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CARICA PAPAYA SEED-EXTRACT AS ORGANIC INHIBITOR ON THE CORROSION OF ALUMINIUM AND MILD STEEL IN A SULPHURIC ACIDIC ENVIRONMENT

Oyebanjo A. Daniel and Ayotamuno Christopher
Mechanical Engineering Department, Covenant University. Ota, Nigeria
daniel.oyebanjo@stu.cu.edu.ng & christopher.ayotamuno@stu.cu.edu.ng

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Abstract: *Mild steel and aluminum are commonly used metals domestically and industrially given their desirable mechanical properties and low cost. However, their applications make them susceptible to the effects of corrosion leading to high maintenance cost and safety issues. The inhibition performance of Carica papaya seed extract (CPSE) as an organic inhibitor was investigated by evaluating the corrosion behavior of mild steel and aluminum in 0.2 M H_2SO_4 solution in varying concentrations of the inhibitor. Weight loss method was employed in evaluating the efficiency of the inhibitor. The results showed that CPSE is a good corrosion inhibitor for mild steel and aluminum in H_2SO_4..The corrosion rate was observed to decrease with an increase in concentration of the inhibitors. The result from the experiment showed that the Inhibitor performed better in the inhibition of mild steel, yielding an inhibition efficiency of 84.26% relative to that of aluminum, 71.89%. The result also demonstrated that showed CPSE can be used as a corrosion preventer as this will curtail the use of inorganic inhibitors that are harmful and toxic to the environment. Carica papaya seed extract was economically good as paw paw is readily available in this part of the world and its extract is cheap to produce.*

INTRODUCTION

Metals continue to play a significant role in the technological advancement of modern civilization, this is evident in their applications in building and construction, tools and automobile manufacturing, agriculture, healthcare, telecommunications, warfare, and energy generation and distribution. The various environmental conditions unto which a metal is subjected during its working life increases its susceptibility to corrosion; hence, prompting analysis on this phenomenon.

The prevalent effects of corrosion in sectors where metals are exploited for their unique characteristics is no trivial matter. The resultant damage to operating equipment lowers reliability, and leads to unsafe operating conditions and extended periods of downtime. Also, productive effort and resources spent initially to produce an equipment are laid to waste due to material loss. Furthermore, efforts made towards restoring a corroded equipment to its initial state are met with high cost (Revie, R. W., & Uhlig, H. H, 2008)

Corrosion naturally exists as the result of the electrochemical interactions between a metal or metallic member and its environment. The outcome of this, is a decline in the properties of

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the metallic material, leading to its destruction and inevitable failure. The nature of a material and the chemistry of the corrosive environment affect the rate of corrosion to a large degree. Although commonly, corrosion in several metals and metallic alloys comes by way of their limited exposure to moist air, aggressive corrosion will occur on exposure to concentrated substances like acids. Generally, iron and other similar metals corrode very easily, however, steels undergo a much slower corrosion rate.

A metal or metal alloy in use is often of a stable state, and the influence of corrosion can lead to a transition to a form in which it possesses a less stable state such as its sulphide, oxide or hydroxide forms that is otherwise, not economically viable. As a result of this, it can be inferred that corrosion is a largely irreversible process that causes a metal or its alloy to deteriorate.

The detrimental effects of corrosion are seen in environmental pollution and unsafe operating environments due to the rapid deterioration of an affected metal. Because of these and many more, we can say that it is in our best interest to manage and control this phenomenon due to its ubiquitous and unavoidable nature (Sowmya et al., 2007).

Corrosion of mild steel can be observed on its exposure to atmospheric air, or a neutral aqueous solution, or an acid environment. In these situations, corrosion attacks could be of galvanic, general, or pitting nature. Furthermore, because of its high iron content and negligible amounts of alloying elements such as chromium, molybdenum and a few others, Its unalloyed nature increases its susceptibility to corrosion attacks, particularly in acidic environments, which feature in industrial operations such as acid pickling or cleaning, descaling.

Aluminium is normally resistant to corrosion; this resistance lies in the passivity generated by a protective oxide film. However, these oxides responsible for its passivity become less stable outside the pH range of about 5 to 8.5 leading to pitting corrosion. Other important factors that affect the passive state include high temperatures and chloride content.Corrosion does not only attack metals but also polymers and ceramics but it is commonly known as degradation, one of the major factors why corrosion
is prevalent in metals is due to the choice of material or its material selection. Corrosion is a natural process through which a metal degrades as it reverts into its naturally occurring (or stable) state, the said state could be in the form of its oxides, sulfides, or hydroxides. Under environmental influence, for example, the atmosphere, seawater and organic or inorganic solutions, there is a gradual or rapid deterioration of the metal surface or its structure (Chigondo, M., & Chigondo, F. ,2016; Xhanari, K., & Finšgar, M, 2019; Omotosho et al, 2018; Vargel et al,2020)
Corrosion research has received much attention over the years, and the following are a few of the papers that address aspects of corrosion that are important to my research.

(Loto and Loto, 2016) studied the effect of allium cepa extract on the carrion of mild steel in 0.5 M Sulphuric acid. The experiment spanned twenty days, and the monitoring techniques employed were weight loss analysis and potentio-static polarization test. Data was collected and analyzed via a potentiostat-computer interface. It was discovered that increasing the inhibitor concentration increased inhibitor performance, with the best performances recorded at lower exposure periods and the highest being 80%.

(Igheghe et al, 2021) investigated the corrosion inhibition effect of avocado oil on mild steel in

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1 M Sulphuric acid for a period of twenty-one days. The technique employed was weight loss measurement. Data plots were obtained using the Langmuir adsorption isotherm modeling analyses. The authors reported that the highest inhibitor efficiency was recorded at 5% avocado oil concentration.
(Okeniyi et al, 2018) in their study, analyzed the gravimetric and electrochemical effects of Mebendazole on the corrosion of mild steel in 0.5 M in Sulphuric acid. The weight-loss method and potentiodynamic polarization experiments were carried out on the metal specimens. The results revealed that inhibition efficiencies of mebendazole reached values greater than 90% for mild steel in HCl
(Sanni et al, 2019) studied the corrosion inhibition effectiveness of bitter leaf and fenugreek seed oils on the corrosion of mild steel in Sulphuric acid solution. The experiment lasted for seventy-two hours. Weight loss and potentio-dynamic polarization techniques were employed in monitoring the corrosion of the metal specimens. (Sanni et al., 2019) the bitter oil extract (BLE) attained an inhibitor efficiency of 87%, while the fenugreek seed oil extract (FLE) gave an efficiency of 90%. In addition, the BLE and FLE inhibition mechanisms were described as that of a mixed-type inhibitor. Further investigation based on a phytochemical test revealed that the FLE might have had a better performance relative to BLE due to the presence of terpenoids.
(Fayomi et al. 2018) investigated the inhibitive performance of 3-(2'- chloro-6' fluorophenyl) on aluminium in a simulated sodium chloride medium for twenty-one days. The weight-loss method was employed in monitoring the corrosion rate (Fayomi et al., 2018). The authors discovered that weight loss declined in the corrosive environments containing 3-(2'-chloro-6' fluorophenyl) with the highest efficiency recorded at 10% of inhibitor concentration. The corrosion of aluminium is dependent on chloride and the inhibitor concentration
As can be seen from the literature review above, different approaches are being followed in order to combat metal corrosion. Using eco-friendly or organic materials to avoid harm to the environment without losing the efficacy of inorganic inhibitors is one of these approaches. The aim of this project is to compare the efficiency of Carica Papaya Seed extract (CPSE) on aluminium and mild steel in the dilute acidic medium, H_2SO_4.

MATERIALS AND METHODS

The mild steel and aluminium samples used for this study were supplied by the metal and fabrication unit of the Mechanical Engineering Department, Covenant University, Ota, Ogun State, Nigeria and their chemical composition was obtained as shown in the tables below:
The composition of mild steel is shown in the table below, it shows the element and content in percentage, mild steel element includes carbon, silicon, manganese, phosphorus, nickel, molybdenum, chromium,sulphur,tungsten, copper and iron which forms mild steel.

Table 1: Chemical Composition of Mild Steel

Element	%Content
C	0.090
Si	0.044
Mn	0.486
P	0.012
NI	0.052
MO	0.017
Cr	0.042
Cu	0.149
S	0.021
W	0.007
Fe	99.04

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Composition of aluminium is shown on the table below, it shows the element and content in percentage, Aluminium element includes fluorine, aluminium, zinc, silicon,lead manganese,magnesium, molybdenum, tin, and silicon, which composes or forms the aluminium metallic sample.

Table 2: Chemical Composition of Aluminium

Element	%Content
F	0.037
Si	0.084
Mn	<0.008
Cu	0.093
Zn	0.024
Ti	0.007
Mg	<0.008
Pb	0.012
Sn	0.007
Al	99.36

Alloy: NI -<0.008, Cr -< 0.008, V- < 0.008
Remarks: Be - <0.000, Sr – <0.000, Zr-0.008, Ca - < 0.001
Source: (Aluminium rolling mills, Ota, Ogun State)

Mild steel and Aluminium metal samples were cut into equal rectangular dimensions of 1cm by 1.5cm each summing a total of 12 samples, 6 samples of aluminium and 6 samples of mild steel. The experiment was performed using a sulphuric acidic environment, consisting of 6 bottles each for both metals filled with 200ml amount of the acid-water mixture giving a sum total of 12 bottles. The Inhibitor concentration was specifically added to the acidic environments with varying concentrations of 0 (control), 2ml, 4ml, 6ml, 8ml and 10ml for the inhibitor.

Preparation of Carica Papaya Seed Extract

The chemical substances used in this study were:

i. Carica papaya seed extract (CPSE) as the inhibitor: Pawpaw, which was purchased from a fruit vendor in Ota, was cut and then the seeds were removed and air dried for four days to remove all moisture content. After this period, an extraction process and chemical composition test were carried out in a laboratory.
ii. Acid environment: The environment used in this study was H_2SO_4, which was prepared for the experiment. The media was prepared using the following equation:

$$V_0 = \frac{MVC_0}{10Pd}$$

where:
V_0 = Required volume of acid in litres,
M = Molecular weight of acid in $gmol^{-1}$,
d = Density or specific gravity in gcm^{-3},
P = Trademark purity in %,
V = Volume of solution in litres,
C_0 = Molar concentration in mol

Table 3: Acid Properties

	Sulphuric Acid
Density	1.83 g/cm^3
Molar mass	98.079 g/mol
Molarity used	0.2 M

Weight Loss Method

Abraded samples of mild steel and aluminium were subjected to three different emery sheets in order to determine how much galvanic action exists in the materials and whether it has an impact on the results. For the gravimetric testing, the samples were cleaned, degreased, and dried before being used for the testing. Once they had been weighed, the samples were submerged in cut bottles containing different volumes of H_2SO_4: 190ml, 192ml, 194ml, 196ml, 198ml, and 200ml, respectively.. Measurements of 10ml, 8ml, 6ml, 4ml and 2ml

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respectively of the inhibitor were added to the solution of H_2SO_4. This analysis was carried out for a time duration of 504 hours (21 days). When this procedure was followed, every 24 hours, the samples were picked up, dipped in water and acetone, dried, and weighed appropriately. A discrepancy exists between the weight of the sample before and after the test.

Weight loss is calculated by W= initial weight – final weight.

The **Corrosion Rate** for the experiment was calculated from the weight loss

Corrosion Rate = (87.6 * W/DAT) mm/yr

Where;

W= weight loss in grams

D = density of metal (g/cm^3)

A = surface area of metal (cm^2)

T = exposure time (hrs)

The inhibition efficiency is also calculated from the weight loss experiment

I.E = {(W1-W2)/W1} * 100

Where;

W1 = the weight loss of the control sample

W2 = the weight loss of other metallic samples

Surface coverage is calculated as;

Surface coverage = (1-W2/W1)

OR surface coverage = I.E/100.

RESULTS AND DISCUSSION

Aluminium

Table 4: Results of Aluminum in H_2SO_4 with Carica Papaya as Seed Extract.

Sample	Inhibitor Concentration (%g/L)	Weight Loss (g)	Corrosion Rate	Surface Coverage	Inhibitor Efficiency (%)
A	0	0.1265	0.014066	0.0000	0.000
B	1	0.0614	0.003953	0.7189	71.890
C	2	0.0934	0.006013	0.5725	57.250
D	3	0.0891	0.005736	0.5922	59.220
E	4	0.0834	0.005369	0.6183	61.830
F	5	0.0730	0.004699	0.6659	66.590

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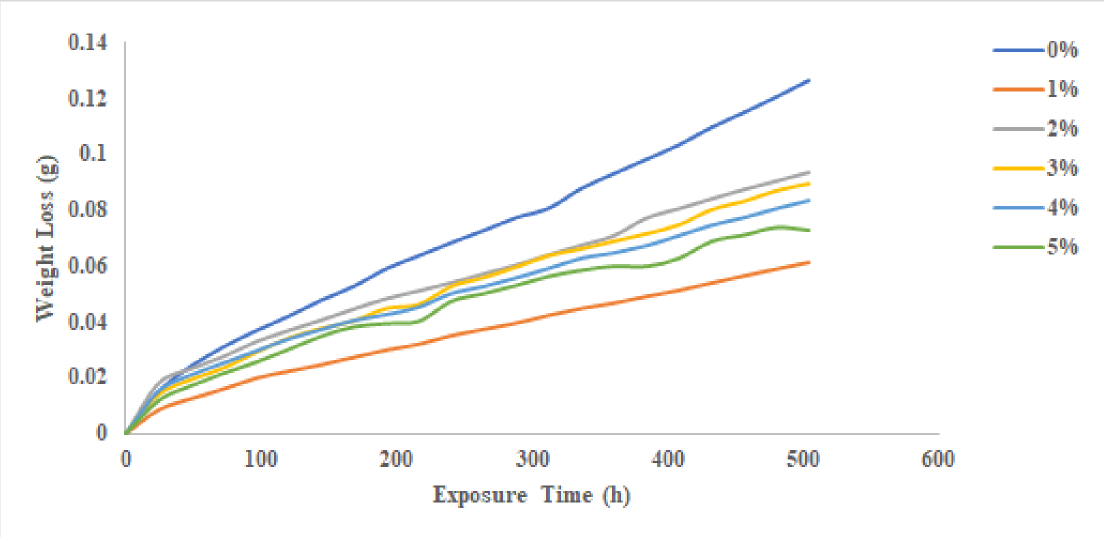

Figure 1: Weight loss of Aluminium in H_2SO_4 with Carica Papaya as Seed Extract

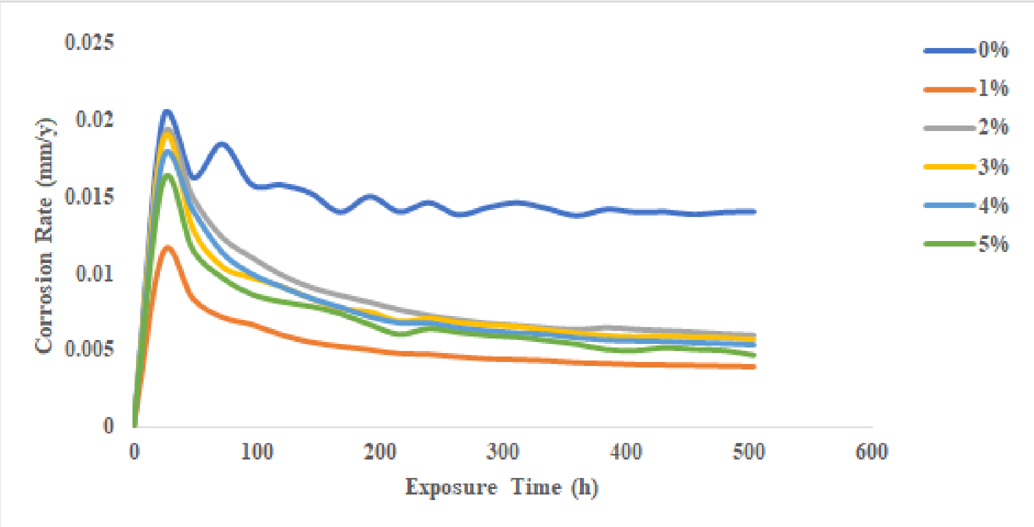

Figure 2: Corrosion Rate of Aluminium in H_2SO_4 with Carica Papaya asSeed Extract

Figure 2 illustrates the rate of corrosion of aluminum samples in sulphuric acid over a period of 504 hours with the highest corrosion rate recorded to be 0.014066 mm/y at control (zero percent inhibitor concentration). The effect of the acid environment on the corrosion rate of aluminum was severe due to the presence of $(SO_4)^{2-}$ ions. On the other hand, Table 4 shows that samples E and F, despite having increased inhibitor concentrations, i.e., four percent and five percent, exhibited somewhat high corrosion rates of 0.005369 mm/y and 0.004699 mm/y respectively in comparison with sample B with the lowest corrosion rate at 0.003953 mm/y at one percent inhibitor concentration. This may have occurred due to the slow formation of the adsorption film on the surface of the metal samples C, D, E and F. From the experiment, sample B showed a better resistance to corrosion and a better inhibition efficiency.

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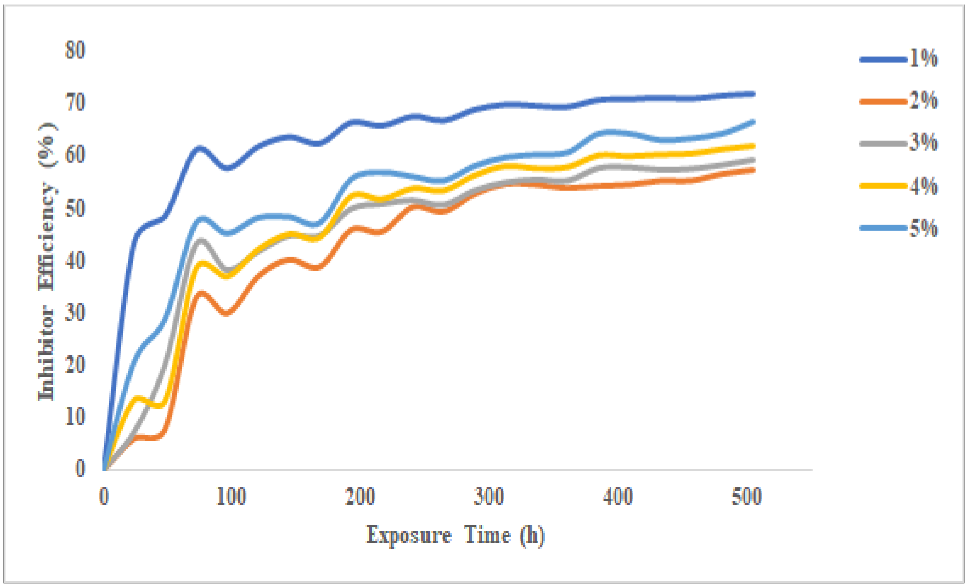

Figure 3: Inhibitor efficiency of Aluminium in H_2SO_4 with Carica Papaya as Seed Extract

The values for inhibition efficiency (I.E.) were calculated from the weight loss values and data in Table 4 was obtained, the graph for Inhibitor efficiency against exposure time is provided in Figure 3. At one percent inhibitor concentration, the inhibitor efficiency with respect to time of exposure was higher than the other inhibitor concentrations with an efficiency of 71.89% and a surface coverage value of 0.7189 at 504 hours. At 2%, 3%, 4% and 5% inhibitor concentrations, the values of inhibitor efficiency were 57.25%, 59.22%, 61.83% and 66.59% respectively with corresponding surface coverage values of 0.5725, 0.5922, 0.6183 and 0.6659. Sample F also had a high inhibitor efficiency at 504 hours. From the experiments, sample B had better inhibition efficiency and surface coverage values compared with the other samples.

Mild Steel

Table 5: Results of Mild Steel in H_2SO_4 with Carica Papaya as Seed Extract

Sample	Inhibitor Concentration (%g/L)	Weight Loss (g)	Corrosion Rate	Surface Coverage	Inhibitor Efficiency (%)
A	0	1.3091	0.028985	0.0000	0.000
B	1	0.3672	0.008130	0.7195	71.950
C	2	0.7355	0.016285	0.4382	43.820
D	3	0.2060	0.004561	0.8426	84.260
E	4	0.2177	0.004820	0.8337	83.370
F	5	0.2165	0.004794	0.8346	83.460

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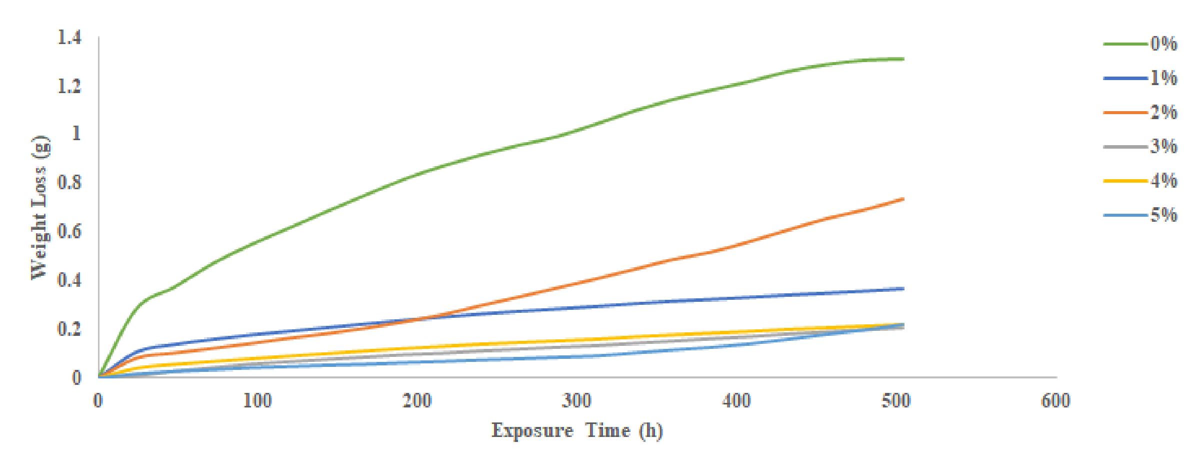

Figure 4: Weight Loss of Mild Steel in H_2SO_4 with Carica Papaya as Seed Extract

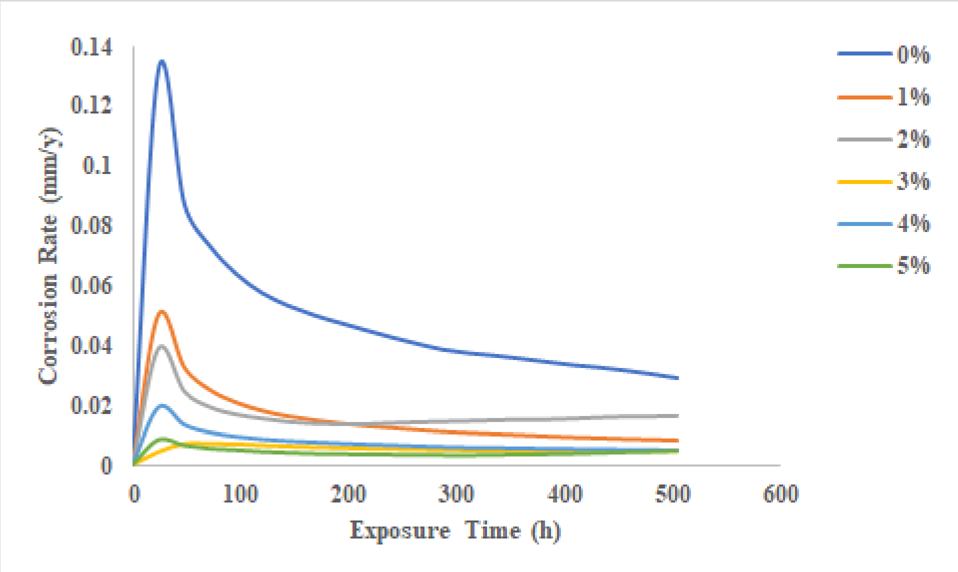

Figure 5: Corrosion Rate of Mild Steel in H_2SO_4 with Carica Papaya as Seed Extract

Figure 5 illustrates the rate of corrosion of mild steel samples in sulphuric acid over a period of 504 hours with the highest corrosion rate recorded to be 0.0290 mm/y at control (zero percent inhibitor concentration). The effect of the acid environment on the corrosion rate of aluminum was severe due to the presence $(SO_4)^{2-}$ ions. On the other hand, Table 5 shows that the samples E and F having increased inhibitor concentrations, i.e., four percent and five percent, exhibited low corrosion rates of 0.00480 mm/y and 0.00479 mm/y respectively in comparison with sample D with the lowest corrosion rate at 0.00460 mm/y at three percent inhibitor concentration. This may have occurred due to a relatively slow formation of the adsorption film on the surface of the metal samples E and F. From the experiment, sample D showed a better resistance to corrosion and a better inhibition efficiency

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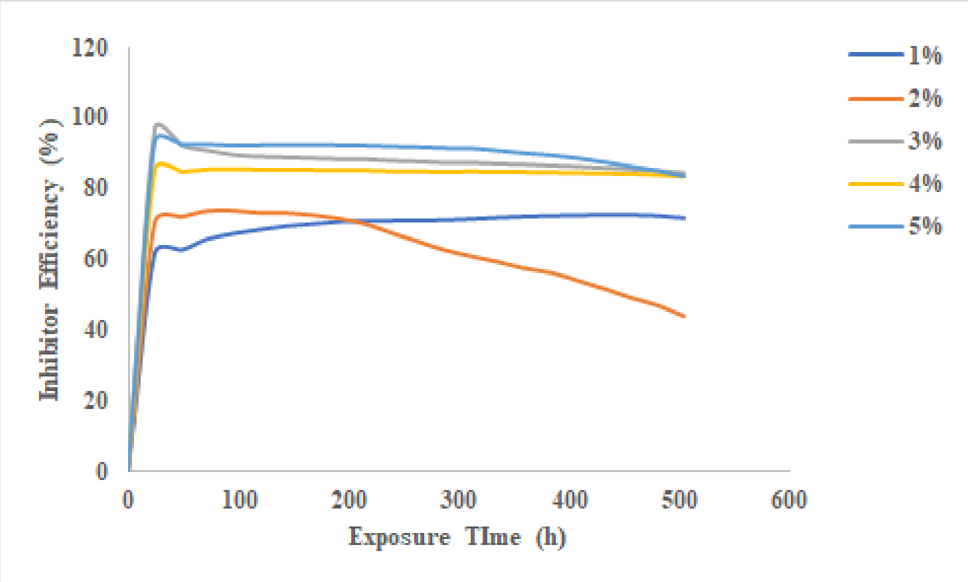

Figure 6: Inhibition Efficiency of Mild Steel in H_2SO_4 Carica Papaya as Seed Extract

The values for inhibition efficiency were calculated from the weight loss values and data in Table 5 was obtained, the graph for Inhibitor efficiency against exposure time is provided in Figure 6. At three percent inhibitor concentration, the inhibitor efficiency with respect to time of exposure was higher than the other inhibitor concentrations with an efficiency of 84.26% and a surface coverage value of 0.8426 at 504 hours. At 1%, 2%, 4% and 5% inhibitor concentrations, the values of inhibitor efficiency were 71.95%, 43.82%, 83.37% and 83.46% respectively with corresponding surface coverage values of 0.7195, 0.4382, 0.8337 and 0.8346. Sample F also had a high inhibitor efficiency at 504 hours. From the experiments, sample B had better inhibition efficiency and surface coverage values compared with the other samples.

CONCLUSION

The use of Carica Papaya Seed extract (CPSE) gave a notably good result on the corrosion inhibition of mild steel and aluminium in a Sulphuric acid environment. From the experiment, it was discovered that the inhibitor is more efficient on mild steel giving an inhibitor efficiency of 84.26% while on aluminium giving an inhibitor efficiency of 71.89%. In conclusion, the organic inhibitor was a better corrosion inhibitor on mild steel than on aluminium in the acidic environment. This research comes timely as the world goes green and all efforts are on deck to reduce toxic substances penetrating the atmosphere. However little research has been done on aluminium using green/organic inhibitors, hence a gap which needs to be bridged.

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COMPETING INTERESTS

Authors hereby declare that no competing interests exists.

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