

Investigation of Corrosion inhibition potentials of *Landolphia dulcis* Extract on Mild Steel in Acidic Medium

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Abstract

The effectiveness of *Landolphia dulcis* extract; an eco-friendly corrosion inhibitor on mild steel in acidic medium was studied using gravimetric (weight loss) and gasometric (hydrogen evolution) techniques considering the kinetic and thermodynamic parameters necessary in corrosion test. The experimental results obtained revealed excellent inhibition properties for the extract even at higher temperatures (333 & 353 K) with the highest inhibition efficiency of 84.09% which is attributed to the presence of heteroatoms seen in the FT-IR spectrum. The calculated values of activation energy (E_a) were all positive which increased with increase in the concentration of the extract indicating a higher energy barrier required for further deterioration of the metal and the average activation energy of 27.17 kJ/mol denotes physical adsorption mechanism. Fairly linear rate constants deduced that the process is of first order reaction. Also, the feasibility of reaction is evidenced by negative ΔG_{ads} values. The experimental data best fitted Langmuir and Temkin isotherm models depicting a monolayer formation as well as strong interaction between the metal substrate and the inhibitor molecules.

Key words: Mild steel, Kinetic studies, Thermodynamic studies, Adsorption studies, Corrosion inhibitor and *Landolphia dulcis*

1.0 Introduction

Metals are broadly used in human activities especially in manufacturing industries due to their excellent mechanical and electrical properties [1,2]. To preserve the desired state of these metals, hindering the corrosion pathway is paramount. Corrosion is probably the most common undesired phenomenon that leads metals to become weaker [3]. The innate process originates from the electrochemical interaction of metal substrate with the corrosive environment. Sulfides, oxides, and others are generated through reactions between the metal surface and the corrosive medium [4]. Amongst metals, mild steel is the most widely used in the oil, food, energy, chemical, and construction industries due to its different applications, most of which are based on its excellent mechanical properties. This metal shows high mechanical resistance, durability, and toughness, among others, which makes it a highly available material and at a relatively low cost. Consequently, solutions to problems related to the degradation by the corrosion of mild steel, is an elevated topic of priority. To a lesser extent, copper and aluminum alloys are studied as well. The high cost associated with corrosion, due to the replacement of rusted metals, can be reduced by using corrosion inhibitors [5].

The disposition of a metal to wear out depends on the grain structure of the metal, its composition as formed during alloying, or the temperature for deformation of a single metal surface developed during fabrication. Corrosion prevention would be more practical than trying to eliminate it completely. Given that the environment plays an important part in corrosion, corrosion mechanisms can be as varied as the environments to which a substance is exposed and thus may be complex to understand. Factors that enhance corrosion of metal include reactivity of metal, presence of impurities, presence of air, moisture, gases like sulphur dioxide and carbon dioxide, and presence of electrolytes. Corrosion prevention and retardation point towards addressing these factors [6].

From the beginning, reduction of corrosion has been managed by various methods including cathodic protection, process control, reduction of the metal impurity content, and application of surface treatment techniques, as well as incorporation of suitable alloys. However, the use of corrosion inhibitors has proven to be the easiest and cheapest method for corrosion protection and prevention in

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acidic media [7]. These inhibitors slow down the corrosion rate and thus prevent monetary losses due to metallic corrosion on industrial vessels, equipment, or surfaces. Inorganic and organic inhibitors are toxic and costly, thus recent investigations tailored toward the use of agricultural wastes/ plant materials which are also known as green inhibitors because they are environmentally friendly and readily available. Few of this green inhibitors are as follows: *Ficus exasperata* extract [8]; coconut leaves [9]; an apple-based green [10]; *Commiphora caudata* [11]; *Talinum triangulare* [12]; *Eucalyptus* leaf extract [13]; Extract of *Olea europaea* L. Leaves [14]; Pigeon pea leaf [15]; *Xanthium strumarium* leaves extract [16].



Figure 1. *landolphiadulcis* (LD) Plant.

This work focused on the exploration of the leaves of *Landolphiadulcis* as an ecofriendly inhibitor in acidic medium on mild steel corrosion using gravimetric and gasometric techniques.

2.0 Experimental Design

2.1 Materials

The mild steel coupons used were obtained from Urata market, Aba in Abia State, Nigeria. The surfaces of the mild steel coupons were polished and treated using modified method according to Daniel *et al.* [17].

2.2 Preparation of the plant Extract

The leaves of *Landolphia dulcis* were washed and dried at room temperature and ground into powdered form. Successive 100 g of each plant powder were extracted with methanol using a soxhlet extractor for 24 hours until a quantitative yield was gotten. The extract was distilled at 60°C in a water bath until almost the entire methanol evaporated. Exactly 1.0 g of each plant extract was digested in 1000 ml of 5.0 M H₂SO₄ and left to cool for 24 hours. The resultant solutions were filtered and stored in a 1.0 L volumetric flask each. Test solutions of extract of the leaves of concentrations 2.0, 3.0, 4.0 and 5.0 g were prepared as above. These solutions were then used for the corrosion inhibition test.

2.3 Experimental Techniques

2.3.1 Weight loss techniques

The weighed polished mild steel coupons were suspended in beakers containing 100 ml of the acid test solutions (5.0 M H₂SO₄) at room temperature. The mild steel coupons were completely immersed in the test solutions and retrieved every hour for 1 – 5 hours. The retrieved coupons were quenched in a washing solution containing 22 % NaOH and 22 g/L zinc dust, washed, scrubbed with brittle brush under fast flowing water, rinsed with methanol, dried using acetone, and re-weighed. The weight loss of the mild steel was evaluated as the difference in the initial and final weight of the coupons. The experiment was carried out for *Landolphia dulcis* leaf extract using concentrations of 1.0, 2.0, 3.0, 4.0 and 5.0 g/L at 30 °C. From the weight loss data, the corrosion rate (CR), Inhibition efficiency (IE%) and Surface coverage(θ) were calculated respectively using equation 1-3 [18]:

$$CR = \frac{WL}{At} \quad (1)$$

$$\theta = \left[\frac{CR_{blank} - CR_{inh}}{CR_{blank}} \right] \quad (2)$$

$$\%IE = \left[\frac{CR_{blank} - CR_{inh}}{CR_{blank}} \right] \times 100 \quad (3)$$

where W_L is weight loss in g, A is the coupon surface area and t , the period of immersion in hours and CR_{blank} and CR_{inh} are the corrosion rates in the absence and presence of the plant extracts respectively.

2.3.2 Gasometric Technique

In the gasometric measurement the volume of hydrogen evolved was determined following modified procedures previously described by Obike *et al.* [19]. The rate of evolution of the hydrogen gas (R_h) was determined from the slope of the graph of volume of hydrogen gas evolved (VHE) versus time (t) according to equation 4.

$$R_h \left(\frac{cm^3}{min} \right) = \frac{(V_{Ht}^o - V_{Ht}^i)}{\Delta t} \quad (4)$$

where V_{Ht}^o and V_{Ht}^i are the volume of hydrogen gas evolved at time t and R_h is the rate at which the hydrogen gas is evolved. The inhibition efficiency (I %) was also determined using the equation 5.

$$I\% = \left(\frac{R_{h_{blank}} - R_{h_{inh}}}{R_{h_{blank}}} \right) \times 100 \quad (5)$$

where $R_{h_{blank}}$ and $R_{h_{inh}}$ are the rates of hydrogen evolution in the absence and presence of plant extract respectively.

3.0 Results and Discussion

3.1 Characterization of the L.D plant using FT-IR

To investigate the functional groups, present in the ecofriendly inhibitor used for the corrosion test at different concentrations, FT-IR analysis was carried out on the crude extract of the plant. Figure 2 shows the spectrum of L.D which has the characteristic peaks of the extract. The peaks at 3357.96 cm^{-1} and 3415.86 are specific to N-H stretch for Amines. The peak having the value 1721.32 cm^{-1} is specific to the C=O group for aldehydes. The $1079.58.00 \text{ cm}^{-1}$ peak corresponds to the C=O stretch specific to carboxylic acids. The peaks 1783.02 cm^{-1} is a characteristics of C=O acid chlorides, whereas 1536.04 cm^{-1} and 1597.80 cm^{-1} are for C=C stretches for aromatic rings. The peaks 1289.00 cm^{-1} and 1053.54 cm^{-1} correspond to C-O for esters and ethers respectively.

The performance of a corrosion inhibitor is related to the chemical structure and physicochemical properties of the compound like functional groups, electron density at the donor atom, p-orbital character, and the electronic structure of the molecule [20]. Several research works have shown that heteroatoms and other notable functional groups are responsible for the corrosion inhibition properties of most corrosion inhibitors [21]. Heteroatoms are found to have higher basicity and electron density and thus act as corrosion inhibitors [20]. When an H atom attached to the C in the ring is replaced by a substituent group ($-\text{NH}_2$, NO_2 , $-\text{CHO}$ or $-\text{COOH}$) it improves corrosion inhibition [22].

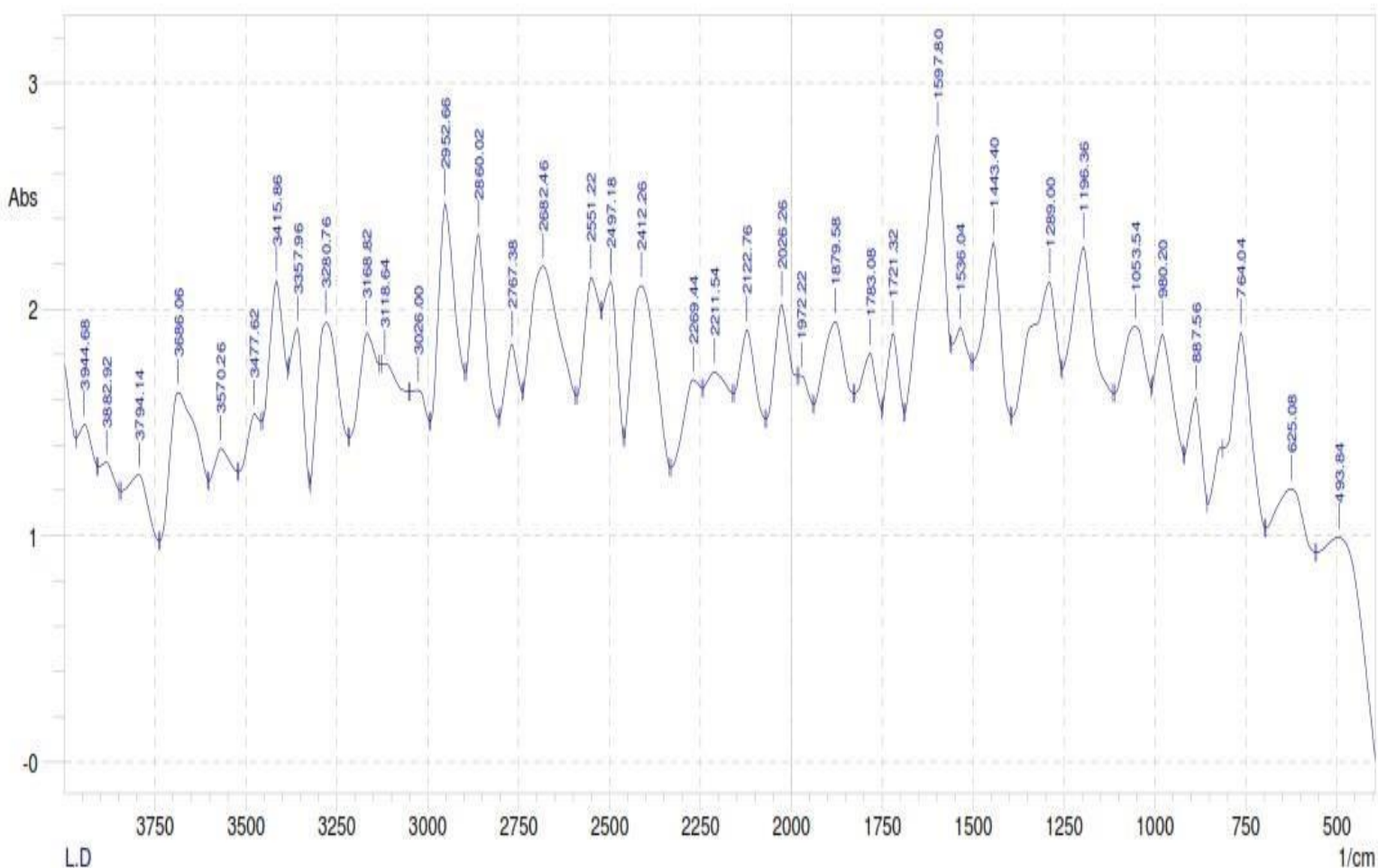


Figure 2: FTIR spectrum of L.D extract

3.2. Effect of Time and Concentration

Effect of exposure time on corrosion inhibition of *landolphiadulcis* (LD) on mild steel in H_2SO_4 solution.

Figure (3) and Table 1 shows the variation of weight loss with time for corrosion of mild steel in 5.0 M H_2SO_4 at different concentrations of L.D at 30 °C. From Fig (2) it is seen that weight loss of mild steel in 5.0 M H_2SO_4 solution increased with time progressively and the blank solution showed the highest weight loss in 5 hours, which is an indication that the rate of corrosion of mild steel in acid medium increases with time. This could be attributed to increase in rate of ionization and diffusion of active species in the corrosion process, more so the rate of chemical reaction increases with increase in acid concentration as the formation of Iron tetraoxosulphate (VI) ion is also corrosive to iron.

An inference was drawn from Fig 4: that weight loss of mild steel in 5.0 M H_2SO_4 solution decreased progressively with increasing concentration of the extract and as immersion time decreased, the blank solutions showed the highest weight loss although the weight loss after the 4th and 5th hour was almost the same. The results indicate that the rate of corrosion of mild steel in acidic medium decreases with increasing concentration of the extract.

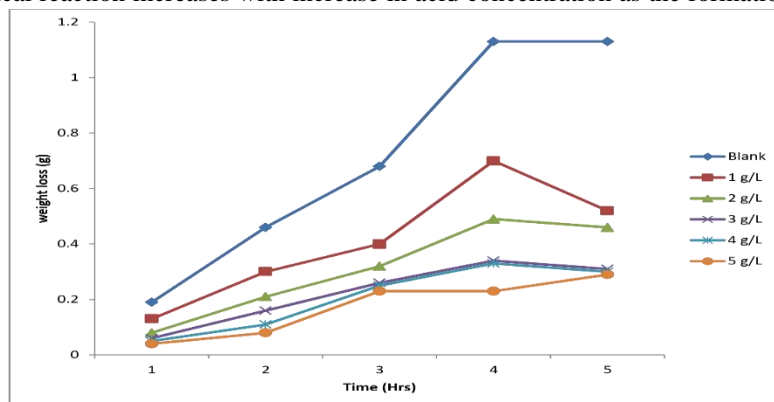


Figure 3: Variation of weight loss with time for the corrosion of mild steel in 5.0 M H₂SO₄ solution in the absence and presence of different concentrations of L.D extract

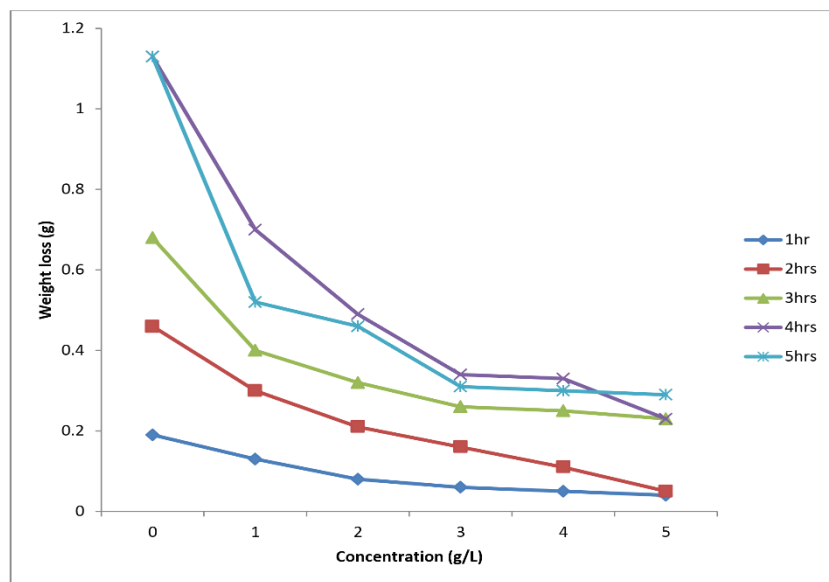


Figure 4: Variation of weight loss with inhibitor concentration for the corrosion of mild steel in 5.0 M H₂SO₄ solution using L.D extract.

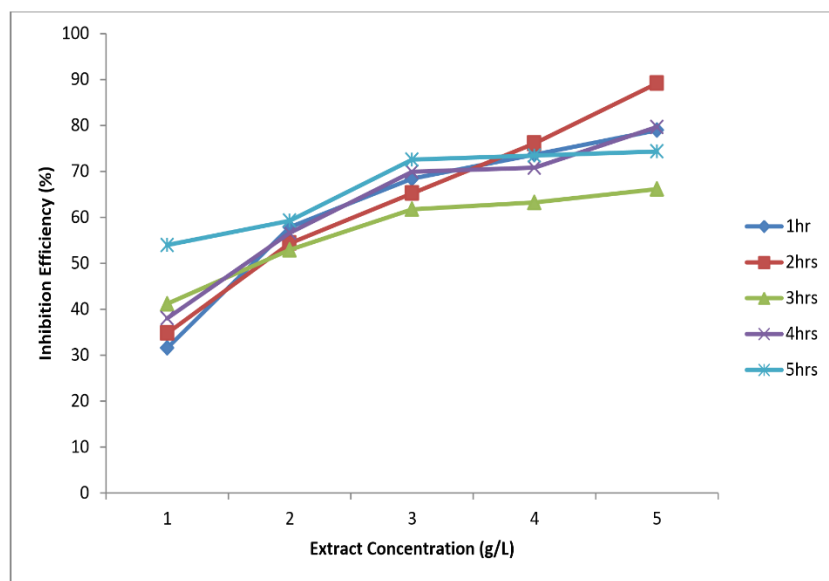


Figure 5: Variation of Inhibition Efficiency of L.D extract with inhibitor concentration for corrosion control of mild steel in 5.0 M H₂SO₄

It was seen from the plot (Figure 5) that the inhibition efficiency of the plant extract increased progressively with increase in the concentration of the extract. The plant extract had its highest efficiency after immersion time of 2 hours with extract concentration of 5 g/L. This indicates that the extract inhibited the corrosion of mild steel in 5.0 M H₂SO₄ solution as their concentration increased.

In summary the obtained results indicate that L.D extract inhibits corrosion of mild steel to an appreciable level with increasing inhibitor concentration at 30 °C. Also the result of some researchers like Obot *et al.* [23], Okafor *et al.* [24], Salawuet *et al.* [24] and Obike *et al.* [25] followed the same trend in weight loss (gravimetric) analysis for corrosion of metals in acid media.

Table 1: Weight loss (g) data for mild steel coupons in 5.0 M H₂SO₄ solution with different concentrations of extract of *Landolphiadulcis* at 30 °C

| Concentration of LD (g/L) | Time (hours) | | | | |
|------------------------------|--------------|------|------|------|------|
| | 1 | 2 | 3 | 4 | 5 |
| Blank | 0.19 | 0.46 | 0.68 | 1.13 | 1.13 |
| 1 | 0.13 | 0.30 | 0.40 | 0.70 | 0.52 |
| 2 | 0.08 | 0.21 | 0.32 | 0.49 | 0.46 |
| 3 | 0.06 | 0.16 | 0.26 | 0.34 | 0.31 |
| 4 | 0.05 | 0.11 | 0.25 | 0.33 | 0.30 |
| 5 | 0.04 | 0.05 | 0.23 | 0.23 | 0.29 |

Table 2: Corrosion rate (mg/cm²hr) and inhibition efficiency (%) of mild steel in 5.0 M H₂SO₄ by the L.D extracts

| Concentration of L.D (g/L) | Time (Hours) | | | | | | | | | |
|-------------------------------|---|-------|-------|-------|-------|---------------------------|-------|-------|-------|-------|
| | Corrosion rate (mg/cm ² /hr) | | | | | Inhibition efficiency (%) | | | | |
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Blank | 11.84 | 14.34 | 14.13 | 17.61 | 14.09 | - | - | - | - | - |
| 1 | 8.10 | 9.35 | 8.31 | 10.91 | 6.48 | 31.59 | 34.54 | 41.19 | 38.05 | 54.01 |
| 2 | 4.99 | 6.55 | 6.65 | 7.64 | 5.73 | 57.85 | 54.32 | 52.94 | 58.61 | 59.33 |
| 3 | 3.74 | 4.99 | 5.40 | 5.30 | 3.86 | 68.41 | 65.20 | 61.78 | 69.90 | 72.60 |
| 4 | 3.11 | 3.43 | 5.19 | 5.14 | 3.74 | 73.73 | 76.08 | 63.27 | 70.81 | 73.46 |
| 5 | 2.49 | 2.49 | 4.78 | 3.58 | 3.62 | 78.97 | 82.63 | 66.17 | 79.67 | 74.31 |

3.2.2 Kinetic considerations

A plot of the logarithm of $\left(\frac{W_o}{W_f}\right)$ against time was used to know if the data will fit into first relation according to equation 6. This conforms to the first-order reaction kinetics, formulated by Okafor *et al.* [26].

$$\text{Log}W_f = \text{Log}W_o - kt \tag{6}$$

Where W_o is the initial weight before immersion, W_f is weight after immersion at time t , k is the rate constant and t is time. The values of the rate constants, k , were obtained from the slopes of the plots of $\log (W_o/W_f)$ against time. From the rate constant values, the half-life values, $t^{1/2}$, of the metal in the test solutions were calculated using equation 6 [27].

$$t^{1/2} = \frac{0.693}{k} \tag{7}$$

Figure 5 shows the plot of $\log (W_o/W_f)$ against time according to equation (6). The values of the rate constants, k , were obtained from the slopes of the linear plots and from the rate constant values, the half-life values, $t^{1/2}$, of the mild steel in the test solutions were calculated. The values are presented in Table 3 for mild steel corrosion in different concentrations of the extract.

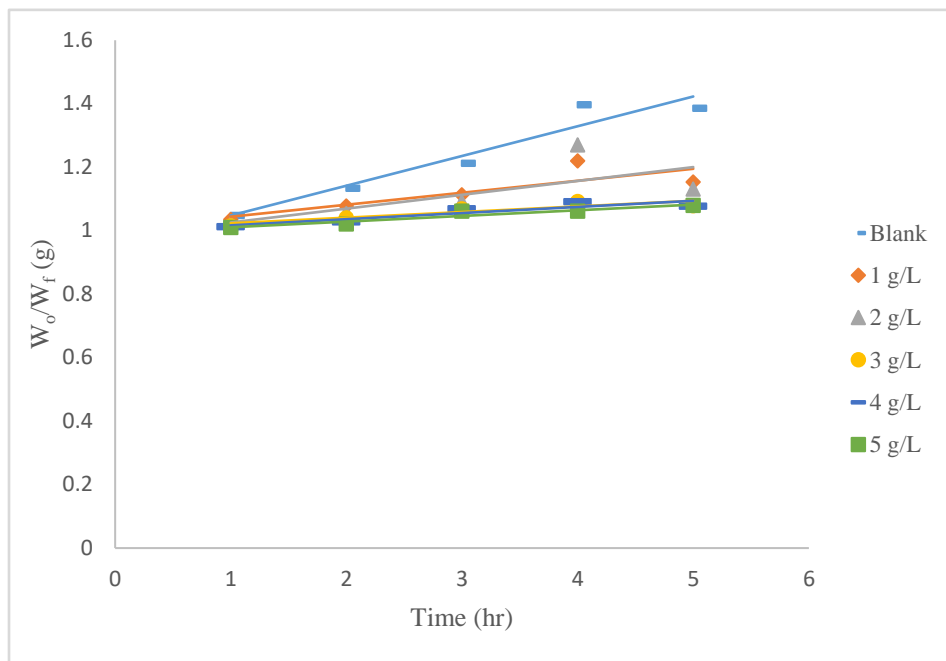


Figure 6: Plot of Log (W_0/W_t) against time for L.D leaves extract in 5.0 M H_2SO_4

Table 3: Rate constant and half -life values for mild steel 5.0 M H_2SO_4 in different concentrations of the leaves extract at 30 °C.

| Kinetic Parameters | Concentrations of K.C (g/L) | | | | | |
|--------------------|-----------------------------|-------|-------|-------|-------|-------|
| | Blank | 1 | 2 | 3 | 4 | 5 |
| k | 0.094 | 0.038 | 0.034 | 0.018 | 0.017 | 0.016 |
| $t^{1/2}$ (hr) | 7.37 | 18.24 | 20.38 | 38.50 | 40.76 | 43.31 |

The fairly closeness of rate constant (k) values seen in Table 3 indicates first-order reaction kinetics for the corrosion inhibition of the mild steel and in 5.0 M H_2SO_4 solutions and a similar conclusion was drawn in Okafor *et al.*[28]. From Table 3 for mild steel corrosion inhibition, the half-life values were observed to increase apparently with increase in concentration of the leaves extract, indicating decrease in the dissolution rate of the mild steel in the solutions with increase in the leaves extract concentration. This indicates that increase in the concentration of the extract prolonged the life span of the mild steel thus increasing corrosion inhibition[17].

3.3. Effect of Temperature on the corrosion of mild steel in 5.0 M H_2SO_4 using gasometric technique

The values for the rate of hydrogen evolution and inhibition efficiency are shown in Table 4 while Figures 7 and 8 showed the Variation of volume of hydrogen evolved, VHE, with time (minutes) for mild steel in 5.0 M H_2SO_4 with and without L.D extract at 333 K and 353 K temperature. From figures 7 and 8, the rate of hydrogen evolution presented in Table 4 was gotten and it was observed that the presence of L.D extract decreased the volume and rate of hydrogen evolution, and consequently decreased the corrosion rate of the mild steel in 5.0 M H_2SO_4 solutions compared to the blank. Further inspection of Table 4 showed that the rate of hydrogen evolution increased with increase in temperature and reduced with increase in the concentration of the plant extract.

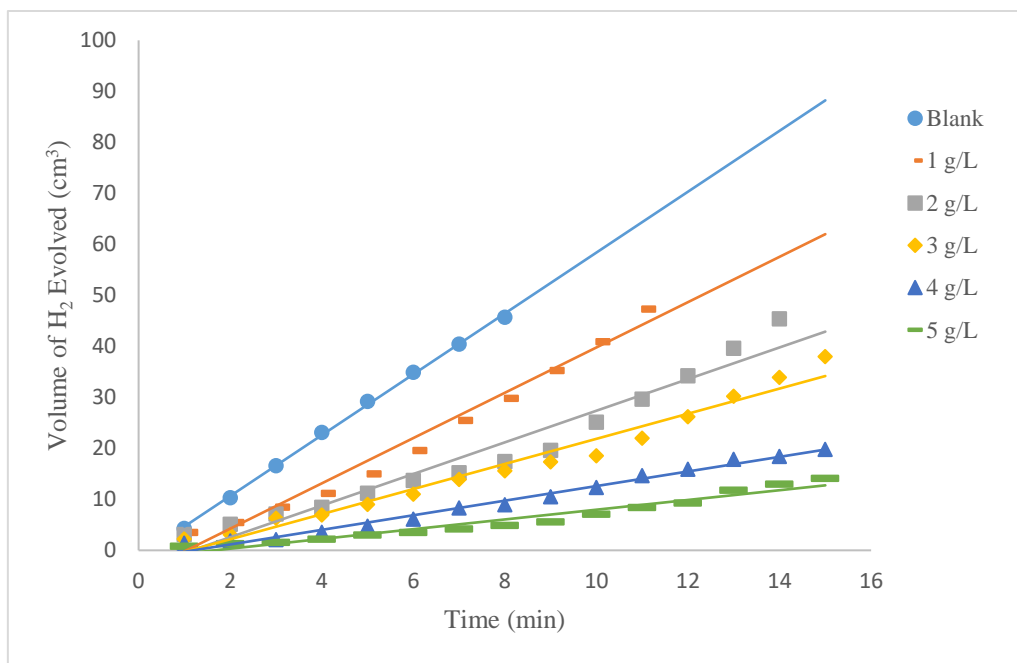


Figure 7: Variation of volume of Hydrogen evolved (cm³) with time (min) for mild steel in 5.0 M H₂SO₄ with and without L.D extract at 333 K

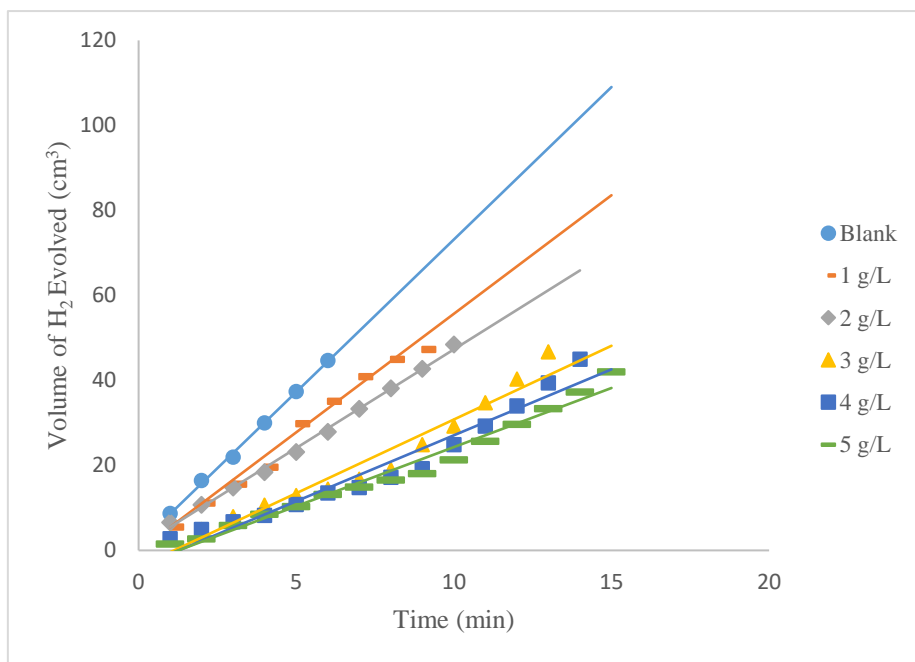


Figure 8: Variation of volume of Hydrogen evolved (cm³) with time (min) for mild steel in 5.0M H₂SO₄ with and without L.D extract at 353 K

Table 4: Gasometric data for rate of hydrogen evolution (cm³/min) and inhibition efficiency (%) on mild steel corrosion in 5.0 M H₂SO₄ solution

| Concentration of KC (g/L) | Rate of Hydrogen Evolution (cm ³ /min) | | Inhibition Efficiency (I%) | |
|------------------------------|---|-------|----------------------------|-------|
| | 333 K | 353 K | 333 K | 353 K |
| Blank | 5.97 | 7.17 | - | - |
| 1 | 4.44 | 5.58 | 25.63 | 22.17 |
| 2 | 3.10 | 4.47 | 48.07 | 37.66 |
| 3 | 2.46 | 3.47 | 58.79 | 51.60 |
| 4 | 1.43 | 3.10 | 76.05 | 56.76 |
| 5 | 0.95 | 2.78 | 84.09 | 61.23 |

3.3.1 Thermodynamic studies and adsorption isotherm for mild steel in 5.0M H₂SO₄

In examining the effect of temperature on the corrosion process, the activation (E_a) was calculated using the condensed Arrhenius equation according to [29].

The values of activation energy and heat of adsorption for the corrosion of mild steel with the plant extract in 5.0 M H₂SO₄ was calculated using equation 8 and 9 [29, 30] and presented in Table

$$E_a = 2.303R \left[\text{Log} \left(\frac{R_2}{R_1} \right) \times \frac{T_1 T_2}{T_2 - T_1} \right] \tag{8}$$

$$Q_{ads} = 2.303R \left[\text{Log} \left(\frac{\theta}{1-\theta_1} \right) - \text{Log} \left(\frac{\theta_1}{1-\theta_1} \right) \times \frac{T_1 T_2}{T_2 - T_1} \right] \tag{9}$$

where; R₁ and R₂ are the corrosion rates; θ₁ and θ are degrees of surface coverage at temperature T₁ and T₂ respectively and R is the molar gas constant.

Basic information on the interaction between the inhibitor and the mild steel surface was provided by the Langmuir, Freundlich and Temkin adsorption isotherms[31] to fit the experimental data as shown in Figures 9, 10 and 11. Table 5 shows the linear correlation coefficient R² of the fitted data.

The K_{ads} values as gotten from Langmuir, Freundlich and Temkin isotherms were used to evaluate ΔG_{ads}, and ΔS_{ads} using equation 10 and 11. These values are presented in Table 5.

$$\Delta G_{ads}^o = -2.303RT \text{Log}(55.5K_{ads}) \tag{10}$$

$$\Delta G_{ads}^o = \Delta H_{ads} - T\Delta S_{ads} \tag{11}$$

Table 5: Values of the activation energy (E_a) and heat of adsorption (Q_{ads}) for mild steel coupons in 5.0 M H₂SO₄ solutions

| Concentration of K.C (g/L) | Activation Parameters and Heat of Adsorption | | |
|-------------------------------|--|---------------------------------|---------------------------|
| | E _a (kJ/mol) | Average E _a (kJ/mol) | Q _{ads} (kJ/mol) |
| Blank | 9.00 | | - |
| 1 | 11.12 | | -7.09 |
| 2 | 17.91 | 27.17 | -11.93 |
| 3 | 16.75 | | -6.38 |
| 4 | 37.82 | | -14.30 |
| 5 | 52.24 | | -15.17 |

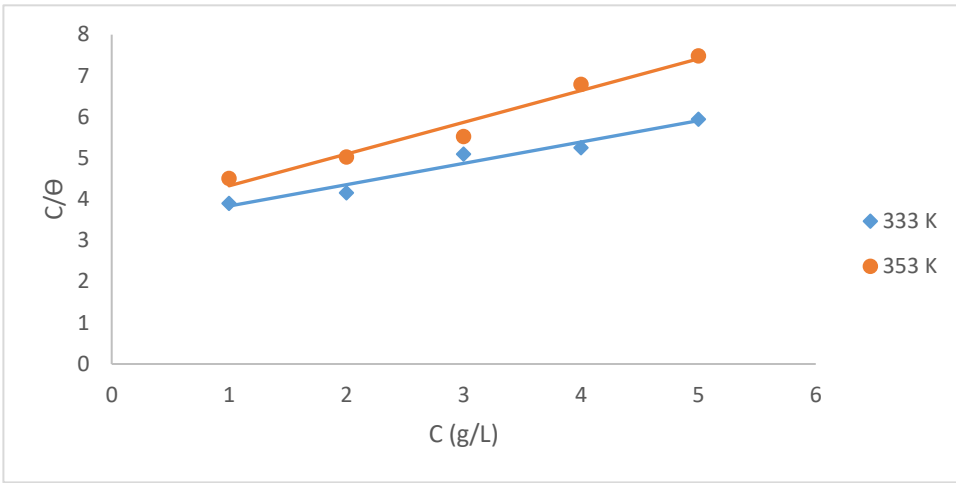


Figure 9: Langmuir Plot for L.D leaves extract in 5.0 M H₂SO₄

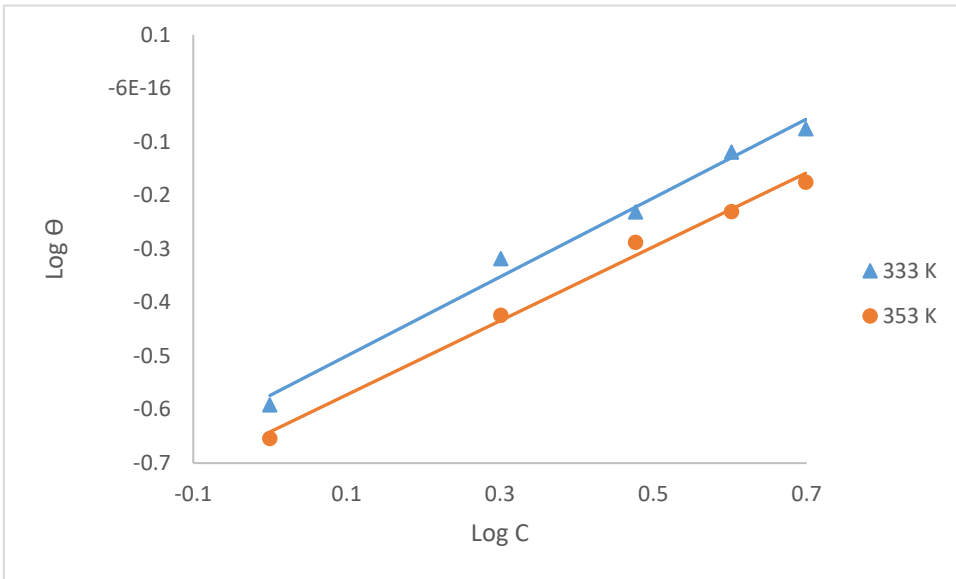


Figure 10: Freundlich Plot for L.D leaves extract in 5.0 M H₂SO₄

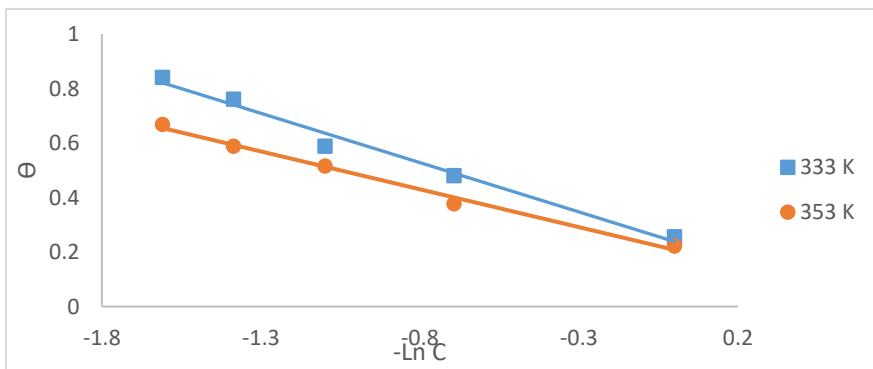


Figure 11: Temkin Plot for L.D leaves extract in 5.0 M H₂SO₄

Table 6: Calculated values of K_{ads} , ΔG_{ads} , ΔS_{ads} , R^2 from the Langmuir, Freundlich and Temkin Isotherm Models

| Isotherm Models | Parameters | Values at specific temperature | |
|-----------------|---------------------------|--------------------------------|--------|
| | | 333 K | 353 K |
| Langmuir | K_{ads} | 1.16 | 0.80 |
| | ΔG_{ads} (kJ/mol) | -11.54 | -10.49 |
| | ΔS_{ads} (J/molK) | -0.15 | -0.14 |
| | R^2 | 0.99 | 0.99 |
| Freundlich | K_f | 0.57 | 0.45 |
| | ΔG_{ads} (kJ/mol) | -9.55 | -8.92 |
| | ΔS_{ads} (J/molK) | -0.16 | -0.15 |
| | R^2 | 0.98 | 0.98 |
| Temkin | K_{ads} | 0.57 | 0.64 |
| | ΔG_{ads} (kJ/mol) | -9.56 | -9.89 |
| | ΔS_{ads} (J/molK) | -0.16 | 0.15 |
| | R^2 | 0.99 | 0.99 |

The results showed that E_a values increased in the presence of LD extract compared to the blank system which is typical of physical adsorption [32-34]. Though the E_a values for L.D increased but at concentration of 3 g/L there was a slight variation. Further inspection of the results as given in Table 5 revealed that E_a values increased with increase in the concentrations of L.D plant extract meaning a higher protection efficiency was attained due to decrease in the energy barrier for the reaction. The negative value of Q_{ads} was an indication that the process was exothermic. The average activation energy value of the inhibitor was 27.17 kJ/mol for L.D extract.

The value for entropy of adsorption, (ΔS_{ads}) was calculated by substituting corresponding values of ΔG_{ads} and ΔH_{ads} into equation 11. From Table 6, It was observed that the values of ΔG_{ads} were negative, an indication that the reaction was spontaneous and feasible (Saedah, 2013). The calculated value of the ΔG_{ads} that was lower than 20K/Jmol⁻¹ was also an indication that the process of adsorption is probably by physical adsorption. Generally, negative values of ΔG_{ads} up to -20 kJ mol⁻¹ are consistent with electrostatic interactions between the charged metal which signifies physical adsorption while values more negative than -40 kJmol⁻¹ involved charge sharing or transfer from the inhibitor molecules to the metal surface to form coordinate type of bond which signifies chemical adsorption [35]. The values of K_{ads} were positive in all cases, indicating a favorable adsorption [36].

The values of ΔS_{ads} were negative. This indicates that before the adsorption of inhibitor molecules on the mild steel coupon, inhibitor molecules might freely move in the bulk solution, but with progress in adsorption, inhibitor molecules become orderly adsorbed onto the coupons 'surface, resulting in a decrease in entropy [37].

For the Langmuir, Freundlich and Temkin isotherms (Figures 9, 10 and 11), linear plots were obtained. However, a comparison of the correlation coefficients of the Langmuir, Freundlich and Temkin isotherms as presented in Table 7 showed that the data fitted best into Langmuir and Temkin than the other isotherms [38]. Langmuir isotherm postulate monolayer adsorption of the adsorbate onto the adsorbent which is expected to have a correlation coefficient close to unity for best fitting while Temkin isotherm postulates strong interaction between the metal substrate and the inhibitor molecules. Thus, a monolayer of the extract species must have been formed onto the mild steel surface without lateral interaction between the adsorbed species.

4.0 Conclusion

Methanol leaf extract of *landolphia dulcis* (LD) was found to inhibit the corrosion of mild steel in 5.0 M H₂SO₄. The corrosion inhibition efficiency increased with increase in the concentration of the extract and decreased with increase in time and temperature. The process of adsorption proposed for the plant extract was physical adsorption as it was seen from the activation energy E_a values for both blank and the inhibited system lower than 80K/Jmol⁻¹. Furthermore, the decreasing values of the K_{ads} , from the Langmuir and Freundlich isotherms, as the temperature increased also show that the mechanism of adsorption was by physical adsorption. The

corrosion inhibition of the landolphia dulcise plant extract fitted best to Langmuir and Temkin isotherm which indicated that a monolayer of the extract species must have been formed onto the mild metal surface without lateral interaction between the adsorbed species. The corrosion inhibition efficiency (%I) in the 5.0 M H₂SO₄ solution exhibited by the plant extract was attributed to the stronger adsorption of the functional groups in the phytochemicals present in the plant extract unto the mild steel. Thus extracts of plant materials are environmental friendly, relatively less expensive and non-toxic or less toxic, hence, they can be used as corrosion inhibitors.

Conflict of Interest

Authors declare no conflict of interest

Funding

None

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