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Raphia taedigera seed extract as a green corrosion inhibitor for the corrosion of mild steel in acidic media

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Abstract

In the present work, ethanolic extract of *Raphia taedigera* seed was used as corrosion inhibitor for Aluminium alloy 6063 (AA6063) in an acidic environment. The evaluation was carried out with different dosages of the seed extract in 1.0 M HCl using the weight loss method at room temperature. The present study results confirmed that the *Raphia taedigera* seed extract acts as an effective green corrosion inhibitor for AA6063 in the acid medium. The inhibition efficiency increased with an increase in the extract concentration of the inhibitor. FTIR and SEM analyses confirmed the formation of a protective layer on the AA6063 surface when the acid solution was inhibited. Changes in the surface functional groups revealed by FTIR also confirmed that there was an interaction between the surface of the alloy surface and the extract constituents. The inhibition efficiency of 86.41% was achieved for *R. taedigera* extract of 2% wt/v.

Keywords: *Raphia taedigera;* Aluminium Alloy 6063; Weight Loss; Corrosion

1. Introduction

The application of mild steel for different construction works in the industrial sectors has become a challenge for corrosion engineers and scientists. Most processes, such as industrial cleaning, refining of crude oil, and petrochemical processes, use equipment made from metals under varied conditions ranging from mild to harsh chemical environments, making the materials' surfaces prone to corrosion [1]. Corrosion leads to an expensive problem for manufacturing industries, chemical plants, and oil industry with a significant impact on the economies of industrial nations. Other adverse effects of corrosion include life-threatening accidents resulting in loss of lives and properties and environmental damage with a massive threat to the ecosystem [2]. Corrosion causes significant deterioration of natural and historical monuments and increases the risk of catastrophic equipment failures. Industries cannot tolerate significant corrosion damages, especially those involving personal injuries, fatalities, unscheduled shutdowns, and breakdown of the ecosystem, hence; the need to intensify effort to minimize corrosion in the society [3, 4, 5]. Many organic compounds containing heteroatoms such as N, S and O have been reported as effective corrosion inhibitors; however, most of these compounds are expensive and pollute the environment [6]. The natural product stands out among the corrosion inhibitors because it is highly efficient, readily available, cost-effective, and eco-friendly. Recently, many green corrosion inhibitors such as *Talinum triangulare* leaves extract [6], *Terminalia catappa* leaves Extracts [7], *Caesapinia bonduc* Seed Coat Extract [8], *Baphia nitida* Leaves Extract [9], have been used and reported for their anti-corrosion abilities.

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On the other hand, *Raphia taedigera* is evergreen and underutilised tree found in the tropical forest. The cespitous, monoecious, monocarpic species is native to Brazil and Nigeria. The mature tree is about 4 – 12 m tall and 25 - 40 cm in diameter. [10, 11, 12, 13] *R. taedigera* belongs to the family of Arecaceae, which produces egg-sized fruits, which are covered by imbricate glossy reddish-brown scales. The fruit contains one seed that is hard when dried with the white shiny inner part [14, 15, 16, 17]. The qualitative screening of ethanolic extract of the *R. taedigera* seed revealed the presence of secondary metabolites such as alkaloids, saponins, phenols, tannins, flavonoids, terpenoids and cardiac glycosides [11, 12]

Therefore, the present work investigates the anti-corrosion activities of *R. taedigera* extracts as green inhibitors for aluminium 6063 alloy in an acidic media of 1.0 M and 2.0 M of hydrochloric acid at room temperature using the mass loss method.

1.1. Preparation of aluminium 6063 alloy

Aluminium A6063 alloy specimen with the following composition (wt.%): 0.10% Cu, 0.60% Si, 0.10% Mn, 0.90% Mg, 0.10% Cr, 0.10% Zn, 0.10% Cr, 0.35% and balance Al was used for the weight loss, and studies described by ASTM G1-03 was used [18]. The metal samples were prepared, degreased and cleaned. Analytical grade reagents were used for the study.

1.2. Preparation of Inhibitor

Raphia taedigera seeds were collected from the farmland in Ise-Ekiti, Nigeria and moved to the Chemistry laboratory, Federal Polytechnic, Ado-Ekiti. The seeds were washed, dried under the shield, crushed and ground into powder. The powdered seed was extracted by soaking 5 g of each sample in 50 ml of ethanol in a beaker for 48 hours with periodic agitation. The mixture was filtered and the filtrate concentrated under reduced pressure using a rotary evaporator to obtain dried inhibitor extracts. 2% w/v (10000 ppm) of the extract was prepared and used for the weight loss experiment.

1.3. Preparation of test solution

1.0 M concentration was prepared using double-distilled water and AR grade hydrochloric acid.

1.4. Weight Loss Experiment

The weight loss experiment was evaluated using Mettler Toledo balance ME204. Five 250 ml beakers were properly washed, dried and labelled A, B, C, D and E. 100 ml of 1.0 M HCl was transferred into beakers A, B, C, D and E. 0.5, 1.0, 1.5 and 2% w/v *R. taedigera seed* extract (RTE) was added to the beakers B, C, D, and E, respectively while beaker A was without inhibitor (W.I.). One pre-weighed aluminium 6063 alloy sample was immersed in each of the beakers using glass hooks and rods at room temperature. The test specimens were removed every 24 h, washed with deionised water, dried and reweighed, and the new weights recorded. The inhibitor efficiency (%) and corrosion rate (mm/yr) were calculated using equations 1 and 2, respectively. The corrosion rate in millimetre per year was calculated on the basis of the apparent surface area Abegunde et al., 2018.

$$Corrosion\ rate\ (mmyr) = \frac{Weight\ loss\ x\ K}{Density\ x\ Area\ x\ Time} = \frac{W\ x\ K}{\rho\ x\ A\ x\ T} \qquad 1$$

Where W is the weight loss in milligrams, ρ is the metal density in g/cm3, A is the area of the sample in cm2, T is the time of exposure of the metal sample in hours, and K is the constant = 87500.

$$IE\% = \frac{W-W1}{W}\ x\ 100 \qquad (2)$$

Where W and W_1 are the corrosion rates of steel coupons in the absence and presence of plants extracts, respectively

2. Material and methods

The surface morphology and functional groups of the test samples were determined before and after the corrosion test using scanning electron microscopy (SEM) and Fourier-transform infrared spectrophotometer (FTIR), respectively.

3. Results and discussion

3.1. Weight loss

The weight-loss method of corrosion measurement was adopted for the present work at room temperature due to its simplicity. Losses in masses of the test samples were closely monitored, and measurements were made every 24 hours for 18 days. The loss in mass is presented in Figure 1. From the plots, the weight loss in all the test samples increased with time. The weight loss was much rapid in the uninhibited solution compared to inhibited solution. Also, the weight loss was reduced with increasing inhibitor dosage. The present result shows the presence of the RTE as a green inhibitor plays a significant role as an anti-corrosion agent.

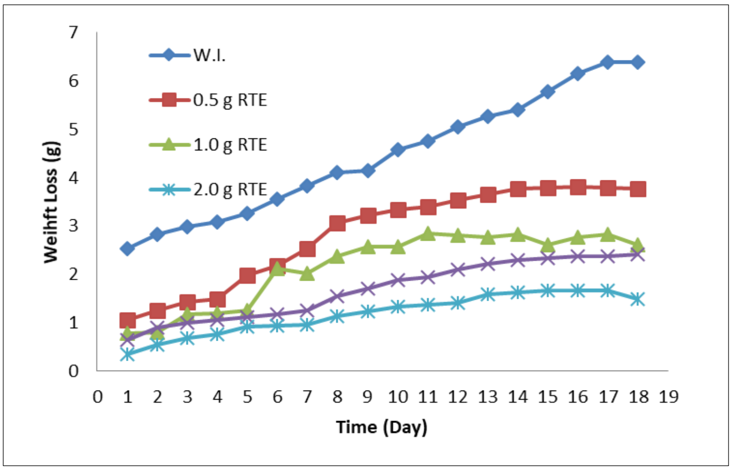

Figure 1 Weight loss with time in 1.0 M HCl for the different mass of RTE inhibitor

3.2. Corrosion Rate

The corrosion rate was monitored at room temperature using 1. 0 M HCl without and with different dosages of RTE inhibitor. The results of the corrosion rate for the inhibited and uninhibited were presented in Figure 2. From the plots, the presence of RTE inhibitor lowers the corrosion rate compared to the uninhibited solution. The reduction in the corrosion rate noticed with the inhibited solutions could be attributed to adsorption of the active secondary metabolites of the seed extract, forming thin inhibitor films on the metal surface, which could isolate the metal surface from the acidic medium, causing reduced corrosion rates with time. Also, corrosion rate was observed to further decreased with increasing RTE dosage, indicating that inhibitor dosage plays a vital role in the control of corrosion. The present result was in agreement with the result of previous work by Leelavathi and Rajalakshmi [19].

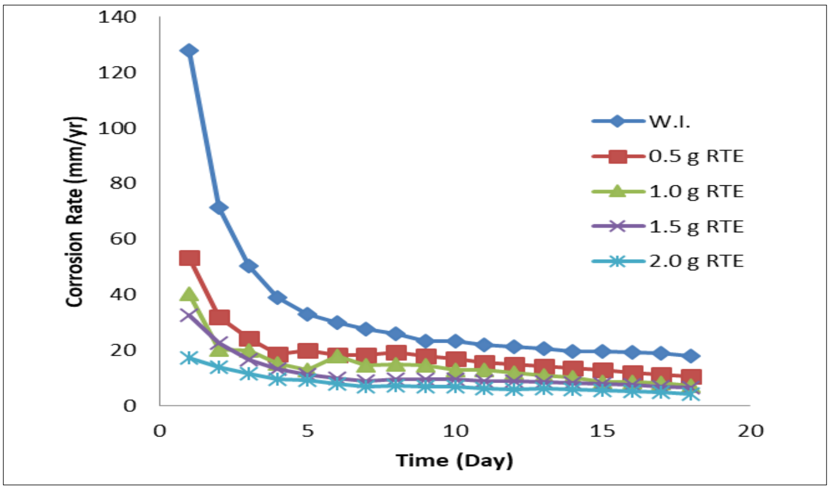

Figure 2 Corrosion rate at room temperature

3.3. Inhibitor Efficiency

The performance efficiency of RTE as a green inhibitor was also evaluated at room temperature with different dosages, and the result was presented in Figure 3. The highest efficiency of 86.4113% was observed for 2.0 g RTE in 1.0 M HCl from the plot. The average efficiencies increased with increasing inhibitor dosage. This indicates that the inhibitory action of the RTE is concentration-dependent.

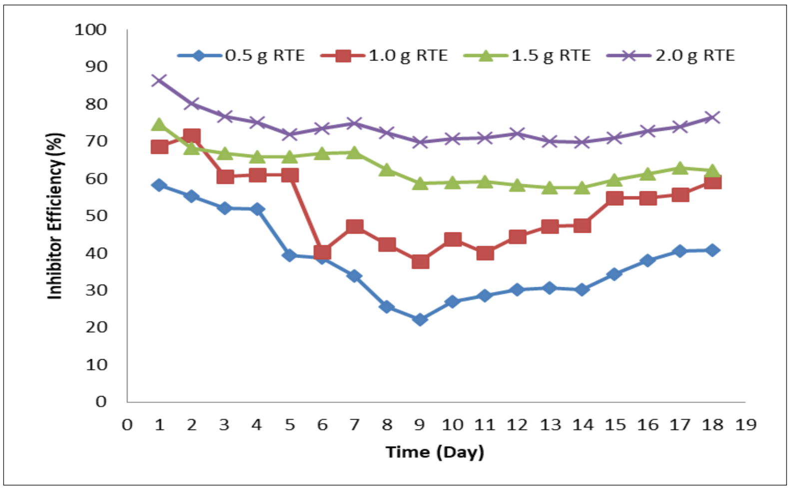

Figure 3 Inhibitor efficiency with time at room temperature

3.4. Sample Characterisation

3.4.1. SEM Analysis

The SEM images of the sample test, uninhibited (in 1.0 M HCl), and inhibited (in 1.0 M HCl) samples were taken to establish the interaction of the green inhibitor molecules with the aluminium surface. The SEM images of the test, uninhibited, and inhibited samples are presented in Figures 4, 5, and 6, respectively. The SEM images revealed that the metal surface immersed in the blank acid solutions is roughly covered with corrosion products, as shown in Figure 4. The metal immersed in inhibited solution (Figure 6) is in better condition with a smooth surface. The result indicates that the phytochemical constituents present in the RTE form a thin protective film on the specimen and thereby reduce the corrosion rate.

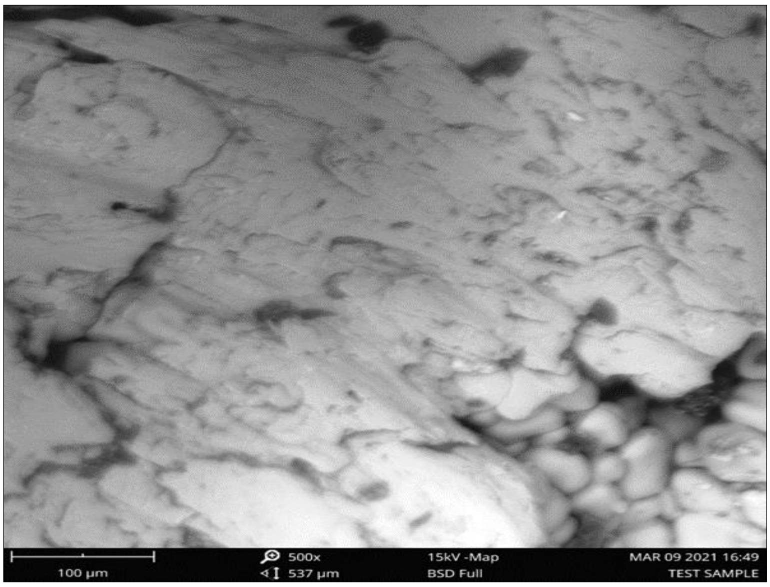

Figure 4 SEM image of a plain metal sample

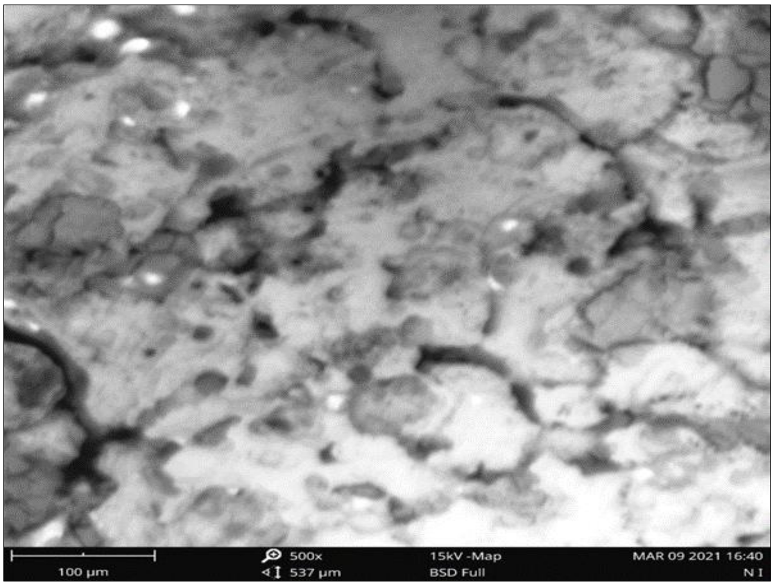

Figure 5 SEM image of the metal sample in uninhibited acid solution'

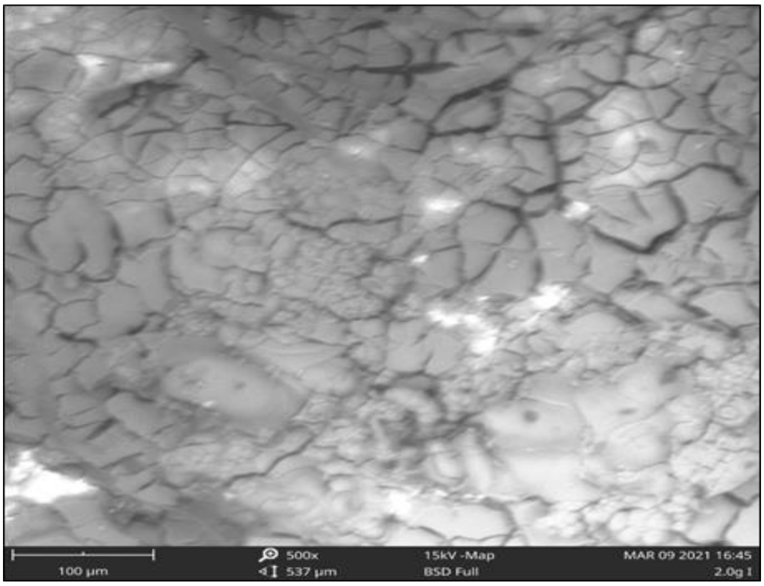

Figure 6 SEM image of metal sample inhibited with 2.0 g RTE acid solution

3.4.2. FT-IR Analysis

The IR spectral of crude *Raphia taedigera* seed extract and that of the corrosion product of metal sample with 2 % wt/v are represented in Figures 7 and 8, respectively. From the figures, it was observed that the band at 3749.7 corresponding to O-H stretch was shifted to 3788.2 cm^{-1}, another band at 3338.0 corresponding to stretching vibration of –OH was shifted to 3321.1 cm^{-1} and a band at 1845.0 corresponding to –C=O stretch was shifted to 1930.4 cm^{-1}. Also, the bands at 1517.0, 1319.5, 1006.4, and 805.1 cm^{-1}correspondings to C=C stretching vibration of aromatic, C=O stretching vibration of ester, C-O stretching and C-H bending vibration, respectively, in Figure 7 disappeared in Figure 8. The shift and the disappearance of bands indicate that there was an interaction between the inhibitor and metal surface through the adsorption of the inhibitor on the surface of the metal.

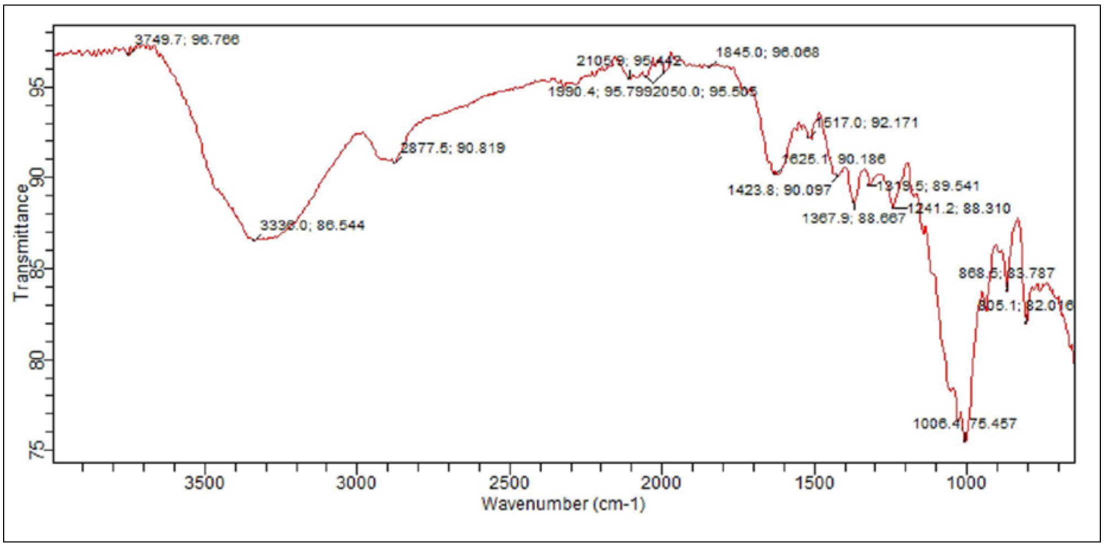

Figure 7 FT-IR Spectrum of crude extract of Raphiataedigera seed

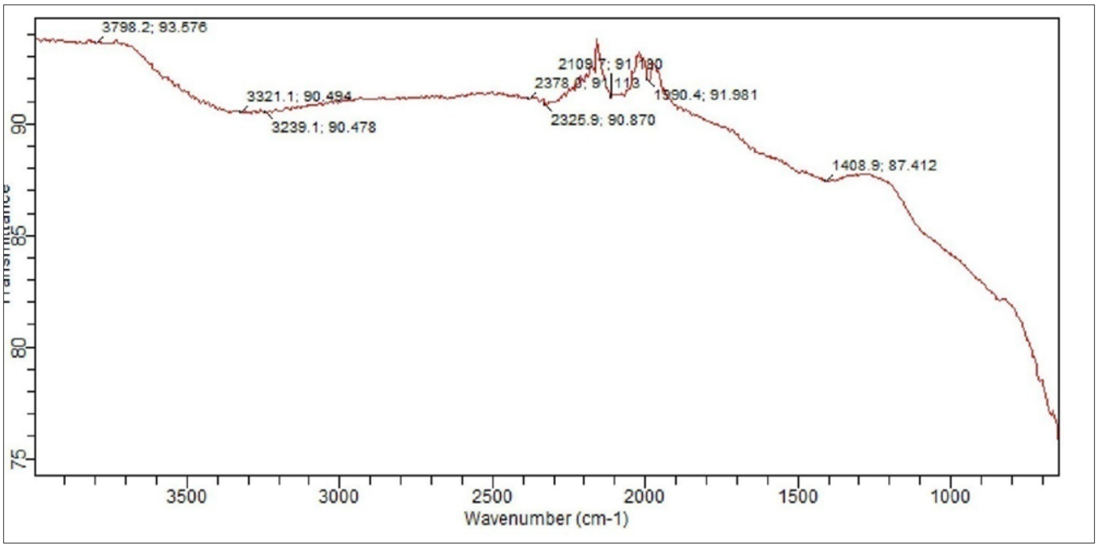

Figure 8 FTIR T-IR Spectrum of corrosion product with Raphiataedigera seed extract

4. Conclusion

The performance of *Raphia taedigera* seed extract as a corrosion inhibitor was evaluated using the weight loss technique. The results obtained from the present study showed that RTE is a good green inhibitor for A6063 in an acidic environment. The FTIR analysis clearly revealed that the phytochemical constituents are adsorbed on the surface of the metal. The SEM images showed that the surface of the metal was covered with adsorbed materials from plant extract that are responsible for corrosion inhibition. The present results predict that ethanolic extract of *Raphia taedigera* seed can be used as an eco-friendly corrosion inhibitor.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest to report regarding the present study

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