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Potency of African Black Velvet Tamarind as Inhibitor of Aluminium Dissolution In Hydrochloric Acid

KEYWORDS: Corrosion; Aluminium; adsorption; Hydrochloric acid.

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ABSTRACT *The potency of African Black Velvet Tamarind (VT) as an environmentally safe inhibitor for aluminium (Al) dissolution in 0.5M hydrochloric acid (HCl) solution was evaluated with weight loss method of corrosion measurement. The examination was carried out under three different conditions; 30, 40 and 50oC. VT inhibited the corrosion of aluminium significantly, with 96% efficiency at the highest concentration (0.25g/500ml) and temperature (50oC) of the inhibitor. Percentage efficiency of the inhibitor increased with temperature and concentration. The thermodynamic parameters for the inhibition process were calculated and a chemical adsorption mechanism was proposed. The potency of VT in reducing aluminium dissolution was attributed to the adsorption and surface chelation of some electron rich chemical compounds in VT on the metal surface. This adsorption behavior of VT fits perfectly with the Langmuir adsorption isotherm at all the temperatures studied.*

INTRODUCTION

Corrosion is the interaction of a material (usually a metal) with its immediate surroundings leading to the degradation of the metal (Ita, 2004). Corrosion of metal is a serious industrial challenge that has led to extensive investigations recently. Many control methods have been applied but the best option so far is the application of water soluble corrosion inhibitors in aqueous environment. Corrosion inhibitors are usually employed to protect metals from dissolving in acidic medium by getting adsorbed onto the metal surface to form a compact protective thin layer on it thereby retarding its deterioration in the aggressive media (Umoren et al, 2008a). Synthetic organic chemicals were used in the past but they are poisonous to the environment. This resulted in the exploration of natural products such as plant extracts as inhibitors of metals corrosion (Okafor et al, 2004).

The consistent usage of plant materials as inhibitors of metal corrosion has become a major breakthrough in research recently because of their availability and non-toxicity which makes them better than synthesized organic inhibitors that are toxic and very expensive (James and Akaranta, 2014, Okafor et al, 2004). A number of plant extracts have been investigated. Among others, extracts of Delonix Regia (Abiola et al, 2007), Ginseng Root (Obot and Obi-Egbedi, 2009), Exudate Gum from Dacroydes edulis (Umoren et al, 2008b) and Citrullus Colocynthis (Rajkiran et al, 2011) have been established as inhibitors of Al corrosion in acidic media. Their inhibition potentials is due to the chemical compounds present in then as active ingredients which get adsorbed onto the metal surface, blocking the corrosion site and retarding the wearing away of the metal (Abiola and Tobun, 2010).

The African black velvet tamarind (VT) contains several biodegradable eco-friendly organic compounds and has been a very versatile natural product because of its many applications (Effiong et al, 2009, Adame, 2002, Ogungbenle and Ebadan, 2014).

Previously, VT has been reported as a green inhibitor for the dissolution of mild steel and copper in HCl and H_2SO_4 acids respectively using weight loss method (Osarolube and James, 2014a, Osarolube and James, 2014b). However, the inhibitive effect of VT on Al corrosion in HCl solution has not been investigated.

This paper therefore reports the potency of VT on retarding Al dissolution in 0.5M HCl.

EXPERIMENTAL

The aluminium test specimens of dimensions 5 cm x 2 cm x 0.053cm and 98.76% in purity were used. This aluminium samples were prepared as described earlier (James et al, 2006).

0.5M HCl of analytical grade was used as the corrodent while 0.5M HCl / VT solutions were prepared as reported earlier (Osarolube and James, 2014a). This gives the VT stock solution and was used to prepare the experimental test solutions of 0.05 – 0.25g/500ml VT concentrations. The weight loss method of corrosion measurement used in this study has been described earlier [15]. Pre-weighted aluminium coupons were introduced into 250ml conical flasks that contained 150ml corrodent (0.5M HCl - blank), followed by the addition of 0.05 – 0.25g/500ml VT concentrations to the corrodent solution. The experiment was monitored at 30, 40 and 50^{o}C. The weight losses (Δwl) of the coupons were monitored for 210 consecutive minutes at 30mins interval and recorded.

Corrosion rates (Rc), surface coverage (ϕ) and Inhibition efficiency, (%Eff) were determined for the 24hours immersion period using the equations (1), (2) and (3) below:

$$Rc = \frac{\Delta wl}{A_T x T_m} \quad \text{............ ....(1)}$$

$$\phi = \frac{Rc_B - Rc_I}{Rc_B} \text{.....................} \quad (2)$$

$$\%Eff = \phi \times 100 \text{................} \quad (3)$$

Where is the weight loss of aluminium coupon (milligram), A_T is the total area of the coupon (cm^2), T_m is the immersion time (mins.), and are the rates of corrosion rates of

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Al metals with and without VT respectively.

2. RESULTS DISCUSSION:

Figure 1 displayed the variation of weight loss of Al coupons in the corrodent studied (0.5M HCl) with different concentrations of VT. VT conspicuously reduced the dissolution of Al which gradually diminished as its concentration increased. This behavioral pattern of VT in the figure showed that it is an effective inhibitor of Al corrosion in 0.5M HCl.

Figure 1: Weight loss of Al coupons (g) versus immersion time (mins) in 0.5M HCl solution with and without VT at 30⁰C.

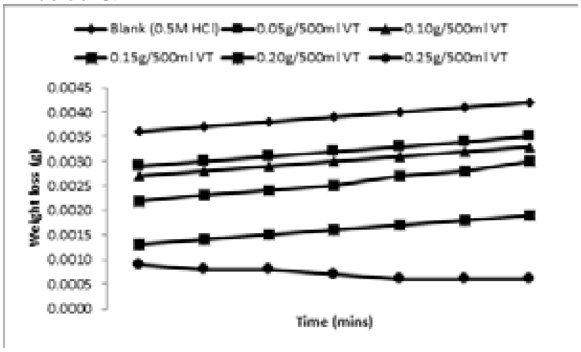


Table 1 further supports the observation in Fig. 1 by showing a consistent reduction in the dissolution rate of aluminium and a corresponding increase in the surface coverage and percentage efficiency of VT as its concentration increased. This point to the fact that VT must have been adsorbed on the aluminium surface to effect inhibition. However Fig. 2 shows an enhancement in the efficiency of VT at higher temperatures of 40 and 50°C, signifying a chemical adsorption mechanism for the inhibition.

Table 1: Corrosion rates (Rc), Surface coverage (ф) and inhibition efficiency, (%Eff) of the African black velvet tamarind extract in 0.5M HCl at 50°C.

VT Concentration (g/500ml)	Rc (mm/yr)	Surface coverage (ф)	Average percentage inhibition efficiency, (%Eff)
0.0	192.16	-	-
0.05	79.67	0.56	55.65
0.10	62.02	0.65	64.70
0.15	46.51	0.77	76.84
0.20	23.11	0.84	83.96
0.25	5.36	0.96	96.00

Also the value obtained from the calculation of VT adsorption free energy change (ΔG^o_{ads}) using the equation (4) (Abiola et al, 2007):

$$K_{ads} = \frac{1}{55.5}\exp\left(-\frac{\Delta G^0_{ads}}{RT}\right) \quad \text{.....................} (5),$$

was found to be equal to - 87.43KJ mol^{-1}.

Meanwhile, it has been earlier reported that the heat of chemical adsorption should exceed 80 kJmol^{-1} and below this value signifies that the inhibitor is physically adsorbed (Ekpe et al, 1995, James et al, 2006, Hamdy et al, 2013). Also, for an inhibition process to be of chemical adsorption mechanism, percentage efficiency must increase temperature rises (Ita and Offiong, 2001). Therefore, the chemical components (Fig. 3) in VT must have been chemically adsorbed on the Al surface.

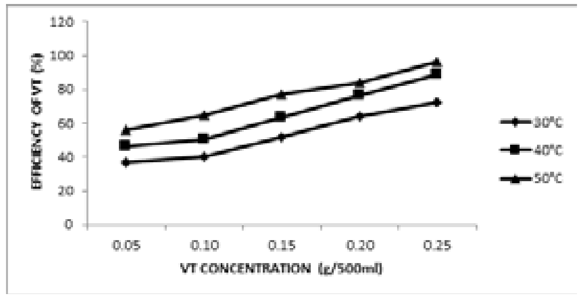
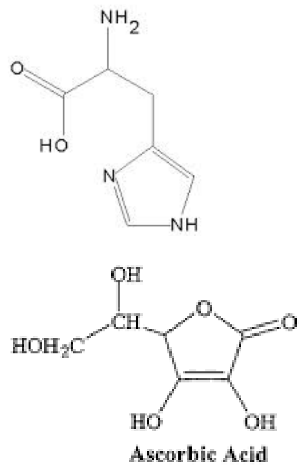


Figure 2: The efficiency of VT (inhibitor) against its concentration at 30° - 50°C.



Glutamic acid (amino acid)

Fig. 3: Chemical compounds in VT responsible for its inhibitory property.

The chemisorption of these VT components on aluminium minimizes the area on the metal exposed to the acidic attack. This leads to an increase surface coverage (Table 1) which is a proof of the enhanced inhibitor adsorption. Fitting the surface coverage values **(ф)** graphically to different adsorption isotherm, a straight line with linear correlation coefficient, R^2 of 0.9501 is obtained, when $VT_c/ф$ is plotted against C. This is a confirmation that VT inhibited aluminium corrosion by its adsorption on its surface which corresponds to the isotherm of Langmuir.

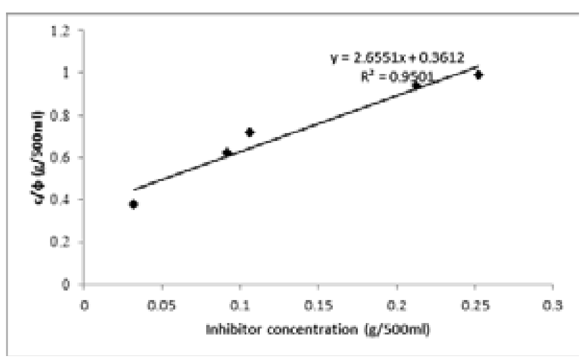


Fig. 4: The isotherm of the adsorption of VT on the surface of aluminium in 0.5M HCl (Langmuir).

3. CONCLUSION

African black velvet tamarind (VT) significantly inhibited the dissolution of aluminium in 0.5M hydrochloric acid (96% efficient at 50°C with 0.25g/500ml VT concentration). The

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negative value of the standard free energy change, ΔG^{o}_{ads}-87.43KJ mol^{-1} proved the spontaneity of VT adsorption on Al surface. The mechanism of the inhibition process was through its chemical adsorption on the metal surface which perfectly fit into the adsorption isotherm of Langmuir.

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