ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Effects of Psiduim Guajava (Guava) and Moringa Oleifera Leaves Extract on the Corrosion Susceptibility of Mild Steel in an Acidic Medium

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ARTICLE INFO

Article history:
Received 10 October 2015
Accepted 30 November 2015
Available online 24 December 2015

Keywords:
Psiduim Guajava, Moringa Oleifera, Corrosion rate, Mild steel, Acidic medium

ABSTRACT

The inhibiting effects of two leaves (Psiduim Guajava (Guava) and Moringa Oleifera) extract on the corrosion susceptibility of mild steel in acidic medium were investigated. Weighed samples of mild steel were immersed in a solution containing the leaves extracts and 0.5 M and 1.0 M of H_2SO_4 respectively. The weight loss in each medium was calculated and the corrosion rate was equally determined. The composition of the mild steel was determined using Metal Analyzer. Our results indicate that peak corrosion rate occurs at 200 hrs in Psiduim Guajava and 350 hrs in Moringa Oleifera. The results equally showed that both leaves extracts are good corrosion inhibitors; however, the extracts of Moringa Oleifera displays better inhibiting properties than that of Psiduim Guajava.

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To Cite This Article: N.E. Idenyi, P.A. Nwofe, P.E. Agbo and H.K. Idu., Effects of Psiduim Quajava (Guava) and Moringa Oleifera Leaves Extract on the Corrosion Susceptibility of Mild Steel in an Acidic Medium. ***Aust. J. Basic & Appl. Sci.,*** *9(35): 245-250, 2015*

INTRODUCTION

Metals and its alloy are exposed to the action of acids in industrial processes which causes severe problems such as an increase in mass and corrosion of surfaces, resulting in economic losses (Abdallah *et al* ,2012). These effects are of particular consequence in the food processing industry as food substances, like other organic and inorganic substances is increasingly becoming corrosive; thereby causing significant impact on the degradation of constructional materials and the maintenance or replacement of products loss or contaminated as a result of corrosion reactions (Agarwala, 2000). These corrosive effects on different constructional materials in all phases of processing and packaging of food – one of the most basic needs of life, are all too common.

The material for most equipment are mild steel which is selected because of its strength, ductility, weldability and it is amenable to heat treatment for varying mechanical properties (Bonyanzer and Hammounti, 2004; Callister, 2001; El Hosary and Salem, 1972; El Hosary *et al*, 1993; Idenyi *et al*, 2015). However, mild steel corrodes easily because all common structural metals form surface oxide films when exposed to pure air but the oxide formed on mild steel is readily broken down, and in the presence of moisture it is not repaired. Therefore, a reaction between steel (Fe), moisture (H_2O), and oxygen (O_2), takes place to form rust. This reaction is complex but it can be represented by a chemical equation of the following type:

$$4Fe + 2H_2O + 3O_2 = 2Fe_2O_3.H_2O \quad (1)$$

$Fe_2O_3.H_2O$ is the rust, and as it is not usually protective, therefore, the corrosion process is not impeded (Okafor, *et al*, 2008). Mild steel as constructional materials are often exposed to juice or used to package juice to a great extent during service. This exposure can be under condition of varying temperature, flow rate, pH, and other factors; all of which can alter the rate of corrosion. The relative acidity of the solution is the most important factor to be considered; at low pH, the evolution of hydrogen tends to eliminate the possibility of protective film formation so that steel continues to corrode but in alkaline solutions, the formation of protective film greatly reduces corrosion rate (Ekuma, and Idenyi, 2007).

Recently, plant extracts have again become important as an environmentally acceptable, readily available, and renewable source for a wide range of needed inhibitors. Plant extracts are viewed as an incredibly rich source of naturally synthesized chemical compounds that can be extracted by simple procedures with low cost. However, synergistic (and antagonistic) effects are often expected with these mixtures of inhibitors that may affect their inhibition efficiency. Several investigations have been reported using such economic plant extracts. (El Hosary *et al*,

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1972) studied the corrosion inhibition of aluminium and zinc in 2 N HCl using naturally occurring Hibiscus *sabdariffa* (Karkade) extract. The inhibition of corrosion of steel, aluminium, and copper in HCl, H_2SO_4, and citric acid by molasses was also studied (El Hosary and Saleh, 1998), and 83% and 13% inhibition efficiencies were obtained for HCl and H_2SO_4 solutions, respectively, containing 0.75% molasses. Loto (1998) reported the inhibitive action of Vernonia amygdalina (bitter leaf) on the corrosion of mild steel in 0.5 M HCl at 28°C. Avwiri and Igho (2003) studied the inhibitive action of V. amygdalina on the corrosion of aluminium alloys in HCl and HNO_3 at concentrations of 0.2 and 0.4 g/L at 29°C. They showed that the solution extract of the leaves serves as an excellent inhibitor. The inhibition effect of *Zanthoxylum alatum* plant extract on the corrosion of mild steel in 20%, 50%, and 88% aqueous orthophosphoric acid has been investigated by weight loss and electrochemical impedance spectroscopy (EIS). Plant extract was found to reduce the corrosion of steel more effectively in 88% than in 20% phosphoric acid (Gunasekran and Chauhan, 2004). An inhibition efficiency of 75.11% was observed with the extract of the leaves of *Nypa fruticans Wurmb* (Orubite and Oforka, 2004) for the corrosion of mild steel in hydrochloric acid solutions. El-Etre *et al*, (1998) examined some naturally occurring substances as corrosion inhibitors for different metals in various environments.

1. Methodology:

1.1 Materials:

The following material were used for this study:

Hydrogen tetroxosulphate (vi) acid (H_2SO_4), *Moringa oleifera* leaves, *Psidium quajava* leaves, measuring cylinder (1000cm^3), volumetric flask (250cm^3), beakers(1200cm^3), funnel, spring weighing balance, electronic weighing balance, filter cloth, mortar and pestle, hand towel, metre rule, Vernier caliper, paper sieve, masking tape, razor blade and nylon thread.

The mild steel used for this study was obtained from Delta Steel Company Aladja, Delta State, Nigeria. Mild steel specimens of the following compositions as in Table1 were used for the experiment (wt %). The composition of the sample was analyzed using Metal Analyzer, Optical Emission Spectrometer. The chemical composition of the specimen is given in Table 1:

Table 1: Chemical Composition of Mild Steel.

Elements	Elements concentration (wt.%)
Mn	0.5096
C	0.2789
Si	0.2428
S	0.0400
Cu	0.1196
P	0.0332
Cr	0.0114
Mo	0.0014
Sn	0.0102
Co	0.0100
Zn	0.0027
Al	0.0008
Ca	0.0010
Fe	98.7391

1.2 Material Preparation:

The cylindrical samples of diameter 1cm and height of 1.5cm have been cut from a long rod of mild steel (total surface area of coupon 6.284cm^2). The weight of each piece was taken and recorded. An abrasive paper was used to remove any mill scale and rust stains on the mild steel specimens before they were cleaned with acetone. The samples were polished; the coupons were degreased by washing them in absolute ethanol, rinsed in acetone and allowed to dry. The dried coupons were stored in moisture free desiccators until required for use. The chemicals and reagents used in this study were of analytical grade and distilled water was used to prepare them.

1.3 Preparation of Leaves Extract:

Use of inhibitors is a very important aspect in the protection of metals from corrosion. Till now the majority of metal corrosion inhibitors in use are the toxic types. The choice of the present inhibitors is based on the following considerations: easy availability, possess no threat to the environment, non-toxic, and less-expensive. For the present study, extract of *Moringa Oleifera* and *Psidium guajava* were used as corrosion inhibitor for mild steel in an acid environment. The leaves were collected from Nkalaha and Mgbabor towns, both in Ebonyi State, Nigeria. The tested extracts were prepared by extracting weighed amount of the fresh leaves of *Moringa Oleifera* and *psidium guajava* for two hours and under room temperature. After this it was manually squeezed by pounding with mortar and pestle to obtain corresponding juice extracts without addition of water and then filtered. Then, the solution was filtered and stored. The concentrations of the extracts are expressed in (cm^3). The tested extracts were measured using a measuring cylinder, and were later poured into the different 36 beakers used, 25cm^3, 50cm^{3,} 75cm^3 and 100cm^3 of each

tested extracts in 0.5M and 1.0M H_2SO_4 environments.

The mild steel rods were cut into cylindrical shapes of 1.5cm by 1cm using the hacksaw, to obtain one hundred and forty four coupons. The whole coupons were weighed individually using the electronic digital weighing balance and their individual weight recorded as labelled (from 1-144). The beakers containing the media were carefully labeled against the medium each contained. The 0.5M and 1.0M H_2SO_4 were prepared in the Industrial Chemistry laboratory, Ebonyi State University, Abakaliki by diluting 16.5cm^3 of concentrated H_2SO_4 in 1000cm^3 of distilled water and diluting 33cm^3 of Concentrated H_2SO_4 in 6000cm^3 of distilled water respectively. Each beaker contains four coupons acid with different molarities of concentration/diluted with distilled water and with/ without inhibitor. The beakers were rinsed with distilled water before use. A total of thirty six (36) beakers were rinsed and left to stand and dried before the experimental were set up, so as to avoid additional water (mass). The coupons were immersed in the different media by means of a nylon thread hung on a retort stand and tied to the coupons. The four coupons were immersed in each of the beakers and it was ensured that none of the coupons touched one another to avoid crevice and galvanic corrosion.

1.4 Weight Loss Method:

The sample coupons of mild steel were first weighed using a digital weighing balance, METTLER TOLEDO model ME204E with a least count of 0.0001g, labeled and immersed in the test solutions of the acid, with and without inhibitor. The weight loss of each of the sample coupons were determined and recorded. The determination of weight loss and recording was repeated consistently every 168 hours (7 days) for a period of 672 hours (28 days). Prior to measurement, each coupon was washed in absolute ethanol, rinsed in distilled water, dried in acetone and then weighed (Iloamaeke *et al*. 2012). The same experiment was repeated in the presence and absence of inhibitor. From the weight loss of the coupons and the corrosion rate (CR) of mild steels were calculated using the expression (Callister, 2003).

$$\textbf{Corrosion Rate} = \frac{K\Delta W}{\rho AT} \quad (2)$$

Where

K = Rate constant equal to 87.6×10^4

ΔW = Weight loss in mg.

ρ = Density of material in gcm^{-3}=7.86gcm^{-3}

T = Exposure time in hours.

A = Exposed area of coupon in cm^2.

CR = Corrosion rate, millimetre per year (mm/yr).

Total surface area of cylinder (coupon) = $2\pi rh + 2\pi r^2 = 2\pi r(h+r)$

Where, r = radius of the coupon = 0.5cm

h = height of the coupon =1.5cm

$\pi = 3.142$

$\therefore = 2\times3.142\times0.5(1.5+0.5) = 3.142(2) = 6.284\text{cm}^2$.

The corrosion rate was calculated on seven (7) days interval for a period of twenty eight (28) days. After, graphs of CPR vs Exposure time were plotted to give clearer perspectives of the corrosion trends for relevant inferences to be conclusively drawn.

RESULTS AND DISCUSSION

Figure 1 gives the plot for the variation of the corrosion profiles in the acidic environment at the respective concentrations in the absence of an inhibitor. The plot shows that the corrosion rate increased with an increase in the exposure time both for 1M and 0.5 M of H_2SO_4, both having peak corrosion rate of 5.8 and 9.9 respectively. The plot also shows that in each medium, the corrosion rate increased, reached the maximum value and started to fall exponentially. The continued decrease in corrosion rate could be attributed to the formation of oxide layer/film which shields the specimen from having direct contact with the environment, hence this fall in corrosion rate with days which is inverse of the expected results is due to passivation. That is, as exposure hours increases, the material become less affected by environmental factors due to the formation of non-reactive and low solubility films on the material surfaces. It is also observed from the plot that the 1.0 M medium has lower corrosion rate as compared with the medium at 0.5 M, thus it can be deduced that the material will perform better in a medium containing 1M of H_2SO_4. We thus conclude that the corrosion rate is inversely proportional to the molar concentration of the acidic medium in the absence of the inhibitor. Corrosion is mainly due to the presence of OH-, $H^{+,}$ SO_4^{2-} and air which accelerates the corrosion process.

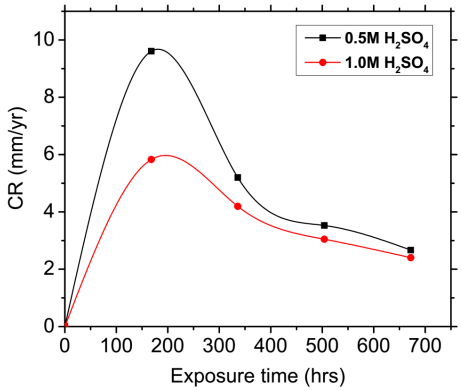

Fig. 1: Variation of the corrosion profiles at different concentrations of H_2SO_4 environment (in the absence of an inhibitor).

The variations of the corrosion rate at different volume for 0.5 M H_2SO_4 is shown in Fig. 2. The plots indicate that for each volume, the corrosion rate increased, reached a peak and began to fall. It is observed that there is no clear trend between the volume and the corrosion rate. The plot equally indicates that highest corrosion rate was observed at volume of 75cm^3, while the lowest corrosion rate was observed at volume of 100cm^3. This may be due to the fact that at increased volume, solubility tends to increase. This implies that increasing the volume do not affect the corrosion rate significantly as one could have expected higher corrosion rate at higher volume. This could be attributed to the fact that volume do not necessarily affect the rate of chemical reaction. The result thus suggests that it is safer to work with higher volume of the precursor.

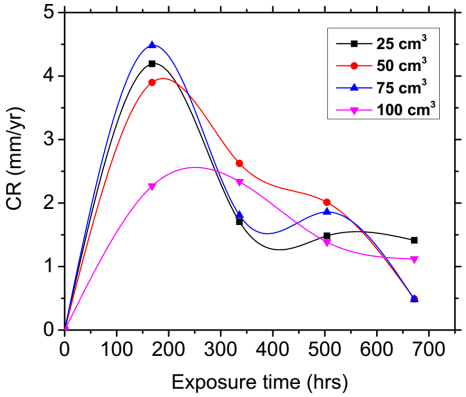

Fig. 2: Variation of the corrosion profiles at different volumes of *Psiduim guajava* in 0.5M H_2SO_4 environment.

The role of inhibitors is to form a barrier of one or several molecular layers against acid attack and this depends on phytochemical compounds which vary widely on the part of the plant and its geographical location. The inhibitive characteristics of such compounds derive from the adsorption ability of their molecules, with the polar group acting as the reaction center for the adsorption process. The resulting adsorbed film acts as a barrier that separates the metal from the corrodent, and efficiency of inhibition depends on the mechanical, structural, and chemical characteristics of the adsorption layers formed under a particular condition.

Figure 3 indicates the variation of the corrosion rate at different volumes of 1 M H_2SO_4, and as usual the corrosion rate increases with hours with maximum at 200 hours before it started to decrease with time until passivation began. When compared to Figure 2, the differences between the corrosion rate at the peak with corresponding volumes are 3mm/yr, 2.7 mm/yr, 2.95mm/yr and 3.0 mm/yr for 100cm^3, 75 cm^3, 50 cm^3, and 25 cm^3 respectively. The two graphs clearly showed that corrosion rate was more pronounced in the 1M H_2SO_4 irrespective of the volume. Thus the addition of *Psiduim guajava* has significantly decreased the rate of corrosion of the mild steel. This could be attributed to the fact that the rate of chemical reaction increases with increase in concentration (Orubite and Oforka, 2004).

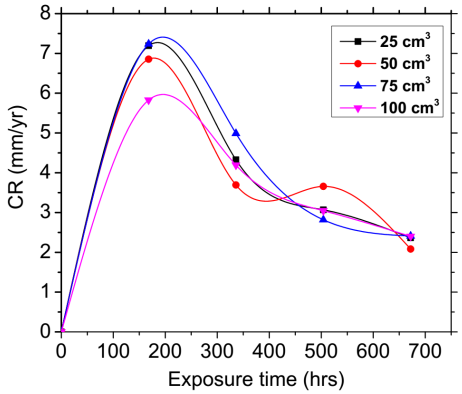

Fig. 3: Variation of the corrosion profiles at different volumes of *Psiduim Quaiaya* in 1.0M H_2SO_4 environment.

The variation of corrosion profile of mild steel at different volumes of *Moringa Oleifera* in 1 M H_2SO_4 is shown in Figure 4. The profile indicates that the corrosion rate increased with time and reached a peak at t = 300 hrs, representing 50 % higher than the time for corrosion rate to reach its peak in *Psiduim guajava* before it started falling with time for all the volumes. From the plot, it can also be observed that as the volume of the inhibitor increases in 0.5 M of H_2SO_4, the corrosion rate decreases. When compared to Figure 2, the corrosion rate has a percentage difference of 81%, 83%, 58% and 54% in *Moringa Oleifera* than in *Psiduim guajava*. This implies that the corrosion rate was significantly reduced in *Moringa Oleifera* as inhibitor. The *Moringa Oleifera* showed better protective effect than *Psiduim guajava* which is suggestive that it has greater capability to destroy passivity than the later.

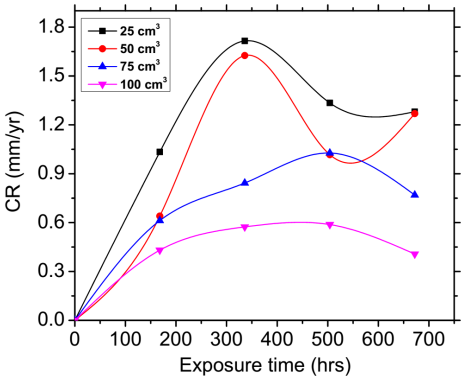

Fig. 4: Variation of the corrosion profiles at different volumes of *Moringa Oleifera* in 0.5M H_2SO_4 environment.

Figure 5 shows the variation of corrosion profile at different volumes of *Moringa Oleifera* at different volumes. The corrosion rate increased with time with a peak at t = 350 hrs. This shows an increase in the time required for passivation to occur. Hence addition of *Moringa Oleifera* extracts slows the rate of corrosion of mild steel in acidic medium than *Psiduim guajava.* The corrosion rate at different volumes from Figure 5 are 2.5, 4.5, 3.85 and 4.0 mm/yr for 100, 75, 50 and 25 cm^3 of the extract. This is lower than the value obtained when the mild steel is immersed in acidic medium only and in extract of *Psiduim guajava* as discussed above. The inhibition of metal corrosion by organic compounds is attributed to either the adsorption of inhibitor molecule or the formation of a layer of insoluble complex of the metal on the surface which acts as a barrier between the metal surface and the corrosive medium (Okafor *et al*., 2008). Since no insoluble material was observed on the metal surface, the inhibitive action of the extract may be due to its adsorption on the metal surface (Ekuma, and Idenyi,2007).

Conclusion:

The effects of two leaves extracts on the corrosion behavior of mild steel in an acidic medium has been investigated in this research. Corrosion rates of 2.5, 4.5, 3.85 and 4.0 mm/yr for 100, 75, 50 and 25 cm^3 were observed in 1.0 M H_2SO_4 in *Moringa Oleifera* which is significantly lower than that found in 1.0 M H_2SO_4 with *Psiduim guajava* extracts. The research also showed that there was no clear trend between the volume of the acid and leaves

extract on the corrosion rate. Even though for some, the corrosion rate increased with increase in volume. The results equally showed that both leaves extracts are good corrosion inhibitors, however, the extracts of *Moringa Oleifera* displays better inhibiting properties than that of *Psiduim guajava*.

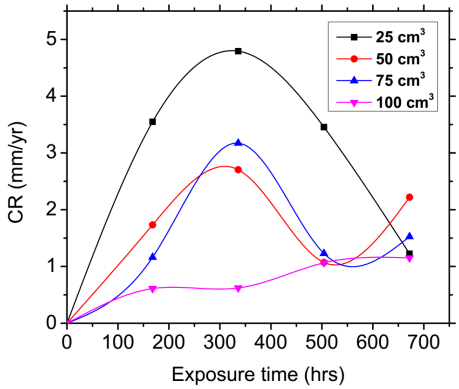

Fig. 5: Variation of the corrosion profiles at different volumes of *Moringa Oleifera* in 1.0M H_2SO_4 environment.

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