

Corrosion Inhibition Study of Aluminum Alloy AA3003 in Alkaline Medium by *Palisota Hirsute* Extract

¹Nnanna Lebe A., ²John Wisdom O., ³Nwadiuko Onyinyechi

^{1,2,3}Dept. of Physics/Electronics, Abia State Polytechnic, Aba, Nigeria

Abstract: In order to solve the problems posed by corrosion of materials used in our daily activities, gravimetric technique has been used to study the adsorption of *Palisota hirsute*, an eco-friendly inhibitor, on and corrosion inhibition of aluminium alloy AA3003 in 0.25 M KOH environment at 303 K. Results obtained showed that the leaf extract functioned as an effective inhibitor in the alkaline medium with inhibition efficiency on the increase with increased concentration of the inhibitor in the medium getting up to 86.21% for 0.5 g/L of the inhibitor in the medium. Values of Gibbs free energy (ΔG°_{ads}) gotten implied that the adsorption reaction was a mixed reaction and was spontaneously adsorbed on the aluminium alloy steel.

Keywords: Aluminium Alloy, Eco-Friendly, Gibbs free energy, *Palisota Hirsute*.

I. INTRODUCTION

Corrosion inhibition has become almost a daily activity in industries due to the presence of either acidic or alkaline environments which causes cathodic processes leading to hydrogen evolution. The study of corrosion behavior of aluminium in different aggressive environments has continued to attract considerable attention because of the many applications of the metal which is due to its many unusual combinations of properties. Applications for aluminium include ship hulls, piers, tank interiors, offshore structure, submerged pipelines, piling (Oguzie, 2007; Musa et al., 2011). Aluminium relies on the formation of a compact, adherent passive oxide film for its corrosion immunity in various environments. This surface film is amphoteric and dissolves substantially when the metal is exposed to high concentrations of acids or bases (Oguzie, 2007; Nnanna et al., 2011; Popova et al., 2003). Bare metal surface sites become exposed to the corrodent after the breakdown of the oxide film, leading to a sequence electrochemical reaction as the metal dissolves.

Recently, importance has been created on investigating the inhibition level of different organic materials from plants instead of the synthesized materials which end up polluting the environments and leaving the human race in a risk of survival. This area of research is of much importance because in addition to being inexpensive, readily available and renewable sources of materials, plant products are environmentally friendly and ecologically acceptable. Plant products are organic in nature and some of the constituents including tannins, alkaloids, saponins, essential oils, flavones, organic and amino acids are known to exhibit inhibiting action (Olabiyi et al., 2003; Chetouani et al., 2005; Umoren et al., 2008; Umoren et al., 2005; Bouklah et al., 2006). In addition to these organic materials, they contain polar functions and conjugated double bonds and aromatic rings, which are the major adsorption centers. In view of our interest in creating a green-environment (Nnanna et al., 2011; Popova et al., 2003; Oguzie, 2008a,b; Ebenso et al., 2009; Ulaeto et al., 2012; Atanda et al., 2012; Okafor et al., 2008), where hazards are at minimal level – not even evolving from what we use in protection, this study uses the *Palisota hirsute* (locally known as Okpete) which is a highly medicinal leaf to inhibit the corrosion of aluminium in alkaline medium. Furthermore, the study goes further to study the effect of temperature, Temkin and Langmuir isotherms on the corrosion rate.

II. MATERIALS AND METHODS

A. Materials preparation:

All materials used were of analytical grade. Doubly distilled water was used in all preparations. The temperature was controlled within $\pm 0.1^\circ\text{C}$. Aluminium sheets of type AA3003 having weight percentage composition of Si-0.362%, Fe-0.54%, Cu-0.077%, Mn-1.219%, Ti- 0.026%, Pb-0.063%, Zn-0.004% and the remainder being Al were used in this study. The test coupons were prepared having a dimension of 20 x 20 mm and thickness 1.11 mm, were polished mechanically with Si-emery papers of grade nos 220, 400 and 600 degreased with ethanol and acetone having been washed with distilled water. The coupons were ensured dried before any measurement was taken on it using the JA 1003A electronic weighing machine, of accuracy ± 0.005 .

In preparing the leaf extract, the *P. hirsute* was obtained from Osusu in Isialangwa North Local government of Abia State, air dried and ground to powder. 10 g of the ground leaf was digested in 0.24 L of 0.25 M KOH, refluxed, filtered and stored. From the stock solution, the filtrate was used to prepare a concentration range of 0.1 g/L to 0.5 g/L.

The dried and measured coupons were introduced into the respective test solutions, using the different concentrations as prepared. At the end of the tests, the specimens were carefully washed in absolute ethanol having used Nitric acid to quench further corrossions from taking place and then reweighed. The experiment was repeated in triplicates and the mean value was reported.

III. RESULTS AND DISCUSSIONS

A. Gravimetric technique and corrosion rates:

Weight loss methods have found broad applications (Umoren et al., 2008). The weight loss of aluminium A3003 in 0.25 M KOH with and without the *P. hirsute* extract was determined after three hours of immersion at 30°C and the corrosion rate values were determined using this equation

$$CR = \frac{k\Delta W}{\rho At} \quad (1)$$

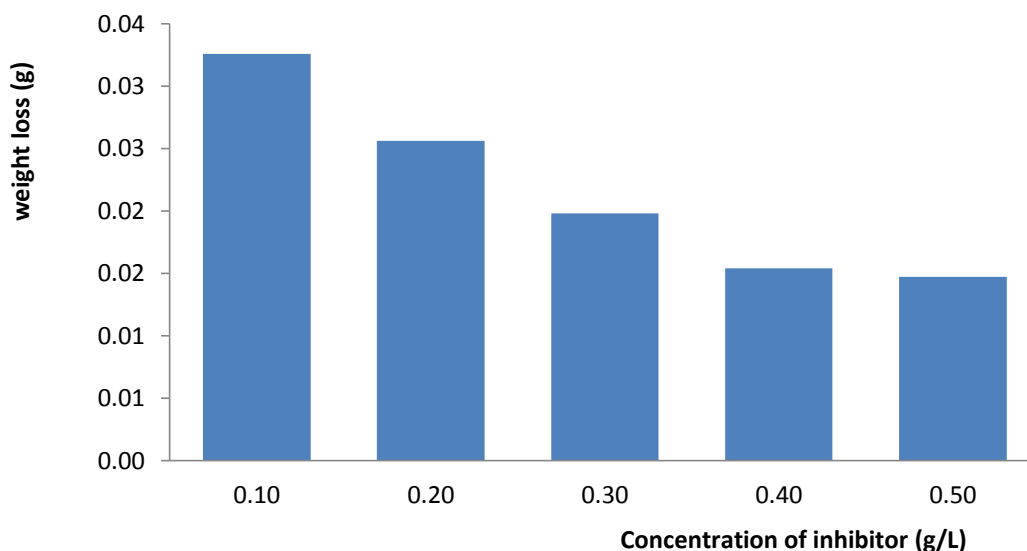


Figure 1: Weight loss of the aluminium AA3003 in different concentrations of *P. hirsute* after three hours of exposure.

As show in Figure 1 above, the loss of weight of the metal reduced as the concentration of the extract in the medium was increased. Furthermore, to explain what resulted to the reduction of loss of weight, the corrosion rates were plotted against the various concentration of the leaf extract (Figure 2). The graph shows that the corrosion rate of the metal in the environment decreased as the concentration of the leaf extract was increased indicating that the increase of the concentration of the leaf extract in the medium rapidly decreased the rate at which the metal corroded.

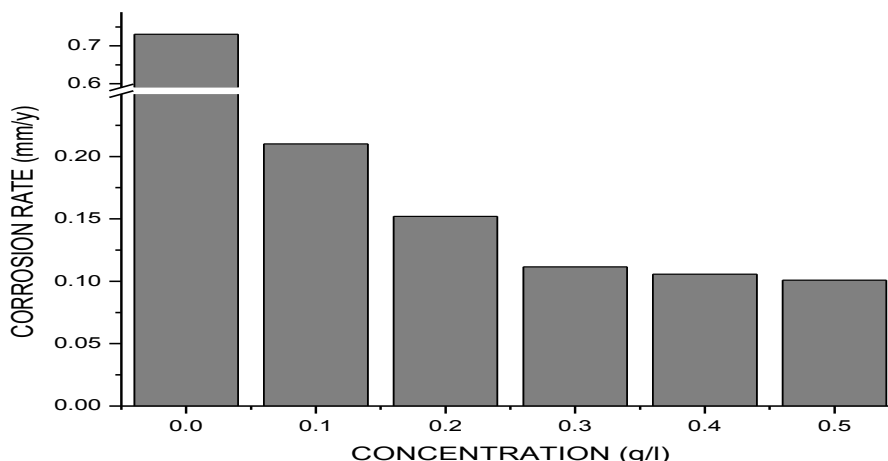


Figure 2: Corrosion rate of various concentrations of *P. hirsute* in 0.25 M KOH on aluminium AA3003.

B. Inhibition efficiency:

The characterisation of the corrosion rate of the aluminium alloy in the inhibitor and corrodent solution was carried out by an assessment of the inhibition efficiency (I%) using the equation 2 below

$$I\% = \left(1 - \frac{\rho_{inh}}{\rho_{blank}}\right) \times 100 \quad (2)$$

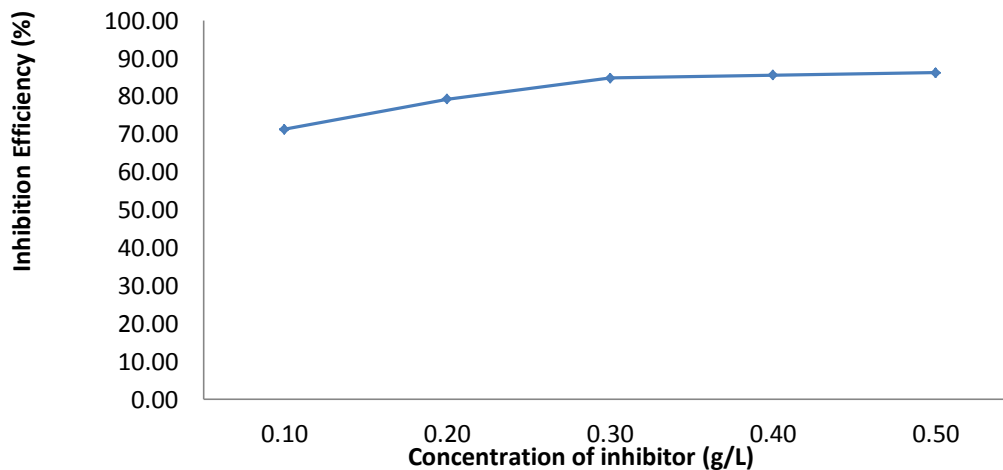


Figure 3: Inhibition efficiencies of different concentrations of *P. hirsute* in 0.25 M KOH.

The bar chart representing the inhibition efficiency with respect to the concentration of the inhibitor, *P. hirsute* was plotted (Figure 3).

The complex chemical composition of the leaf, *P. hirsute* makes it rather difficult to assign its inhibiting action to a particular or a group of constituent. The degree of protection varies for different extracts, with very significant sensitivity on the concentration of the extract in the medium. The mechanism of action of the inhibitor relies on the formation of a compact adherent passive oxide film for its corrosion immunity in various environments. The surface film of the aluminium is amphoteric and dissolves substantially when the metal is exposed to high concentration of acids and bases but with the presence of the extract in the corrosive medium, there is a formation of these oxide films on the surface of the AA3003. The thickness of the film is then dependent on the concentration of the extract in the liquid. As the concentrations gets higher, the film takes over more parts of the surface, exposing almost nothing, hence, no amphoteric surface of the aluminium is exposed and few corrosion points, thus, reduced weight loss and an increase in the inhibition efficiency. The result from Figure 2 showed that inhibition efficiency increased virtually proportionally from 71.26% in

the first concentration, 0.1 g/L to 86.21% in 0.5 g/L. This showed that an increase in the concentration of the inhibitor in the medium reduces the corrosion rate and the inhibition efficiency increases.

IV. ADSORPTION STUDIES

To study the adsorption mechanism from the experimental data, the adsorption modes of the inhibiting specie (ionic or molecular) was estimated from the data derived in the gravimetric measurements. The common expression for the common adsorption isotherms is of the form

$$f(\theta, x) \exp(-\alpha\theta) = kC \quad (3)$$

Where $f(\theta, x)$ is the configuration factor, which depends on the physical model adopted and the assumptions made in deriving the isotherms. The parameter, x is the size ration which represents the relative size of the adsorbed molecule to the solvent molecule. The predominant adsorption modes will be dependent on factors such as extract composition, chemical changes on the extract and the nature of the surface charge on metal. A negative surface charge will favour the adsorption of cations, as anions adsorption are favoured by a positive surface charge. The ability of the OH^- ion in the KOH to be strongly adsorbed by the metal surface, facilitating physical adsorption of the inhibitor ions is an important consideration.

The plot of the ratio of concentration to surface coverage (C/θ) against concentration (g/L) displayed a straight line for the tested inhibitor in the alkaline media (Figure 4). The linear plots, with high correlation coefficient clearly reveal that the surface adsorption process of *P. hirsute* on the aluminium alloy, AA3003 surface obeys the Langmuir adsorption isotherm. The Temkin adsorption isotherm (Figure 5) was also plotted. The Gibb's free ($\Delta G^\circ_{\text{ads}}$) energy of adsorption was evaluated for temperature, 303 K using equation 4 to determine the adsorption process involved in the reaction. Values of -18.9513kJmol and -17.6115kJmol were gotten for Langmuir and Temkin isotherms respectively. These values indicate that the process of inhibition used in this reaction is mixed. All the $\Delta G^\circ_{\text{ads}}$ values are negative, implying that the adsorption process is a spontaneous process.

$$\Delta G^\circ_{\text{ads}} = -RT \ln(55.5K) \quad (4)$$

As far as corrosion inhibitor studies are concerned, a large number of experimental adsorption data fit the Langmuir isotherm ($C/\theta = 1/k + C$), at least quantitatively. Often, however, the linear fits intercept the y-axis (C/θ) or the x-axis (C) and the slope is about unity, which collaborates to the isotherm prediction. A number of modifications to the Langmuir equation have been suggested, with the molecular interaction term included. Nevertheless, the probability of adapting the Langmuir isotherm to describe hemisorptions and physiosorption processes may account for its widespread applicability (Ruth et al., 1999; Nnanna et al., 2013).

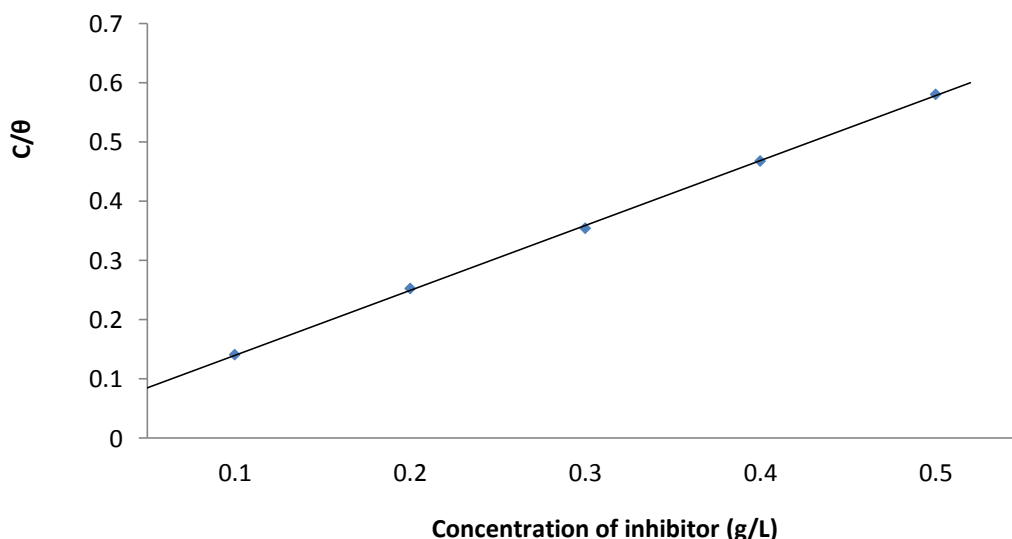


Figure 4: Langmuir isotherm for *P. hirsute* adsorption on Aluminium AA3003 alloy in 0.25 M KOH

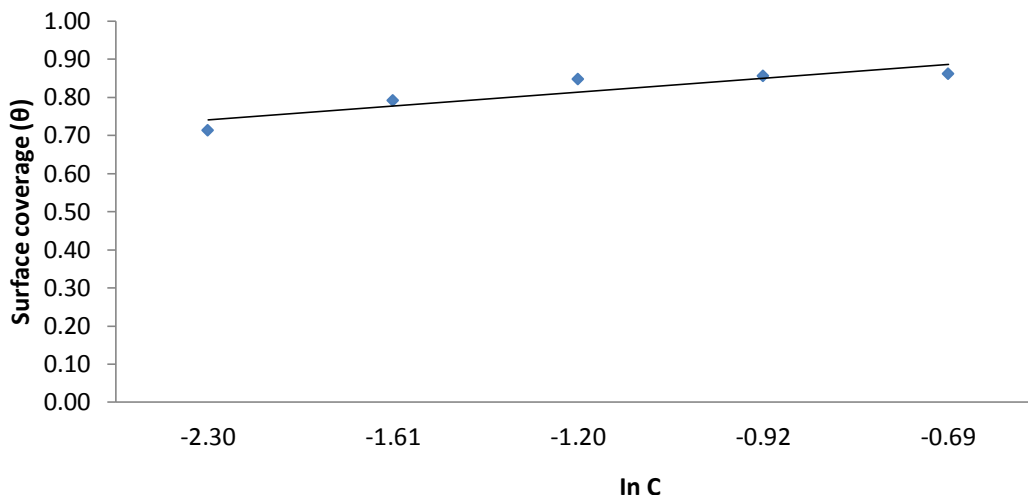


Figure 5: Temkin isotherm for *P. hirsute* adsorption on Aluminium AA3003 alloy in 0.25 M KOH

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V. CONCLUSION

The extract from the studied leaf material was found to be effective green inhibitor of aluminium alloys corrosion in 0.25 M KOH environment. The extract inhibited the corrosion of aluminium alloys media by means of hindering both cathodic and anodic electrode processes, because the greater the number of bonds in the extracts, the higher the inhibition efficiency. The inhibitive action was basically controlled by the concentration of the inhibiting extract in the medium. The inhibitor obeys both the Langmuir adsorption isotherm and the Temkin isotherm in the medium.

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