1.52%) respectively.

Before being used, the coupons were carefully cleaned, distilled water and ethanol were used to rinse it. After that, clean, lint-free towels were used to fully dry the cleaned samples fully.

An analytical balance was then used to weigh each mild steel sample precisely. Surface characterization techniques were performed using an xmet7500 maxi package and an inverted metallurgical microscope from Turret Engineering Services Ltd., 3 Eze Wake Lane, opposite Wazobia FM, East-West Road, Rumuosi, Port Harcourt.

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Gravimetric Experiment (with extract)

The mild steel samples were placed in the following manner, with seed extract added, in an acidic medium: Using an electronic weighing balance to determine the initial weights, each coupon was first knotted with a thread. 0.1 M HNO_3 was used to create nine different stock solutions of the seed extract, each with a different concentration of 2, 4, 6, 8, 10, 12, 14, 16, and 18 millilitres. The 200 concentration of nitric acid solution that was stored in several Bama (mayonnaise) bottles—each with a different coupon suspended in it—was then mixed with these stock solutions. These coupons were withdrawn every 24 hours for 7,14, 21 and 28 days respectively. After being washed with distilled water, scrubbed with a bristle brush, and submerged in ethanol to halt the corrosion process, each coupon was removed, dried, and reweighed.

In addition, one metal coupon was immersed in a 200 ml, 0.1 M HNO_3 acid solution without an inhibitor (0 g extract) that served as the control medium. Their final weights were recorded after accounting for the days of retrieval. Each coupon's weight loss was evaluated and recorded using formulas that accounted for the weight variances of the coupons.

Electrical Measurement Test

This conductivity, resistivity and impedance test was conducted at the advanced physics laboratory of the Federal University of Agriculture Makurdi, Benue State, Nigeria, which is now known as JOSTUM.

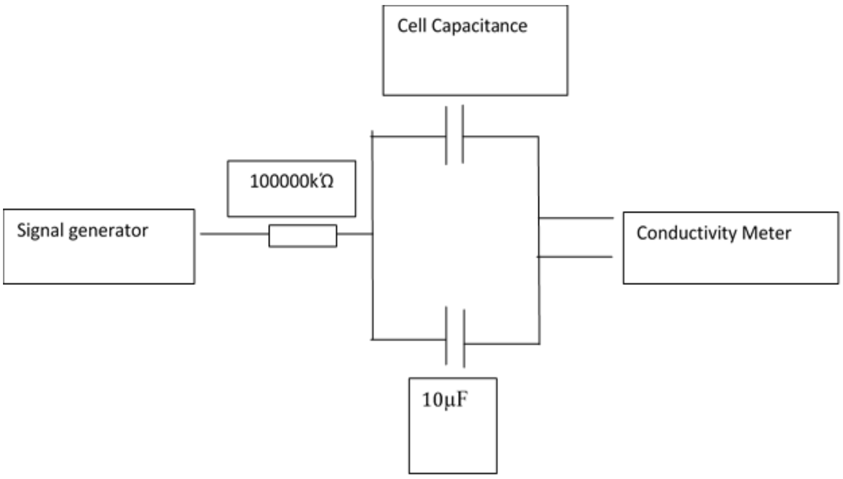

Fig 2.1: Circuit diagram of conductivity test

Microstructure Examination Methodology and Surface Characterization

The surface characterisation (micrograph) was done at Turret Engineering Services LTD, No. 3 Eze Woke Lane, beside Wazobia FM, East – west Road, Rumuosi, Port Harcourt. The C-4120 Alloy steel sample was ground using 80, 180, 320 and 600 grits emery papers; polished with 1200 grit and diamond paste. The C-4120 sample was then etched with Nital 5% etchant. The sample was then examined using an inverted metallurgical microscope before the immersion into the solution containing nitric acid only and nitric acid + carica papaya seed extract. At the expiration of the exposure time, the coupons were removed rinsed with distilled water, and dipped into ethanol. On drying, the mild steel coupons were wrapped with aluminum foil and shipped out for SEM investigation.

RESULTS AND DISCUSSIONS

Effects of inhibitor on weight loss, corrosion rate and inhibition Efficiency.

The weight loss of mild steel following corrosion is depicted in Figure 1. The weight loss varied between 0.1455g and 0.1963g, with the 24 hours corrosion time with 2mlinhibitor concentration and the 672 hours corrosion time with 18 ml inhibitor concentration recording the lowest and largest weight loss, respectively. The results showed that the mild steel's weight loss increased over time. In addition, compared to the uninhibited coupons, the inhibited coupons were slowly attacked by the acid. This demonstrates that*caricapapaya* seed extract is an effective inhibitor. Furthermore, the research indicates a dose-response relationship between the effectiveness of *Carica papaya* seed extract's corrosion inhibition and its concentration. This suggests that stronger inhibition is produced at higher concentrations, offering a useful way to tailor corrosion control tactics.

The corrosion rate and inhibitor efficiency of *carica papaya* seed extract are displayed in Figures 2 and 3. The inhibitor efficiency ranged from 1.73% to 58.38% for different inhibitor concentrations and corrosion times, with the lowest and highest inhibitor efficiencies being recorded for 48 hours with a 4 ml inhibitor concentration and 672 hours with an 18 ml inhibitor concentration, respectively. The efficiency was measured through weight loss measurement. The lowest and highest values were reported for the 24 hour corrosion time with 2 ml inhibitor concentration and the 672 hour corrosion time with 18 ml inhibitor concentration, respectively. The corrosion rate ranged from 1.829 x 10^{-5} $gcm^{-2}hr^{-1}$ to 3.797 x 10^{-4} $gcm^{-2}hr^{-1}$.

The first four (4) days have extremely low inhibitor efficiency values and a corrosion rate. On the seventh (7) day, there was a noticeable increase in value, indicating the *carica papaya* seed extract's efficacy. Additionally, it may be inferred that the mild steel surface was exposed to the corrodent as a result of the extract molecules being absorbed over time, resulting in lower values at the beginning of the recorded values. As stated by Oguzie et al. (2012a, 2012b); Chahul et al. (2019).

Furthermore, as the corrosion rate drops, the inhibition efficiency rises, as seen in figures 2 and 3 above, demonstrating the effectiveness of the *carica papaya* seed extract as an inhibitor.

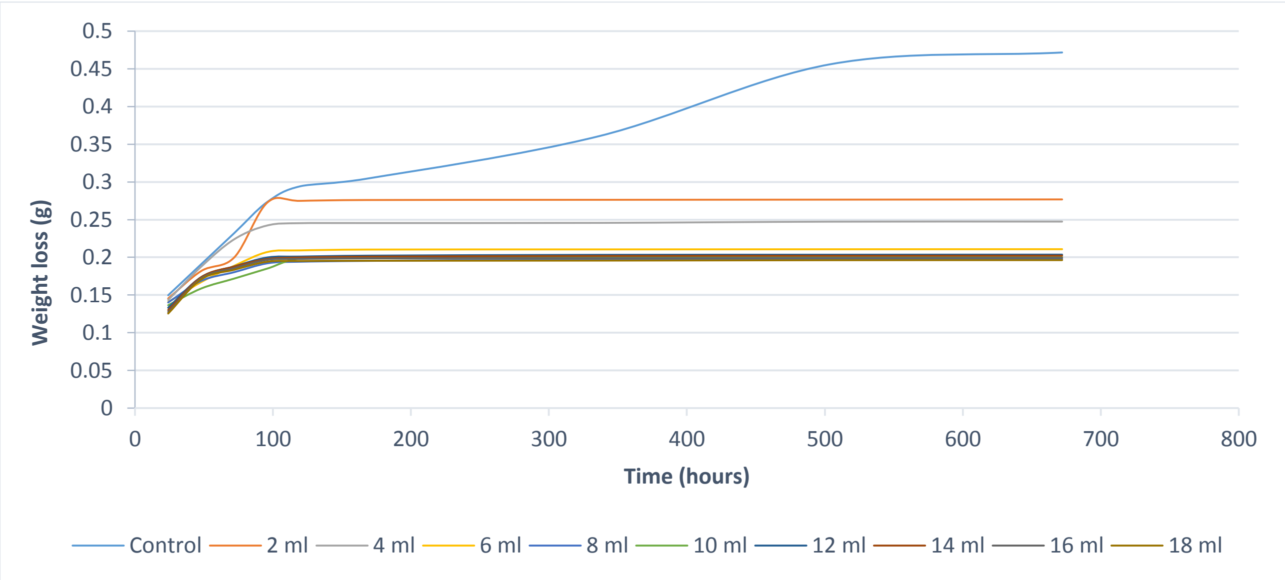

Figure 1: Variation of weight loss (g) with time (hours) of mild steel in 0.1 M Nitric acid

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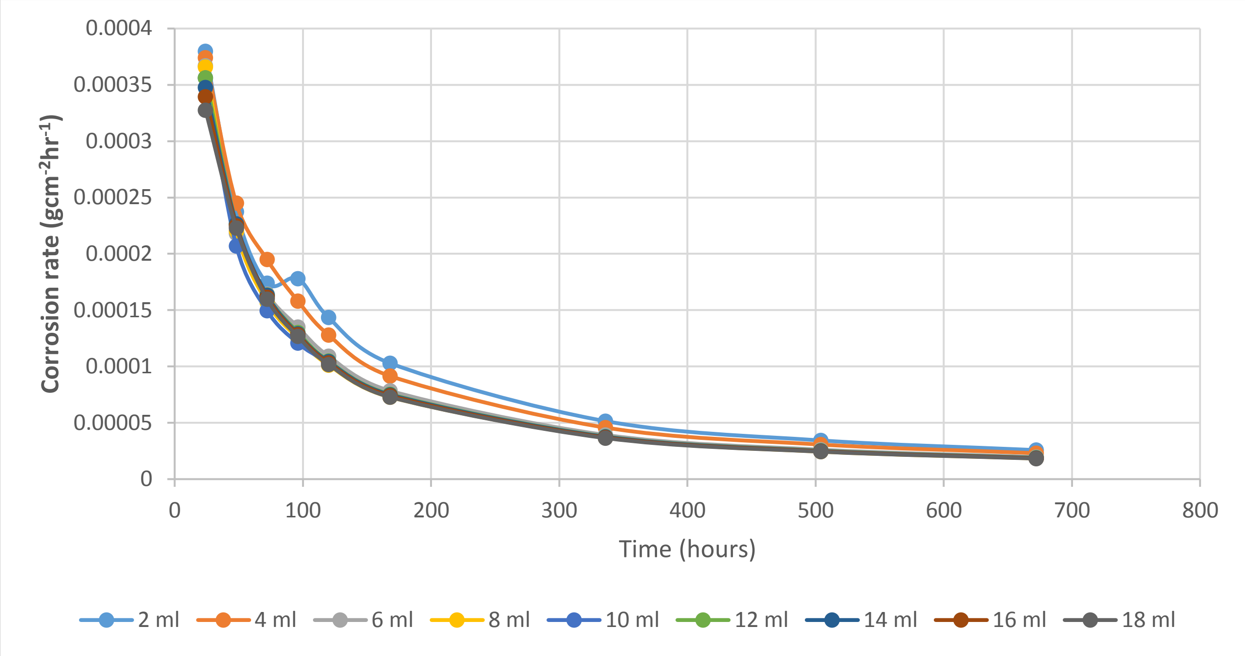

Figure 2: Variation of Corrosion rate with concentration and time

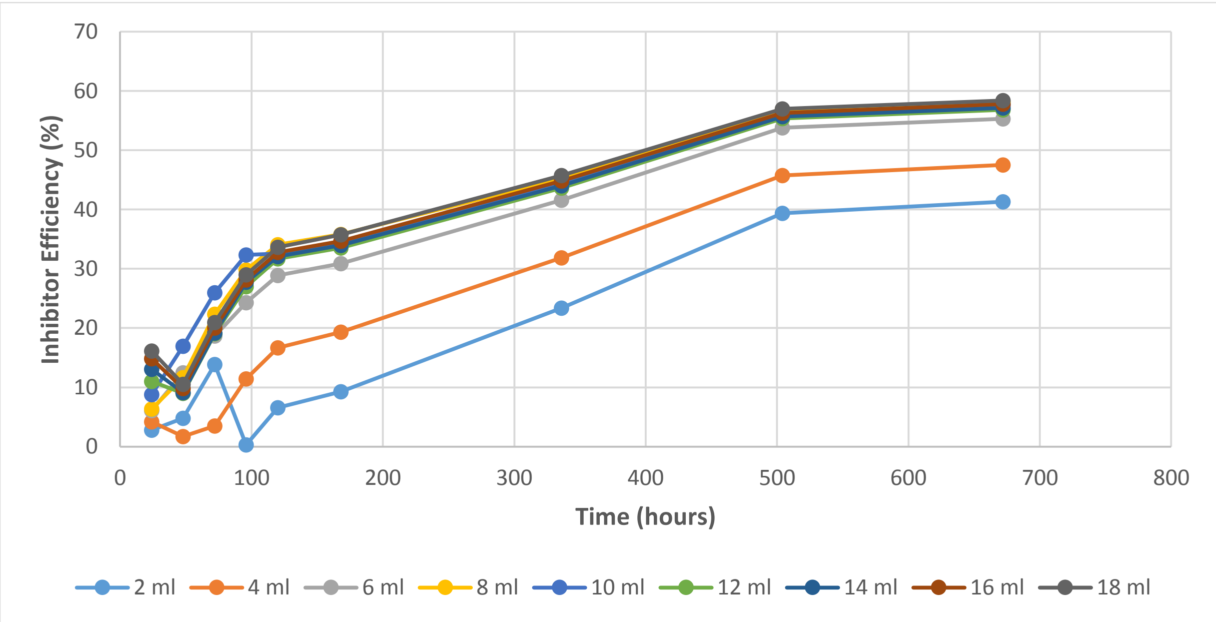

Figure 3: Variation of Inhibitor Efficiency at different concentration and time

Electrical and Microstructural Properties

The conductivity, resistivity, and impedance at different frequencies and times are shown, respectively, in Figures 4, 5, and 6. All resistivity measurements at all frequencies and times of measurement were above the control values, whereas all conductivity measurements were below the control values. The measured impedance at every point during the measurement and frequency seemed to match the impedance control parameters.

The decrease in electrical conductivity value relative to the control is consistent with findings by Nelson and Stile (1988) and Dawson and Turner (1988). Brikby et al. (1999) and Darry and Spear (1992). These alterations are frequently connected to the development of a shielding layer on the metal surface, which may have an impact on charge transport processes. The decrease in the coupons' electrical conductivity upon exposure was caused by the mild steel surface deteriorating during the corrosion process. The reason for this is that the damaged coupons exhibit a small decrease in electrical conductivity as a result of significant current leakage brought on by the skin friction that the samples experience during the corrosion process.

Surface Characterization

The coupons' spectroscopic and scanning electron microscopy (SEM) surface analyses are displayed on Plate 1 prior to their immersion in an acidic environment. The microstructure is composed of ferrite and pearlite in combination.

Additionally, the SEM and spectroscopic surface studies on plates 2 through 6 show clear distinctions between the mild steel samples that were inhibited and those that were not. The predominant microstructure features are ferrite (light) and pearlite (dark). The ferrite content increases on day one and decreases significantly on day three, whereas the pearlite content increases on days seven and fourteen. This suggests that the pearlite matrix may prevent dislocations from occurring, resulting in enhanced mild steel strength and hardness.

Less pitting and surface deterioration, as well as surface characteristics that were associated with the development of a protective layer, were seen in the show samples. The findings of the surface analysis indicate that the *Carica papaya* extract changed the mild steel's surface morphology, resulting in modifications to the surface topography that prevented corrosion. Moreover, the extract's surface characteristics and imperfections may interfere with the uniform corrosion process, reducing its effectiveness.

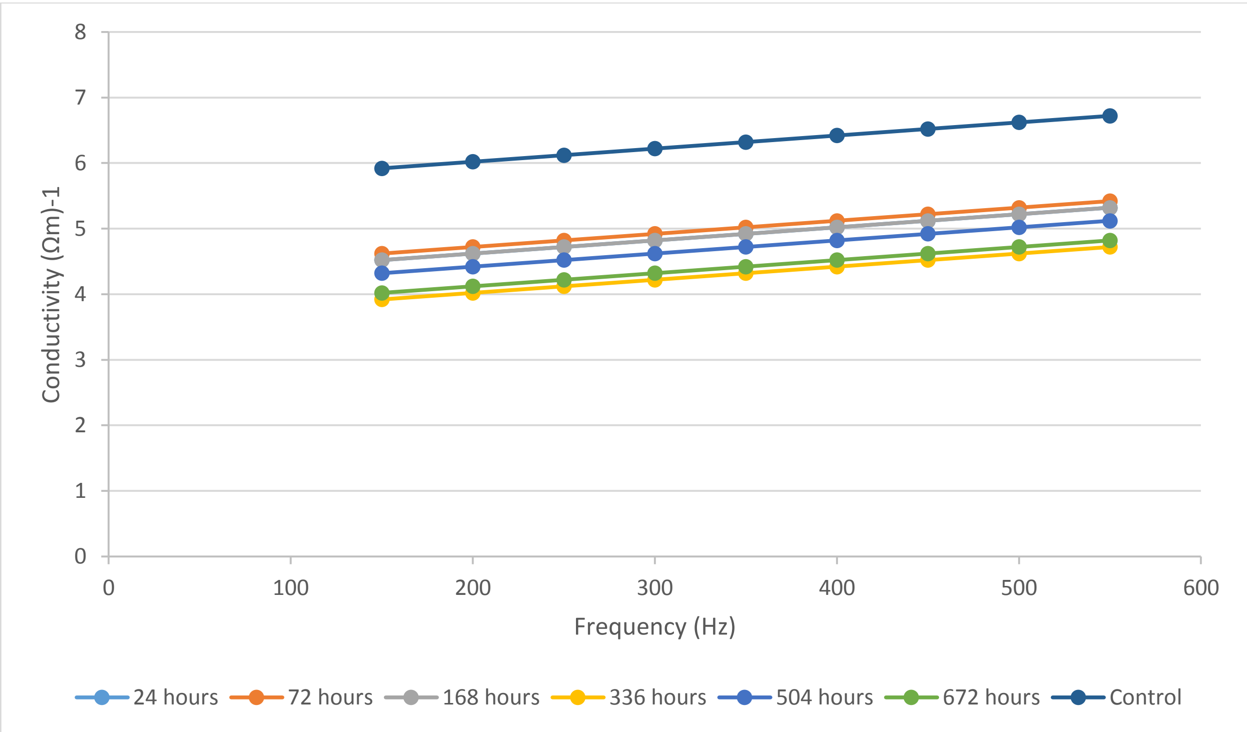

Figure 4: Variation of Conductivity with Frequency and Time

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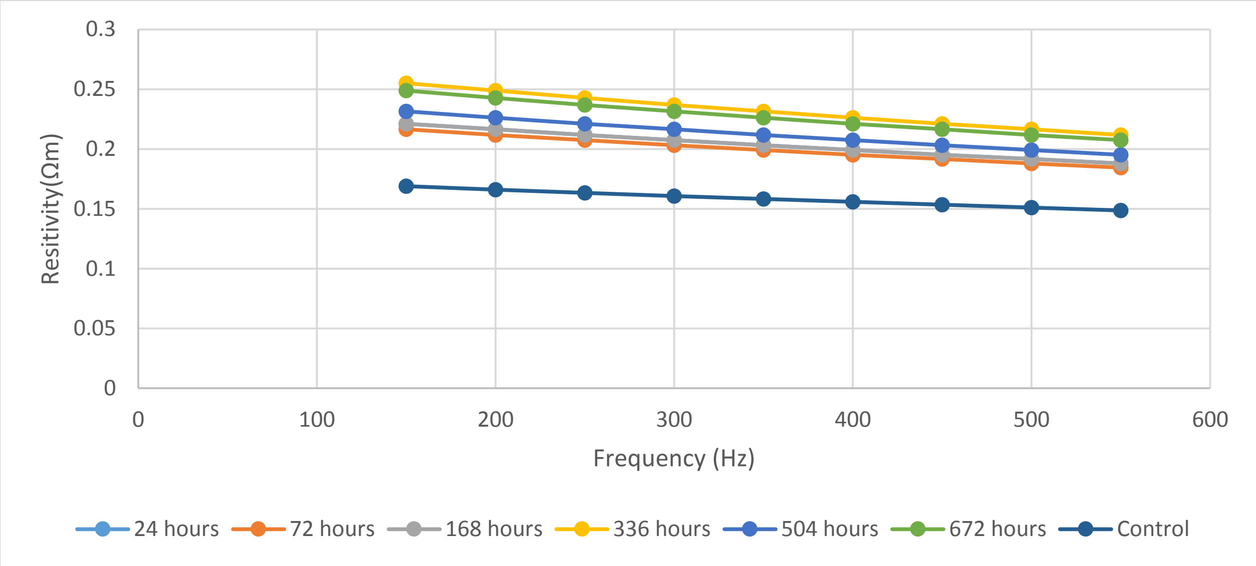


Figure 5: Variation of Resistivity with Frequency and Time

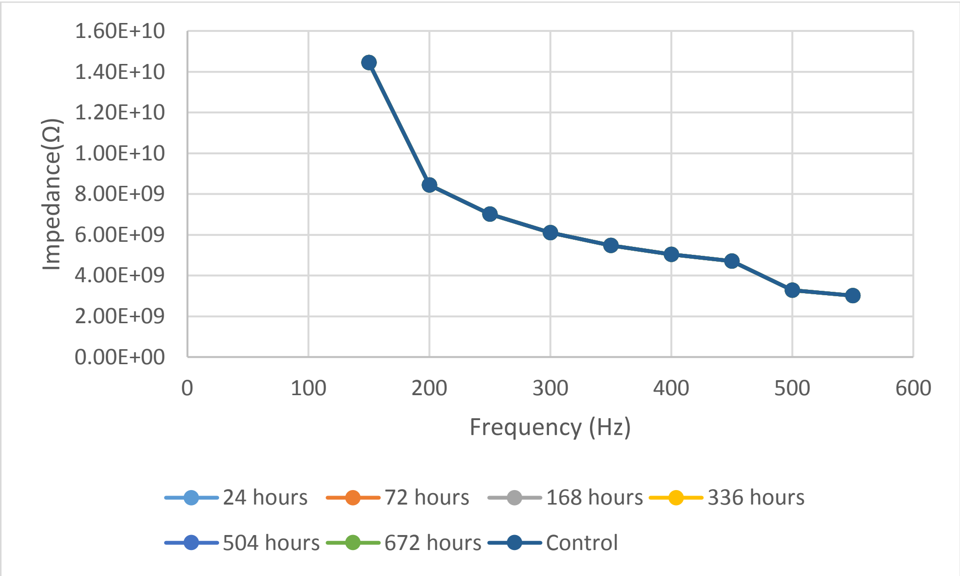


Figure 6: Variation of Impedance with Frequency and Time

MICROGRAPHS OF MILD STEEL BEFORE AND AFTER CORROSION

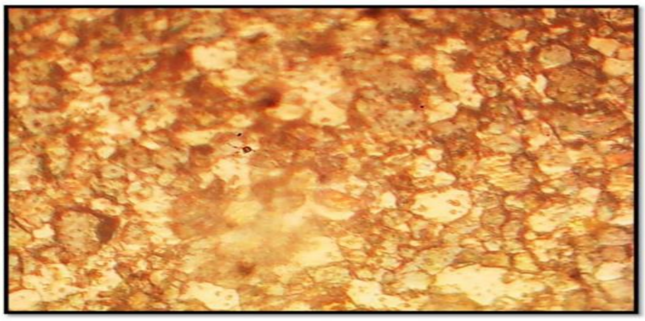
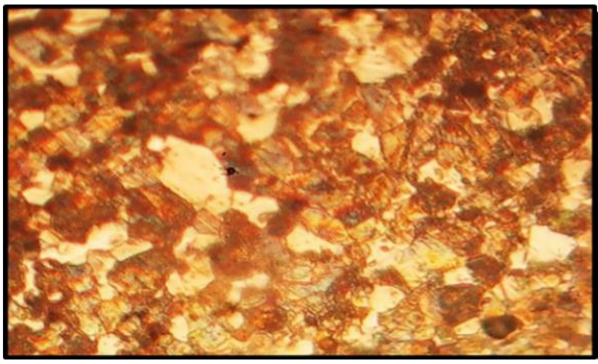


Plate 1 Micrograph before immersion.



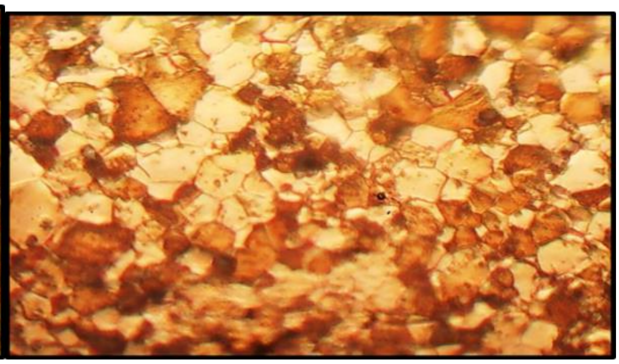
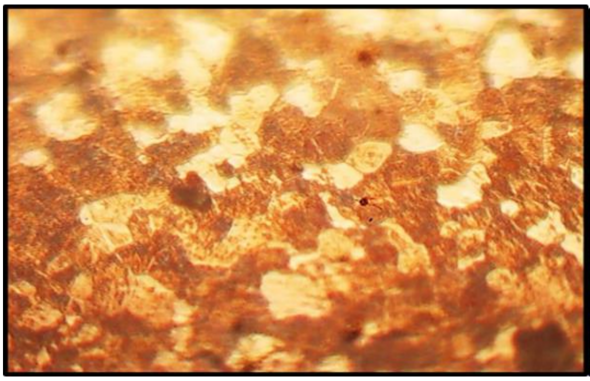


Plate 2: Micrograph of Sample after day 1 **Plate 3:** Micrograph of sample after day 3



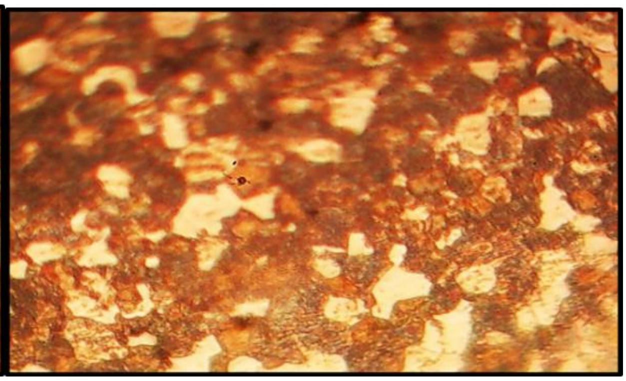


Plate 4: Micrograph of sample after day 7 **Plate 5:** Micrograph of sample day 14

Note: The magnification of the plates after corrosion is x200.

CONCLUSIONS

This study has shown that *Carica papaya* seed extract is a very effective mild steel corrosion inhibitor. The coupon with an 18 ml of extract submerged in a nitric acid environment yielded an efficiency of 58.38%, demonstrating the extract's potency. The results also revealed that the mild steel's electrical conductivity decreased after immersion and that its electrical resistance increased as the inhibition concentration increased. The impedance remained constant both before and after the immersion, and the microstructure mostly consisted of pearlite, which is dark, and ferrite, which is light. The amount of ferrite was higher on day 1 and decreased over time, while the pearlite content increased starting on day 7.

The relationship between corrosion rates and electrical properties, add a new level of complexity to corrosion monitoring, with possible uses in real-time evaluation.

REFERENCES

Brikby I. Harrison P. and Stevens R. (1999), “The effect of surface Transformation due to Degradation”, J. European Soc. 5 (1), 37-46.

Osarolube, E., Owate, I.O., and Otorka, N.C. (2008). “Corrosion behaviour of mild and high carbon steels in various acidic media”. Research gate, 3(6): 224-228

Chahul, H. F., Danat, T. B., andWuana, R. A. (2019). Corrosion inhibition studies on the influence of colocasiaesculenta leaves extract on mild steel in 1.0 M HCl. *Journal of Matererials and Environmental Science, 10*(3), 266-273.

Darry P. and Spear K. (1992), “Corrosion of Materials in N2 – H – Co”, Journal of Corrosion Science, 75 (12) 3257-77.

Avwiri, G.O., and Igho, F.O (2003).” Inhibitive action of vernoniaamygdalina on the corrosion of aluminium alloys in acidic media”. Journals of Science Direct, volume 57 3705-3711.

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Dawson, J.L. and Turner, N.E.D (1988), "Corrosion Monitoring and Control", J. Inst. of Metals 4, 218-222.

Nelson, P. and Stile, J.R. (1988), "Metallurgical Failures of Offshore oil Installation", Journal of the Institute of Metals 4, 559-564.

Oguzie, E. E., Adindu, C. B., Enenebeaku, C. K., Ogukwe, C. E., Chidiebere, M. A., &Oguzie, K. L. (2012). Natural products for materials protection: mechanism of corrosion inhibition of mild steel by acid extracts of Piper guineense. *The Journal of Physical Chemistry C*, *116*(25), 13603-13615.

Oguzie, E. E., Ogukwe, C. E., Ogbulie, J. N., Nwanebu, F. C., Adindu, C. B., Udeze, I. O., … Eze, F. C. (2012b). Broad spectrum corrosion inhibition: corrosion and microbial (SRB) growth inhibiting effects of Piper guineense extract. Journal of Materials Science, 47(8), 3592–3601.

Oyebanjo, A. D., &Ayotamuno, C. (2023). Carica papaya seed-extract as organic inhibitor on the corrosion of aluminium and mild steel in a sulphuric acidic environment. *Advance Journal of Current Research*, *8*(3).

Zehra, S., Mobin, M., & Aslam, R. (2022). Corrosion inhibitors: An introduction. In Environmentally Sustainable Corrosion Inhibitors (pp. 47-67). Elsevier.