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A Study on Corrosion Inhibitor of Mild-Steel in Hydrochloric Acid Using Cashew Waste

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ABSTRACT: *Corrosion is an everyday challenge in all sectors of the economy particularly the manufacturing industry and this has led to massive economic loss. The aim of this research is to produce an eco-friendly inhibitor from cashew waste fruit. Cashew waste fruits collected were cleaned, washed, dried and pulverized. Mild carbon steel with thickness 0.1 cm was used and coupons of dimensions 4 x 5 x 0.1 cm. The cashew waste extract produced was used as a corrosion inhibitor on mild carbon steel in 0.1M hydrochloric acid. It was observed that as the concentration of inhibitor increases, the inhibitor efficiency also increases. The optimum inhibition efficiency observed in hydrochloric acid was 80.5%. After 336 hours of test, it was concluded that cashew waste is an efficient corrosion inhibitor as this will reduced the importation cost, increase the gross domestic product (GDP) of the nation and make the environment free of toxic chemical inhibitor.*

Keywords: *Corrosion, Inhibitor, Mild Carbon steel, Cashew, Hydrochloric acid.*

I. INTRODUCTION

Corrosion is the gradual deterioration of a material by electrochemical reaction due to its interaction with its environment. It has been an everyday challenge in all sectors of the economy particularly the manufacturing industry (El-Etre, 2006). Carbon steel is one of the most important alloys being used in a wide range of industrial applications. Corrosion problems arise as a result of the interactions between aqueous solution and carbon steel, especially during the pickling process where alloy is brought in contact with the highly concentrated acids (Xiang-Hong et al. 2010). There are several ways of tackling the issue of corrosion in the industry and one of such ways is the use of inhibitors which is eco-friendly.

Inhibitors protect metals by effectively adsorbing its surface and blocking the actives sites for metal dissolution and/ hydrogen evolution, hereby hindering overall metal corrosion in aggressive environments (Nnanna et al. 2011). Many studies had been carried out to find suitable compounds useful as corrosion inhibitors for this metal in different aqueous solutions. (Rajendra, et al.2005). According to Rocha et al. (2012), it was reported that there are a number of organic and inorganic compounds which can inhibit corrosion of steel.

Naturally occurring molecules exhibiting a strong affinity for metal surfaces are the focus of research oriented toward the development of environmentally friendly corrosion inhibitors; compounds showing good inhibition efficiency and low environmental risk. Many researchers have done some works on green corrosion using grape pomace (James and Akaranta, 2011), apricot juice (Singh et al. 2012). Among the so-called ‘‘green corrosion inhibitors" are organic compounds that act by adsorption on the metal surface, such as ascorbic acid, succinic acid, tryptamine , caffeine and extracts of natural substances. The efficiency of organic corrosion inhibitors is related to the presence of polar functional groups with S, O or N atoms in the molecule, heterocyclic compounds and pi electrons. The polar function is usually regarded as the reaction center for the establishment of the adsorption process. Studies have been conducted on natural extracts that can significantly replace synthetic compounds. One of these natural compounds is fruits. According to James and Akaranta 2011, banana peel, fruit peel (mango, orange and passion fruit), coffee grounds, papaya seed, seeds and peels from papaya and garlic produced inhibitors. The use of industrial wastes as corrosion inhibitors is indeed welcoming and very appealing. This research investigated the use of cashew waste as an eco-friendly inhibitor for mild carbon steel in Nigeria. A simple test for measuring corrosion is the weight loss method. The method involves exposing a clean weighed piece of the metal or alloy to the corrosive environment for a specified time followed by cleaning to remove corrosion products and re-weighing to determine the loss of weight. The rate of corrosion (R) is calculated as

$R = KW/(\rho At)$

Where k is a constant, W is the weight loss of the metal in time t, A is the surface area of the metal exposed, and ρ is the density of the metal (in g/cm^3).

II. MATERIALS AND METHODOLOGY

Materials

Waste fruits of cashew (Anacardium occidentale L.) were collected from Landmark University, Omu Aran, Kwara state, Nigeria.

Chemicals.

All the chemical and reagent used in this work were of analytical grade of sigma chemical company UK. They include: Hydrochloric Acid, Acetone and Ethanol

Preparation of samples

The samples prepared here are the corrosion medium for the mild steel bar needed in calculating the weight loss of the material. The samples are 1M of HCl and 0.1M of H_2SO_4. The electrolytes 0.1 $molL^{-1}$ HCl and 0.1 $molL^{-1}$ were solution prepared using double-distilled water. All chemicals were of analytical-grade. The experiments were carried out under non-stirred and naturally aerated conditions.

Preparation of plant extract

The 2kg of waste cashew fruits were sun dried. After sun drying them .the cashew nut was separated from the dried waste fruits; after which the dried waste fruit was pulverized. 150g of the ground dried waste cashew powder was weighed and soaked in 250 ml of ethanol for 24 hours, and then filtered and concentrated using rotary evaporator and water bath. The resulting extract was in semi-solid form.

Preparation of Specimen

Carbon steel strips (BDH grade) containing (weight %): C 0.2, P 0.024, Si 0.003, Mn 0.35, and rest Fe were used in this research. Coupons cut with 4 x 5 x 0.1 cm dimensions were used for weight loss measurements. 10 mild steel bars of this dimension where cut and where used for this test. These coupons were cleaned by distilled water and ethanol. These coupons were further treated using emery paper. Upon treatment, it was washed using distilled water and degreased with acetone. These materials were stored in the desiccator.

Weight Loss Measurements

The gravimetric method (weight loss) is probably the most widely used method of inhibition assessment. The simplicity and reliability of the measurement offered by the weight loss method is such that the technique forms the baseline method of measurement in many corrosion monitoring programmers. Weight loss measurements were conducted under total immersion using 250 ml capacity beakers containing 20-100% test solution at 30-33°C maintained in the laboratory (room temperature). The carbon steel coupons were weighed and suspended in the beaker with the help of rod and hook. For the effect of temperature on the inhibition efficiencies, all the tests were carried out in the temperature ranges of 30-33°C.

Procedure

The mild carbon steel specimens was immersed in 100 mL of 0.1M HCl various concentrations of the inhibitor (20%, 40%, 60%, 80%) in the presence and absence of the corrosion inhibitor for 336 hours. A two control experiment for HCl was also investigated.

Then various percentages of the inhibitor were added to the other beakers containing the various test samples. The specimens were totally immersed in all ten (10) test solutions and were left for 336 hours during which readings were carried out at intervals of 48 hours. A total of 7 readings were carried out and the results penned down accordingly. The weight of the specimens before and after immersion was determined after every 48 hours using weighing balance. The corrosion products were cleansed with distilled water, dried and then weighed to determine its weight. The inhibition efficiency (IE) was calculated using the following equation:

X100%..3.1

Where W_1 is the corrosion rate in the absence of the inhibitor, and W_2 is the corrosion rate in the presence of the inhibitor.

Surface Examination

For morphological study, surface features (2.0 cm x 2.0 cm x 0.15 cm) of carbon steel were examined before and after exposure to 0.1M HCl solution for 336 hour with and without inhibitor. Scanning Electron Microscope was used for this investigation. Also FT-IR was used in examining the control experiment of HCl and also the optimum corrosion inhibitor in the acid.

III. RESULTS AND DISUCUSSION

Weight Loss Method

The corrosion of mild steel in 0.1M HCl solution containing various concentrations of inhibitor at room temperature was studied by weight loss measurements. The corrosion rate of mild steel was determined via the below formula:

$W=\Delta m/S\times t$……………………………………………………………………………….2

Where Δm is the mass loss (g)

$S= 20cm^2= 0.002m^2$[the area (cm^2)]

t= 48hours [immersion period (hours)]

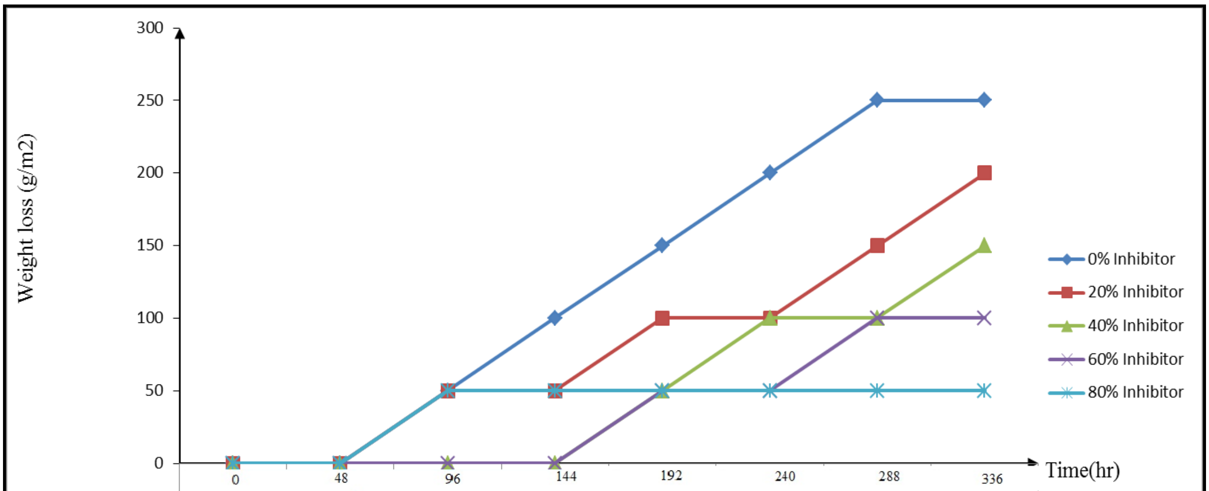
The percentage inhibition efficiency [IE%] was calculated using the relationship:

X100%...3

Where W_1 is the corrosion rate in the absence of the inhibitor, and $_2$ is the corrosion rate in the presence of the inhibitor.

Table 1: Corrosion rates data of mild steel in 0.1M HCl in absence and presence of different concentrations of cashew inhibitor.

Inhibition concentration (%)	Corrosion rates ($g/m^2.hr$)	Θ	IE (%)
0	0.87		
20	0.69	0.207	20.7%
40	0.52	0.402	40.2%
60	0.35	0.598	59.8%
80	0.17	0.805	80.5%



	0	48	96	144	192	240	288	336
0% Inhibitor	0	0	50	100	150	200	250	250
20% Inhibitor	0	0	50	50	100	100	150	200
40% Inhibitor	0	0	0	0	50	100	100	150
60% Inhibitor	0	0	0	0	50	50	100	100
80% Inhibitor	0	0	50	50	50	50	50	50

Figure 1: Weight loss-time curves of carbon steel in 0.1M HCl in the absence and presence of different concentrations of Cashew inhibitor.

Surface Morphology

FT-IR was used to evaluate the nature of the film formed on the surface of the metal. After the concentration of the inhibitor with the highest Inhibition Efficiency (IE %) was discovered, the samples were sent to the laboratory for analysis. Figures 4.3, 4.4, 4.5 and 4.6 both show the analysis done on the metal with 0% inhibition concentration and that of 80% inhibition concentration in both 0.1M HCl and 0.1M H_2SO_4.

The strong band at approximately $3450cm^{-1}$ can be associated with O-H stretching of the phenolic group. The band at 2928 cm^{-1} is related to C-H stretching vibration. The strong band at 1630 cm^{-1} is assigned to conjugated C=O stretching vibration. The band at 1552 cm^{-1} can be attributed to C=C-C aromatic ring stretching. The bands between 1467 and 1431 cm^{-1} can be attributed to angular deformations of C-O-H in phenols. The band at approximately 1321 cm -1 is attributed to C-O stretching from the pyran-derived ring structure present in the flavonoids. The bands at 1083 and $1151cm^{-1}$ can be assigned to C-H deformations of the aromatic ring. This result indicates that cashew extract contain flavonoids in their composition, which can act as corrosion inhibitors. The FT-IR spectra for figures 4.4 and 4.6 are almost the same, so it can be concluded that the extracts have the same composition, and differ mainly on their concentration.

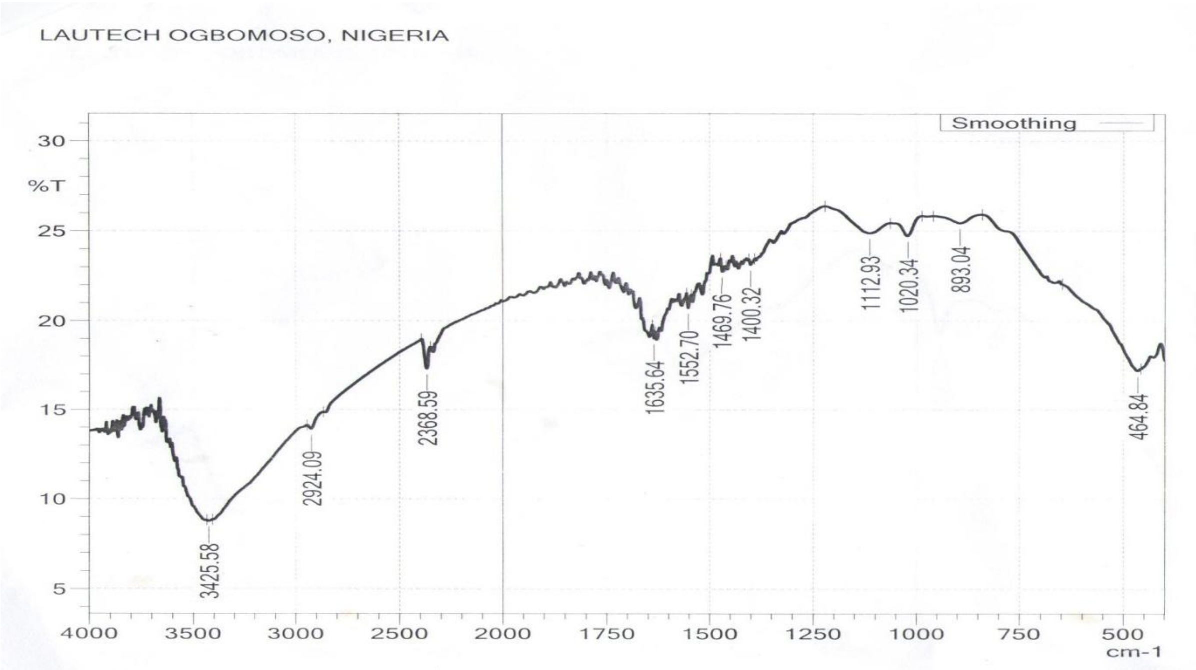


Figure 2: FT-IR spectra of coupon with 0% inhibition concentration in 0.1M HCl

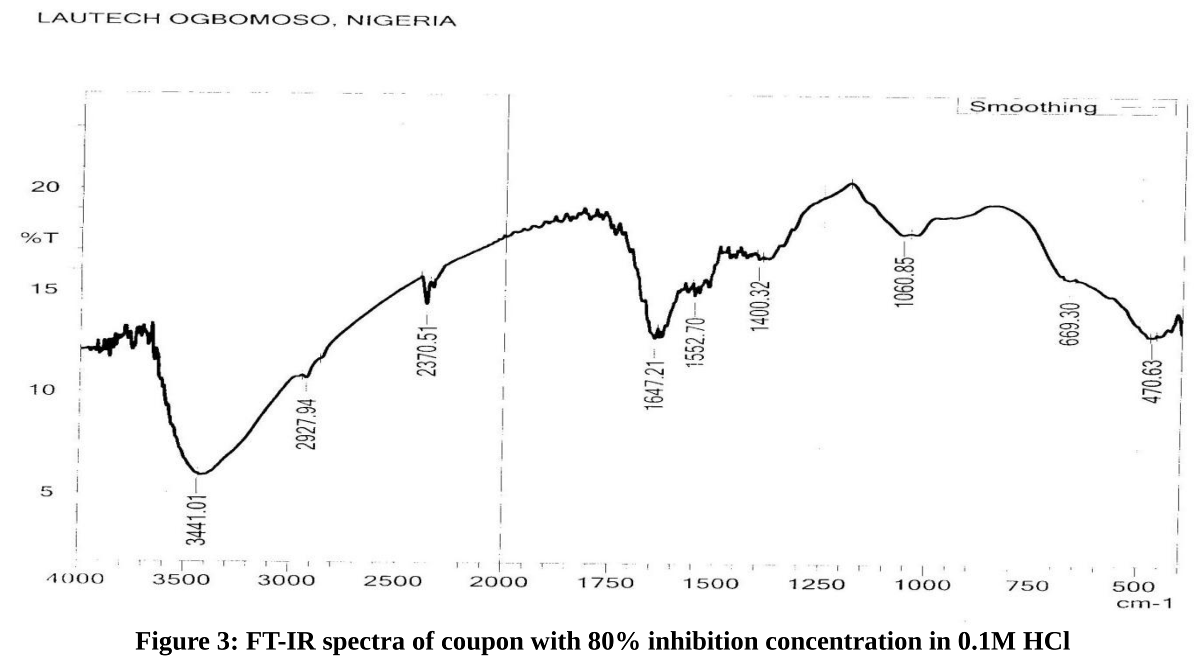
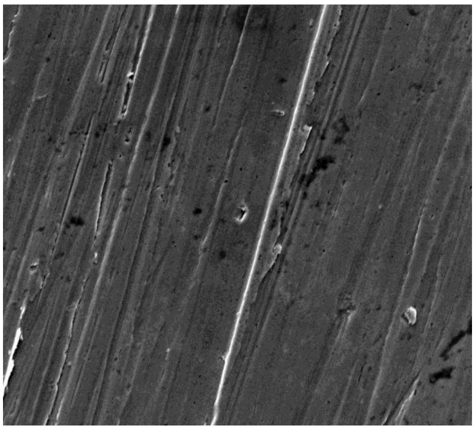


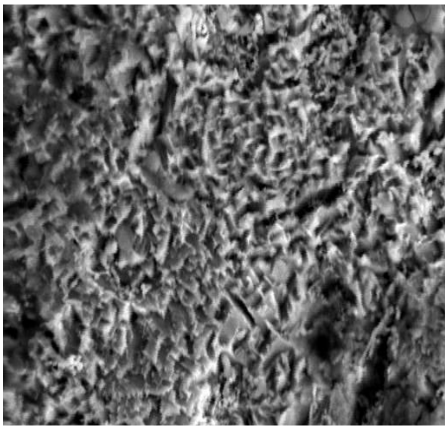
Figure 3: FT-IR spectra of coupon with 80% inhibition concentration in 0.1M HCl

Scanning electron microscopy (SEM)

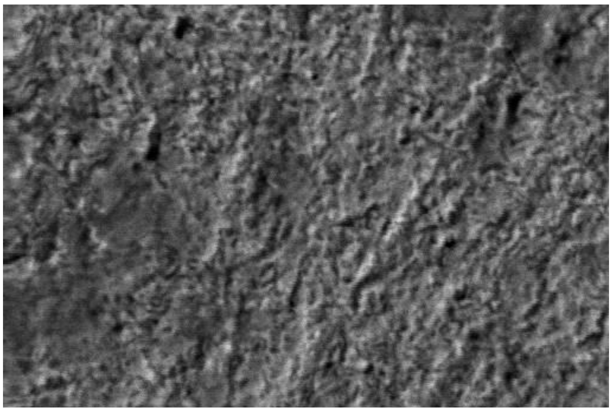
Surface morphology of polished mild steel, mild steel immersed in 0.1M HCl and mild steel immersed in 0.1M HCl with 80% corrosion inhibitor and were recorded and depicted in Figures (a) - (c)



(A)



(B)



(C)

Figure 4.: SEM micrographs of mild carbon steel surface (a) before immersion (b) total immersion in 0.1M HCl (c) immersion in 0.1M HCl with 80% inhibition concentration

IV. DISCUSSION OF RESULTS

It was observed that the inhibition concentration of 80% for 0.1M HCl gave the highest inhibition efficiency i.e. 80.5%. From Figures 4.1- 4.2, the graphs clearly showed that weight loss reduced as more concentrations of the corrosion inhibitor was added. Within the test hours of 336 hours, there was a $300g/m^2$ of weight loss in 0.1M HCl with 0% inhibition concentration while $50g/m^2$ of weight loss was observed. The inhibition efficiency is directly proportional to the concentration of the inhibitor (i.e. inhibition efficiency increases with increase in inhibition concentration). It was observed from the FT-IR result that the cashew extract contain flavonoids in their composition, which acted as corrosion inhibitors.

In the test of cashew waste as a suitable corrosion inhibitor for mild carbon steel in 0.1M HCl. The inhibitor (concentrations of 20%, 40%, 60% and 80% respectively) was added to the medium while the coupons (mild carbon steel) were totally immersed in it. At 80% concentration of the inhibitor, it was discovered that the inhibition efficiency was highest in at 80.5% for HCl. Also the FT-IR spectra of the metal show a high degree of correlation with each other. From the SEM analysis, the metals without inhibitor were more corroded than those with inhibitors. It was concluded that cashew waste fruit was a very good eco-friendly corrosion inhibitor for mild carbon steel. Furthermore, as the concentration of the inhibitor increases, the corrosion rate decreases and the inhibitor has an optimum efficiency of 80.5%. The result obtained from the FT-IR spectra showed flavonoids which are the active corrosion inhibiting agents in the cashew. SEM analysis showed a better passive layer against the corrosive ions on the surface of the mild steel in HCl.

V. CONCLUSION

It was concluded that cashew waste fruit was a very good eco-friendly corrosion inhibitor for mild carbon steel. Furthermore, as the concentration of the inhibitor increases, the corrosion rate decreases and the inhibitor has an optimum efficiency of 80.5%. The result obtained from the FT-IR spectra showed flavonoids which are the active corrosion inhibiting agents in the cashew.

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