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Delonix regia extracts as non – toxic corrosion inhibitor for acid corrosion of mild steel in HCl solution

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The corrosion inhibition properties of *Delonix regia* leaf extract (DLE), flower extract (DFE) and seed extract (DSE) in 0. 5 M HCl solutions were studied using weight loss technique. *D. regia* extracts inhibited the corrosion of mild steel in HCl solution. The inhibition efficiency increased with increasing concentration of the extracts at 30°C. The seed extract (DSE) was found to be more effective than both the leaf (DLE) and flower extracts (DFE) at the lowest concentration. The results obtained revealed that the adsorption of the inhibitor molecule onto mild steel surface accords with Lanqmuir adsorption isotherm.

Key words: Acid corrosion, adsorption, corrosion inhibitor, mild steel, *Delonix regia*.

INTRODUCTION

The use of synthetic compounds as corrosion inhibitors are desirable due to their metal protecting properties , however, the problem of toxicity, non-degradability and environmental pollution posed by these compounds have been of serious concern (Obi- Egbedi et al., 2012; Babatunde et al., 2011). Consequently, attention has been focused on the need to design and develop green or non-toxic corrosion inhibitor to replace toxic ones for a sustainable development (Babatunde et al., 2011; Abiola and Tobun, 2010; Abiola et al., 2011, 2007, 2002). In our previous works (Abiola et al., 2007) we studied the effect of Delonix regia extract on acid corrosion of aluminium in HCl solution using chemical techniques. The D. regia extract inhibited the acid corrosion of aluminium in HCl solution and the inhibitive action was ascribed to the presence of phytochemicals in the extract.

In furtherance of our interest on the development of non-toxic corrosion inhibitors, this paper reports the investigation on the inhibitive effects of the extracts of leaf, flower and seed of *D. regia* on the acid corrosion of mild steel in 0.5 M HCl solution at 30°C.

MATERIALS AND METHODS

The test specimens of dimensions 5 × 2 × 0.07 cm were mechanically press-cut from mild steel sheet of 0.04 cm in thickness and 97.9% purity. The mild steel samples were prepared, degreased and cleaned as described earlier (Abiola et al., 2002; Abiola and Oforka, 2004). HCl was of analytical grade and 0.5 M HCl was employed as the aggressive solution for this study. The stock solution of the plant extract was prepared as reported previously (Abiola et al., 2007). The stock solution of the extract

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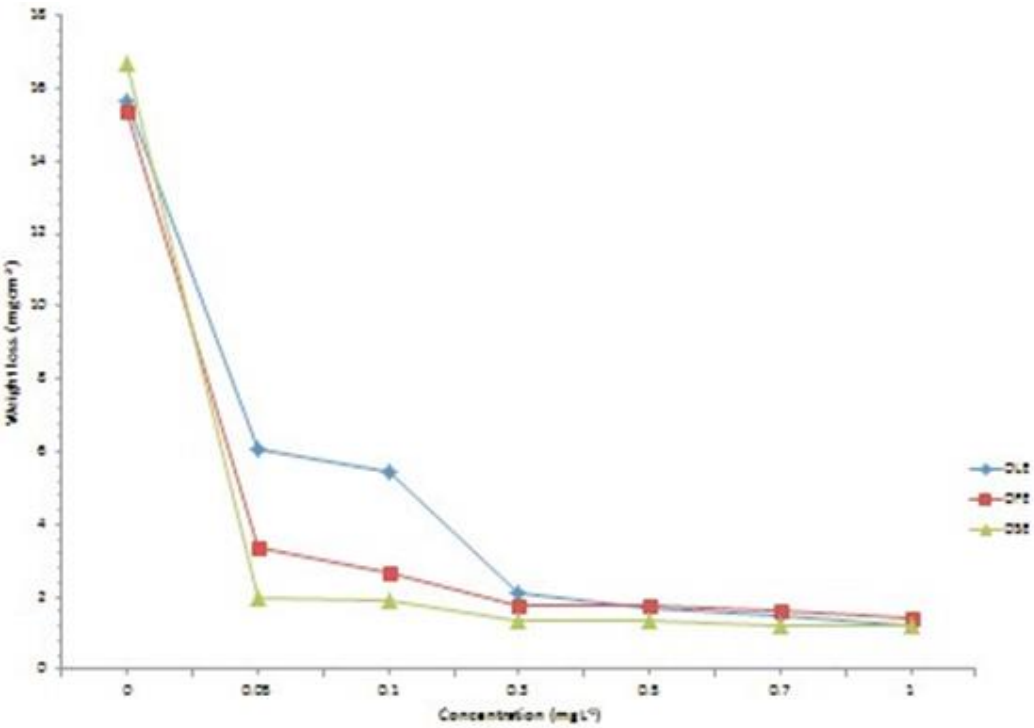

Figure 1. Relation between material loss and extract concentration for mild steel in 0.5 M HCl solution for 4 h immersion period.

was diluted with appropriate quantity of 0.5 M HCl solution to obtain inhibitor test solutions of 50-1000 mg/L concentrations. The procedure for weight loss determination was similar to that reported earlier (Abiola and Oforka, 2002; 2004).

According to this method (Abiola et al., 2002; Abiola and Oforka, 2004) previously weighed mild steel coupons were immersed in 100 ml open beakers containing 100 ml of 0.5 M HCl (blank) and then with addition of different extract concentrations to the 0.5 M HCl (50-1000 mg/L) at 30 ±0.3°C. The variation of weight loss was monitored after 4 hour immersion per coupon progressively for a total of 24 h at 30°C. The weight loss was calculated in mg as the difference between the initial weight and the weight after the removal of the corrosion product. The experimental readings were recorded to the nearest 0.0001 g on a Mettler digital analytical balance (digital analytical balance with sensitivity of ±1 mg). Duplicates experiments were conducted for each concentration of the extract.

RESULTS AND DISCUSSION

The results obtained are presented in Figures 1-2 and Table 1 for three different extracts of *D. regia* from weight loss measurements. The amount of material loss (mg cm^{-2}) decreases significantly with increasing concentration of DLE, DFE and DSE extracts, as presented in Figure 1. The addition of the three extracts resulted in noticeable reduction in the amount of material loss from the surface of the mild steel in comparison with that of control (0.5 M HCl) at 30°C. As seen in Figure 1, the weight loss decreased by a factor of 2.9, 5.8 and 8.7 over that of control at 100 mg L^{-1} concentration for the three extracts. This indicates that the three additives inhibit the acid corrosion of mild steel in HCl solutions.

The values of percentage inhibition efficiency (% E) and surface coverage (è) were determined for 4 h immersion periods from the material loss using the following equations (Abiola et al., 2011):

$$E\% = [w_u - w_b/w_u] \times 100 \quad (1)$$

$$è = E\% / 100 \quad (2)$$

Where; w_u and w_b are the uninhibited and inhibited weight loss respectively.

The values of percentage inhibition efficiency at different extract concentration are listed in Table 1. Table 1 indicates that *D. regia* extracts act as good corrosion inhibitor for the acid corrosion of mild steel in 0.5 M HCl solution. The % inhibition efficiency increases with increasing extracts concentration and % inhibition efficiencies were relatively high in 0.5 M HCl solution (65.3% for DLE, 82.6% for DFE and 88.6% for DSE) at 100 mg L^{-1} of extract concentration. The seed extract (DSE) was found to be more effective than both the flower (DFE) and leaf (DLE) extracts at lower concentrations of 50 and 100 mg L^{-1}.

The *D. regia* extract contains 4-hydroxybenzoic acid, gallic acid, 3,4-dihydrroxycinnunmic acid, 3,5-dinitrobenzoic acid, alkaloid, L-azetidine-2-carboxylic

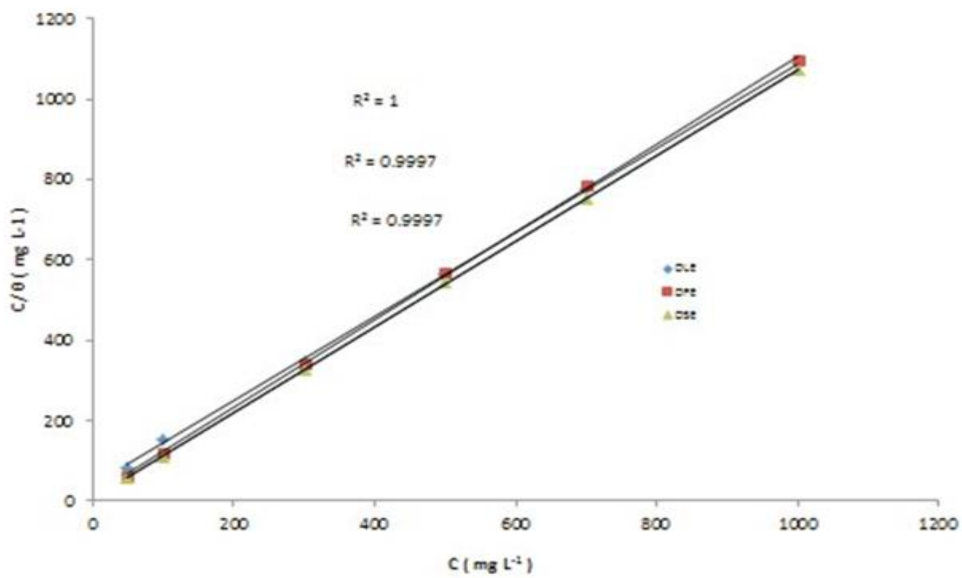

Figure 2. Langmuir adsorption model on the mild steel surface of *D. regia* extracts in 0.5 M HCl solution for 4 h immersion period at 30°C.

Table 1. Percentage inhibition efficiencies of mild steel immersed for 4 h at 330°C in 0. 5 M HCl solution in the presence of three different extracts of *D.regia*.

Percentage inhibition efficiency			**At different**	**Concentrations of inhibitor**		
Inhibitor	**50 mg/ L**	**100 mg/L**	**300 mg/L**	**500 mg/L**	**700 mg/ L**	**1000 mg /L**
DLE	61.1	65.3	86.3	89.3	90.5	92.5
DFE	78.2	82.6	88.3	88.3	89.4	90.8
DSE	88.3	88.6	91.9	92.0	92.6	92.7

acid, amine base, 3,4-diydroxybenzaldehyde, chlorogenic acid, kaempferol-3-glucoside, cyanidine-3-O-glucoside, cyanidine-3-O-rutinoside and coumarin (Chou and Lev, 1992; Sharma and Arora, 2015). The inhibition properties of *Delonixregia* is ascribed to the presence of these organic compounds in the extracts. Organic compounds having centers for pie electrons and functional groups -OR, -NR2 and /or –SR have been reported as corrosion inhibitors for metals in acid solutions (Abiola et al., 2015; Abiola, and James, 2010; Abdel-Gaber et al., 2006; Bhawsar et al., 2015). The adsorption of these compounds on the metal surface reduces the surface area that is available for the attack of the aggressive ion from the acid solution. The material losses decrease with increase in extract concentration due to higher degree of surface coverage as a result of enhanced inhibitor adsorption (Figure 1). Similar view has been expressed in our previous reports (Babatunde et al., 2011; Abiola and Tobun, 2010; Abiola et al., 2011, 2007, 2015; Abiola, and James, 2010) and other workers on inhibition of metals in acid solutions by plant extracts (Abdel-Gaber et al., 2006; Bhawsar et al., 2015).

Values of è were tested graphically for fit to different isotherms. As presented in Figure 2, straight line is obtained when C/è isplotted against C and the linear correlation coefficients of the fitted data are good (0.998). This confirms that the inhibition is due to the adsorption of the active organic compounds onto the metal surface and the adsorption obeys the Lanqmuir's adsorption isotherm (Babatunde et al., 2011; Abiola and Tobun, 2010; Abiola et al., 2011, 2007) expressed as:

$$\frac{C}{\theta} = \frac{1}{k} + C \qquad (3)$$

Where C is the inhibitor concentration and K the equilibrium constant for the adsorption/ desorption of process of the inhibitor molecules on the metal surface.

Conclusions

(i) Results obtained revealed that the three extracts of Delonixregia act as efficient corrosion inhibitors of the mild steel in acid solution.

(ii) The inhibitory action of the extract is ascribed to the adsorption of the phytochemicals in the plant.
(iii) The adsorption of inhibitors on the mild steel surface follows Langmuir adsorption isotherm.
(iiv) The extract can be added to acid solution as a non-toxic corrosion inhibitor for mild steel in HCl Delonixregia solution.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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