

Corrosion Inhibition Studies of Mild Steel in Acid Medium using Azanza Garckeana (Goron Tula) as Green Corrosion Inhibitor

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ABSTRACT

The inhibitive effect of Plant extracts has become vital as an eco-friendly and renewable resource for a wide range of corrosion inhibition applications. Corrosion control of metals and their alloys is significant and environmentally imperative. Extracts of plant material serve as the superior alternative to replace the ecologically hazardous organic and inorganic corrosion inhibitors. The mass loss method has studied the corrosion inhibition of mild steel in 1M HCl by Azanza garckeana extract. Usually, weight loss methods are adopted to measure the corrosion inhibition efficiencies. The results showed that the weight loss varies inversely with concentration and directly with time while the inhibition efficiency increases with an increase in concentration of azanza garckeana extract, this means that azanza garckeana is an absorption inhibitor for the corrosion of mild steel in a solution of HCl. The least inhibition efficiencies of 40.00% and 47.37% were recorded by the sample with 3g/l and 2g/l concentrations of extract respectively on their first day and the best inhibition of (91.14%, and 94.12%) was recorded by the sample with 4g/l and 5g/l concentrations on their sixth days respectively. These findings strongly suggest that azanza garckeana can be used as an inhibitor for preventing the corrosion of mild steel.

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INTRODUCTION

Desalination plants, construction materials, pharmaceutical industry, and thermal power plant, uses steel due to their stability, high strength, workability and weld ability. Hydrochloric acid solutions are widely used in several industrial processes, this have cause failures and loss of materials due to corrosion process, some of the important fields of application being acid pickling of steel, chemical cleaning and processing, ore production and oil well acidification. Because of the general aggression of acid solutions, inhibitors are commonly used to reduce the corrosive attack on metallic materials, Mahgoub *et al* (2019). The inhibitors are adsorbed and depend on the structure and surface of metal atom. Among the methods of corrosion control, use of inhibitors is very popular because they are easily accessible, less expensive, ease of application

and biodegradable (Eddy *et al.* 2010). Plant extracts are organic and contain phytochemical compounds (Kristianto *et al.* 2019). Organic inhibitors are those containing hetero-atoms such as N, O, S and P in their structures, which allows easy adsorption onto the surface of the metal. They are adsorbed directly onto the metals surface through polar atoms and thereby forming the protective layer. Plant extracts have become important due to environmentally acceptable, non-toxic, readily available and are also renewable.

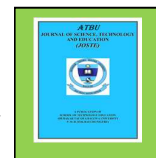
Most of the corrosion inhibitors are synthetic chemicals which are expensive and very hazardous to environments. Due to the toxicity of some corrosion inhibitors, there has been increasing search for green corrosion inhibitors Sehaibani, (2000) in A. Mathina, (2016). In this research we intend to investigate the inhibitive effect of acid extract of Azanza

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garckeana ("Goron Tula") for the corrosion of mild steel using the weight loss, method.

Azanza garckeana known as "Goron Tula" (Tula Kola nut) in Gombe State and Morojwa in Botswana is a valuable edible indigenous fruit widely distributed in Tula, Kaltungo Local Government Area of Gombe State and in Michika in Adamawa State. It is an indigenous fruit tree species that is semi-domesticated by the people of Tula.

Literature shows the use of plants as green corrosion inhibitors. Plant leaves, such as *Ananas comosus* leaves and olive leaves are used to protect the metals, Fatma, (2019).

Naturally occurring substances, especially plant extracts as inhibitors for corrosion of materials, have received attention worldwide as a replacement for synthetic ones, which have several detrimental effects on the environment and human beings (Ebenso et al. 2008).

Behpour et al. (2011) carried out a comparative study of two oleo-gum resins exudate from *Ferula assa-foetida* and *Dorema ammoniacum*, as inhibitors for mild steel corrosion in 2M HCl solution using weight loss measurements, potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) methods. Potentiodynamic polarization curves indicated that both oleo-gums behave as mixed type inhibitors.

Organic inhibitors are those containing hetero-atoms in their structures, which allows easy adsorption onto the surface of the metal. Sulphur, phosphorus, nitrogen and oxygen are heteroatoms present in their structures which act as adsorption centres (Ebenso et al. 2010).

The fruit of *Azanza garckeana* extract has not been explored to combat the corrosion of mild steel in acidic environments.

MATERIALS AND METHODS

Materials

Sheets of mild steel were obtained from building materials shop in Jimeta, Yola Adamawa State. The sheets were mechanically cut into different coupons of average dimensions $1.8\text{ cm} \times 3.8\text{ cm} \times 0.2\text{ cm}$. The coupons were pickled for 10 minutes in undiluted tetraoxosulphate (IV) acid this

provides a proper exposure of the of the main coupon bodies for direct corrosion attack. The coupons were then removed and washed in double distilled water, degreased with ethanol, dried and stored in a desiccator, after taking their initial weight using electronic balance of accuracy 0.01g.

Preparation of the extract

The fruit of *Azanza garckeana* was collected in Tula town, Kaltungo local government area, Gombe State, Nigeria. The fruits were air dried and subsequently crushed into powder. 50g of the powder were soaked in distilled water (100ml) for 24 hrs, it was filtered with Whatman grade 1 paper.

Experimentation

Gravimetric method

The previously weight coupons in duplicate were tied to string and suspended in an open beaker containing 100ml of 1M HCl acid without the extract and with the extract of different concentration, 1g, 2g, 3g, 4g and 5g at the immersion time of 24, 48, 72, 96 and 144 hours at room temperature. After every 24 h, the coupons were removed and washed with water and weight using electronic balance of accuracy 0.001g.

The experiment was repeated and in each case, the difference in weight for a period of 144 hours was taken as the total weight loss. From the average weight loss (mean of three replicate analysis) results, the inhibition efficiency (% IE) of the inhibitor, the degree of surface coverage (θ) and the corrosion rate of mild steel (CR) will be calculated using Equations 1, 2 and 3 respectively (Eddy, 2010):

$$\begin{aligned} \text{Inhibition Efficiency (\% IE)} \\ &= \left(1 - \frac{CR_{blank}}{CR_{inh}}\right) \\ &\times 100\% \end{aligned} \quad 1$$

$$\begin{aligned} \theta \\ &= 1 - \frac{W_1}{W_2} \end{aligned} \quad 2$$

$$\begin{aligned} CR \\ &= \frac{534W}{DAT} \end{aligned} \quad 3$$

Where CR_{blank} W_1 and W_2 are the weight losses (g) for mild steel in the

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presence and absence of the inhibitor, θ is the degree of surface coverage of the inhibitor, $\Delta W = W_1 = W_2$, A is the area of the mild steel coupon (in cm^2), t is the period of immersion (in hours) and ΔW is the weight loss of mild steel after time, t.

The total surface area, A, of the rectangular steel coupons used in this investigation was calculated using the relation $A = 2(LB + BT + LT)$ Ovri, et al (2013) in Nwigwe, et al., (2023)

Where L = 3.8 cm, B = 1.8 cm and T = 0.2cm
 Therefore A = 15.92

RESULTS AND DISCUSSION

Gravimetric Measurement

The corrosion rate – time graph for the control experiment for mild steel was compared to the inhibited experiment experiments in fig1.

The weight loss were used to observe the extend of corrosion of mild steel for a period of six days (144 hours) in 1M HCl solution at room temperature due to addition of various concentration (1g, 2g, 3g, 4g, and 5g) of *azanza garckeana* extract. Table 1 and figure 1 shows that the mild steel experienced varying amount

of weight loss in the acidic medium of various concentrations they were subjected to. From figure 1, it can be seen that the weight loss varies inversely with concentration and directly with time, this mean that *azanza garckeana* is an absorption inhibitor for the corrosion of mild steel in solution of HCl Abdallah et al., (2003) in Paul et al (2012). The metal surface on interaction with the corrosion medium normally reacts swiftly with the medium forming an oxide that coats the entire surface and acts as a barrier, thereby preventing further reactions. The presence of uniform corrosion attack dominated in each coupon's surface though the blank sample suffered minor pitting corrosion which is due to the lack of inhibitor with appreciable uniform corrosion. The uniform attack was fairly and evenly distributed over the surface area of the coupons, which resulted to an almost even reduction in thickness. Usually, homogeneous materials which shows little or no reasonable likelihood for passivation in their current environment are pruned to suffer this kind of corrosion attack Nwigwe, et al (2023). The blank (0g/l) specimens suffered the highest weight loss which is responsible for the highest corrosion rate it also recorded.

Table 1: weight loss values of mild steel in 1M HCl in the absence and presence of the *azanza garckeana* extract of different concentration

TIME(HRS)	Blank	Weight loss values of different Concentrations					θ	$\frac{\theta}{1-\theta}$
		W_1	W_2	W_3	W_4	W_5		
24	0.52	0.35	0.23	0.18	0.14	0.04	0.3217	0.47
48	0.64	0.38	0.25	0.20	0.14	0.04	0.4025	0.67
72	0.90	0.51	0.30	0.27	0.20	0.05	0.4321	0.76
96	0.88	0.46	0.34	0.23	0.11	0.03	0.4749	0.90
144	0.74	0.35	0.18	0.09	0.07	0.02	0.5283	1.12

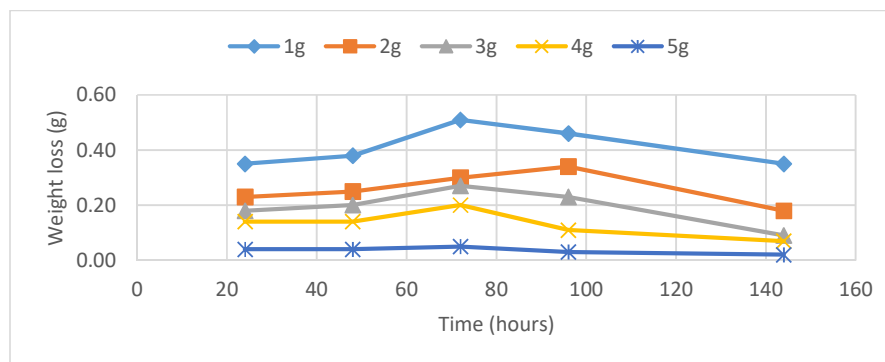


Fig. 1: Mild steel weight loss against time/concentration

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Corrosion Rate

Table 2: Corrosion rate of mild steel in the absence (blank) and presence of inhibitor

TIME(HRS)	CR _{blank}	CR _{inh 1g}	CR _{inh 2g}	CR _{inh 3g}	CR _{inh 4g}	CR _{inh 5g}
24	0.078	0.062	0.014	0.032	0.025	0.039
48	0.047	0.034	0.007	0.018	0.012	0.024
72	0.050	0.030	0.013	0.016	0.012	0.023
96	0.073	0.020	0.060	0.010	0.005	0.012
144	0.031	0.010	0.016	0.003	0.002	0.010

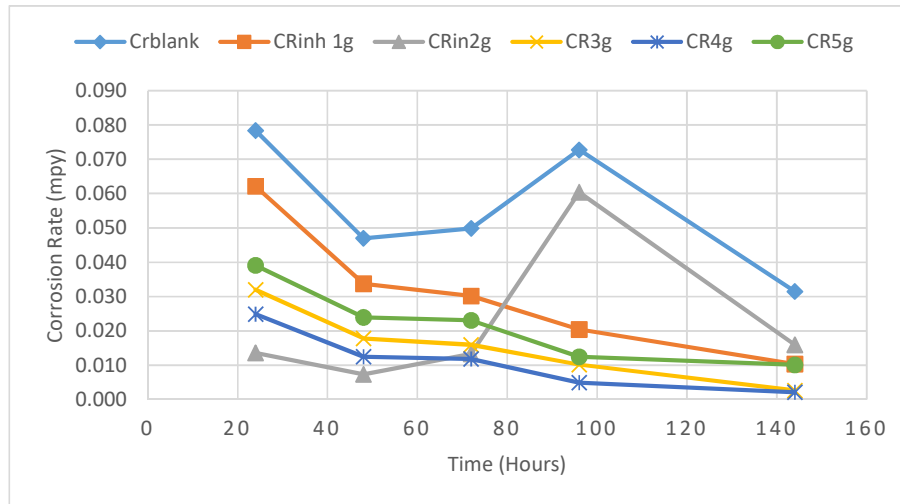


Figure 2: Corrosion rate plots of mild steel in 1M HCl in the presence of *azanza garckeana* for five concentrations

From Figures 2 it can be seen that there is an initial steep rise in corrosion rate, then peaking at a maximum and subsequently decreasing as exposure time increased. This means that the corrosion rates obtained were

typical of those of passivating metals. The rate of corrosion of mild steel also decreased with increase in volumetric values of the extracts and the highest corrosion recorded was without inhibitor.

Table 3a: Corrosion inhibition efficiencies vs time of mild steel in the presence of inhibitor

TIME(HRS)	IE%	IE%	IE%	IE%	IE%
24	56.79	58.93	64.00	71.43	81.82
48	61.62	68.75	60.78	77.05	85.19
72	57.50	72.73	66.67	79.80	87.18
96	66.67	73.23	72.29	82.26	89.29
144	73.88	77.50	79.55	91.14	94.12

Table 3b: Corrosion inhibition efficiencies vs concentration of mild steel in presence of inhibitor

Conc.	IE%	IE%	IE%	IE%	IE%
1g	56.79	70.54	60.47	66.67	73.88
2g	47.37	59.09	61.80	66.18	77.48
3g	40.00	51.22	66.67	72.29	79.55
4g	71.43	77.05	79.80	82.26	91.14
5g	81.82	85.19	87.18	89.29	94.12

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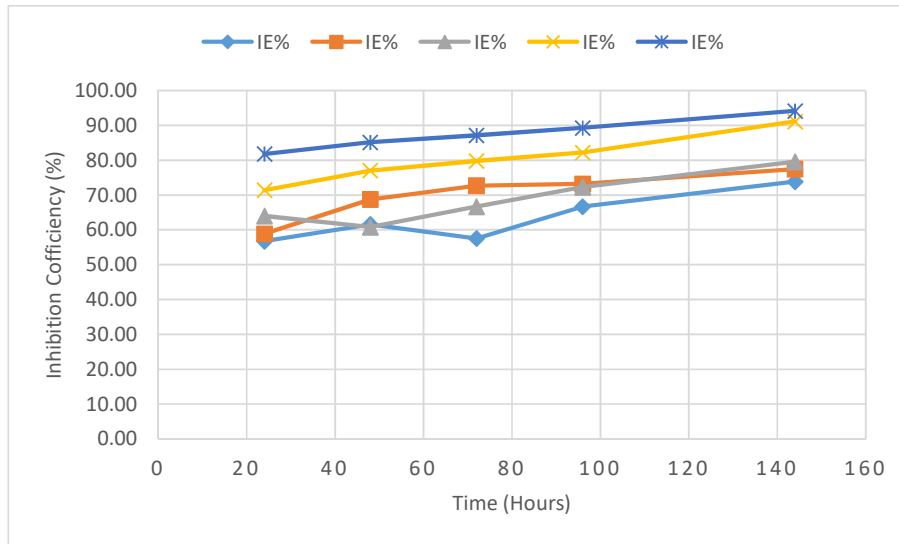


Figure 3a: Inhibition efficiency (IE%) verse Time plots of mild steel in 1M HCl in the

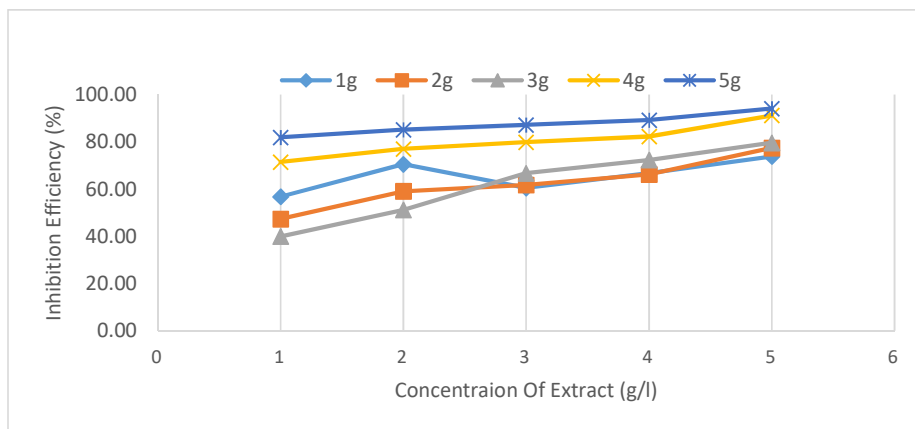


Figure 3b: Inhibition efficiency (IE %) verse Concentration plots of mild steel in 1M HCl

In general, inhibition efficiency was observed to be decreasing with increase in exposure time. The least inhibition efficiencies of 40.00% and 47.37% were recorded by 3g/l and 2g/l concentrations of extract respectively on their first day. Similarly, Samples in 4g/l and 5g/l concentrations indicated the best inhibition efficiencies (91.14%, and 94.12%) on their sixth days respectively. In general, inhibition efficiency was observed to be decreasing with increase in exposure time.

Increase in inhibition efficiency with increase in extract concentration is an indication of an increase in the number of components of

the extract adsorbed over the mild steel surface blocking the active sites, in which direct acid attacks proceed and protect the metal from corrosion. Mathina, (2016)

Effect of concentration

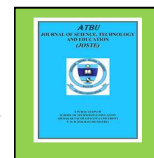
Values of corrosion rate and inhibition efficiencies are given in Table 2 and figure 2 respectively. It is clear from the table that corrosion rate decreases with the increase in concentration of *azanza garckeana* extract while the inhibition efficiency increases with an increase in concentration of *azanza garckeana* extract. This indicates that more inhibitor

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molecules are adsorbed on mild steel surface at high concentration, leading to the formation of protective film, Rao et al, (2009). That is inhibition efficiency increases with an increase in concentration.

Effect of immersion time

The results obtained for the variation of inhibition efficiency with different exposure time for mild steel specimens immersed in 1M HCl with and without the various concentrations of *Azanza garckeana* extract are presented in Table 3a. The inhibition efficiency was found to increase with time suggesting the formation of persistent film on the metal surface. Maximum inhibition efficiency of 94.12% was obtained at 144hrs of immersion period. The variation of inhibition efficiency with immersion time is shown in Figure 3b.

CONCLUSION

Research results show that Azanza garckeana extract serves as a highly effective corrosion inhibitor for mild steel in 1M HCl, with efficiency augmenting in line with increasing inhibitor concentration, making it an attractive eco-friendly and effective green corrosion inhibitor for acidic applications.

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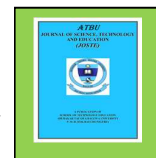
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