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Inhibition Effect of Alkaloids Extract from *Annona Squamosa* Plant on the Corrosion of C38 Steel in Normal Hydrochloric Acid Medium

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In this work, an alkaloids extract from *Annona squamosa* plant have been studied as possible corrosion inhibitor for C38 steel in molar hydrochloric acid (1 M HCl). Potentiodynamic polarization and AC impedance methods have been used. The corrosion inhibition efficiency increases on increasing plant extract concentration. Polarisation studies showed that *Annona squamosa* extract was mixed-type inhibitor in 1 M HCl. The inhibition efficiency of *Annona squamosa* extract was temperature-dependent and its addition led to an increase of the activation corrosion energy revealing a physical adsorption between the extract and the metal surface. The adsorption of the *Annona squamosa* extract followed Langmuir's adsorption isotherm. The inhibitive effect of *Annona squamosa* is ascribed to the presence of organic compounds in the extract. The examined extract is considered as non-cytotoxic substance.

Keywords: Plant extract, corrosion inhibitors, C38 steel, acidic media, adsorption.

1. INTRODUCTION

The study of corrosion of steel and iron is a matter of tremendous theoretical and practical concern and as such has received a considerable amount of interest [1, 2]. Acid solutions are widely used in industrial acid pickling, industrial acid cleaning and oil-well acidizing. It's requiring the use of corrosion inhibitors in order to restrain the corrosion attack on steel has been studied in some detail [3–9]. Several researchers studied the effect of natural products as corrosion inhibitors in different media [10–19]. 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 or/and antagonistic effects are often expected with these mixtures of inhibitors, that may affect their inhibition efficiency. Many plants are known to produce various types of alkaloids [20, 21]. Alkaloids such as papaverine, strychnine, quinine and nicotine were studied as corrosion inhibitors in acid medium [22]. The Annonaceae is a large family of tropical plants which, it's found to contain alkaloids [23–25]. *Annona squamosa* belongs to Annonaceae family and generally distributed in the tropics [23]. Sakhive et al. studied the inhibitive effect of *Annona squamosa* on the corrosion of mild steel in 1 M HCl and 0.5 M H_2SO_4 solutions [26]. However, no information about the nature of the extract and the mechanism of inhibition were given. In the present work, we focused on anti-corrosion activity of alkaloids extract from *Annona squamosa* plant. The alkaloids extract was evaluated as corrosion inhibitor for C38 steel in 1 M HCl solution by potentiodynamic polarization and electrochemical impedance spectroscopy. The effect of temperature on the corrosion behaviour of C38 steel in 1 M HCl with and without addition of plant extract was studied in the temperature range 25 – 55 °C. The thermodynamic functions of dissolution and adsorption processes were calculated from experimental polarisation data and the interpretation of the results are given. The adsorption of these plant extract on the C38 steel surface obeys the Langmuir adsorption isotherm. The toxicity of the alkaloids extract from *Annona squamosa* plant was determined using KB cells culture system.

2. EXPERIMENTAL

2.1. Electrode and solution

Corrosion tests have been carried out on electrodes cut from sheets of C38 steel. Steel strips containing 0.36% C, 0.66% Mn, 0.27% Si, 0.02% S, 0.015% P, 0.21% Cr, 0.02% Mo, 0.22% Cu, 0.06% Al and the remainder iron. The specimens were embedded in epoxy resin leaving a working area of 0.78 cm^2. The working surface was subsequently polished with 180 grit and 1200 grit abrading papers, cleaned by distilled water and ethanol. The solutions (1 M HCl) were prepared by dilution of an analytical reagent grade 33% HCl with doubly distilled water. All the tests were performed at ambient temperature (25 °C).

2.2. Preparation of plant extract

The fresh leaves and seeds of *Annona squamosa* plant were washed by water, shade dried, powdered into small pieces and the powdered leaves were extracted successively from crude extract by acid-base extraction, according to a previously described experimental procedure [27]. The alkaloids extract was purified by acid-base extractions with $CHCl_3$ in the usual manner. The alkaloids extract was used to study the corrosion inhibition properties. The concentration range of alkaloids extract employed was 5 – 100 mg l^{-1}.

2.3. Electrochemical measurements

Electrochemical measurements, including potentiodynamic polarization curves and electrochemical impedance spectroscopy (EIS) were performed in a three-electrode cell. The C38 steel specimen was used as the working electrode, a platinum wire as the counter electrode and a saturated calomel electrode (SCE) as the reference electrode. Before each Tafel and EIS experiments, the electrode was allowed to corrode freely and its open-circuit potential (OCP) was recorded as a function of time during 3 h, the time necessary to reach a quasi-stationary value for the open-circuit potential. This steady-state OCP corresponds to the corrosion potential (E_{corr}) of the working electrode.

The anodic and cathodic polarisation curves were recorded by a constant sweep rate of 20 mV min^{-1}. Electrochemical impedance spectroscopy (EIS) measurements were carried out, using ac signals of amplitude 10 mV peak to peak at different conditions in the frequency range of 100 kHz to 10 mHz. Electrochemical measurements were performed through a VSP electrochemical measurement system (Bio-Logic). The above procedures were repeated for each concentration of the two tested inhibitors. The Tafel and EIS data were analysed and fitted using graphing and analyzing impedance software, version EC-Lab V9.97.

2.4. Viability test

The human carcinoma buccal epithelial KB cell lines were obtained from ECACC (Salisbury, UK) and grown in D-MEM medium (Dulbecco's modified Eagle's medium) supplemented with 10% fetal calf serum (Invitrogen), in the presence of penicilline, streptomycine and fungizone in 75 cm^3 flask under 5% CO_2. Cells were plated in 96-well tissue culture microplates with a density of 800 cells/well in 200 µl medium and treated 24 h later with compounds dissolved in DMSO with compound concentrations ranged 1 µg l^{-1} and 10 µg l^{-1}. Controls received the same volume of DMSO (1% final volume). After 72 h exposure MTS reagent (Promega) was added and incubated for 2 h at 37 °C: the absorbance was monitored at 490 nm and results expressed as the inhibition of cell proliferation calculated as the ratio [(OD490 treated / OD490 control) × 100]. The cytotixicity test was performed according to a previously described experimental procedure [28].

3. RESULTS AND DISCUSSION

3.1. Polarisation curves

Following three hour's immersion at open-circuit, the corrosion potential (E_{corr}) was determined. Polarization curves were then performed in 1 M HCl solution and in the presence of various concentrations of *Annona squamosa* extract (Fig. 1). As it can be seen, the anodic reactions of steel electrode corrosion were inhibited with the increase of the *Annona squamosa* extract concentration in 1 M HCl. Also, the addition of *Annona squamosa* extract has suppressed the cathodic reaction to greater extents than the anodic one. It means that the addition of *Annona squamosa* extract reduces anodic dissolution, retards the hydrogen evolution reaction and suggests it to act as a mixed-type inhibitor. Tafel lines of nearly equal slopes were obtained, indicating that the hydrogen evolution reaction was activation-controlled. The constancy of this cathodic slope may have indicated that the mechanism of proton discharge reaction did not change by addition of *Annona squamosa* extract.

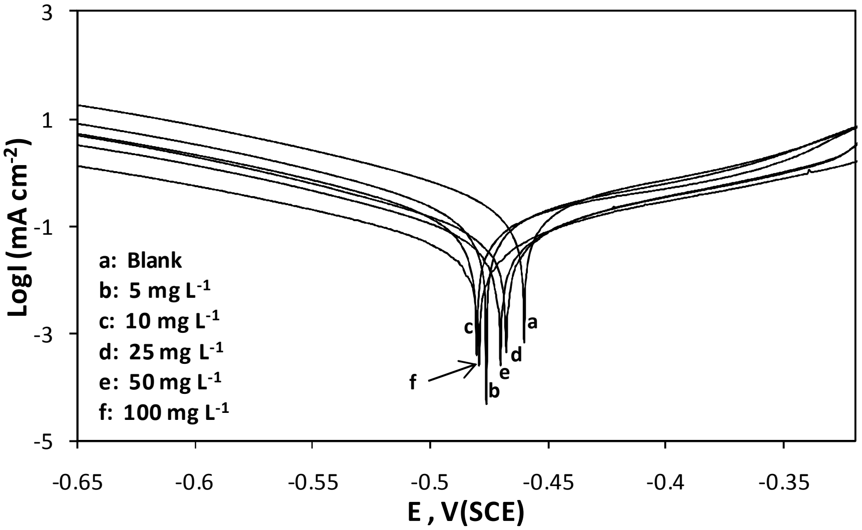

Figure 1. Polarisation curves for C38 steel in 1 M HCl containing different concentrations of *Annona squamosa* extract.

Table 1. Polarization parameters and the corresponding inhibition efficiency for the corrosion of C38 steel in 1 M HCl containing different concentrations of *Annona squamosa* extract at 25 °C.

Concentration mg l^{-1}	E_{corr} vs SCE	I_{corr}	b_a	b_c	R_p	IE_{Icorr}	IE_{Rp}
	(mV)	(µA cm^{-2})	(mV dec^{-1})	(mV dec^{-1})	(Ω cm^2)	(%)	(%)
1 M HCl	-460	232	88	104	76		
5	-476	145	67	123	118	37	36
10	-480	94	63	125	152	59	56
25	-467	55	58	113	229	76	72
50	-470	51	52	123	264	78	75
100	-478	33	65	130	421	86	84

Electrochemical corrosion kinetic parameters, such as corrosion potential (E_{corr}), cathodic and anodic Tafel slopes (b_a and b_c) and corrosion current (I_{corr}) which obtained by Tafel extrapolation method, are given in Table 1. Percentage of inhibition efficiency (*IE* %) are also given in the same Table. The polarization resistances (R_p) were calculated from the linear *I–E* plots in the potential range ± 25 mV from the corrosion potential. The R_p fit was obtained with a good correlation coefficient (R ≥

0.999). As it can be seen from these polarisation results, the I_{corr} values decrease and R_{p} increase considerably in the presence of extract with increasing inhibitor concentration. The addition of the extract modifies slightly the anodic and cathodic slopes. Corrosion potential shifted slightly to negative direction; although there was not a specific relation between E_{corr} and extract concentration. This shows that the effect of inhibitor on the cathodic reaction is more observable than on the anodic reaction. *IE* (%) values also increase with inhibitor concentrations. The inhibition efficiencies calculated from corrosion current (I_{corr}) show the same trend as those obtained from the polarization resistances (R_{p}).

3.2. Electrochemical impedance spectroscopy (EIS)

Figure 2 shows a typical set of Nyquist plots for C38 steel in 1 M HCl solution in uninhibited and inhibited acidic solutions containing various concentrations of *Annona squamosa* extract at 25 °C. As it can be seen, from Nyquist plots that all most of the impedance spectra obtained (except for 5 and 10 mg l^{-1}) for the corrosion of C38 steel in HCl solutions with inhibitor consist of two capacitive loops (two well-defined time-constants in the Bode-phase format; Fig. 3). The high-frequency loop, the smaller one, can be attributed to the film formation at the steel surface while the low-frequency loop, the larger one, can be attributed to the charge transfer reaction. Considering the impedance diagrams, the size of the two capacitive loops increased by increasing the concentration of *Annona squamosa* extract. This indicated that *Annona squamosa* extract increased the charge transfer resistance and then it had an inhibiting effect on steel corrosion in electrolyte solutions. It can be noticed that the impedance spectra showed a depressed form of the low-frequency capacitive loop (corresponding to the charge transfer resistance). The centre of the experimental arc was displaced below the real axis. This phenomenon could be related to the surface heterogeneity due to the microscopic roughness of the electrode surface and inhibitor adsorption [29–33]. For analysis of the impedance spectra exhibiting two capacitive loops, the equivalent circuit (EC) given in Fig. 4a was used while the EC shown in Fig. 4b was used for the impedance spectra containing only one capacitive loop. In both equivalent circuits, a constant phase element (CPE) is used to give a more accurate fit [34]. It's observed that a reasonable accuracy of the fitting was obtained, as evidence by Chi-square in the order of 10^{-3} for all the experimental data. The main parameters (R_{f}, R_{ct}, A and n) deduced from the analysis of Nyquist diagram for 1 M HCl containing various concentrations of *Annona squamosa* extract are given in Table 2. Estimates of the margins of error calculated for the parameters are also presented in Table 2. In the same Table are shown the calculated ″double layer capacitance″ values (C_{dl}), using the Eq. (2) [35–37] and the relaxation time constants using the Eq. (3) [36, 38]:

$$C_{\mathrm{dl}} = (A.R_{\mathrm{ct}}^{\,1-n})^{1/n} \qquad (2)$$

$$\tau = C_{\mathrm{dl}}\, R_{\mathrm{ct}} \qquad (3)$$

Inspection of data in Table 2 shows clearly that R_{ct} and C_{dl} values have opposite trend at the whole concentration range (R_{ct} increases and C_{dl} decreases with extract concentration). The decrease in this capacity with increase in plant extract concentrations may be attributed to the formation of a protective layer on the electrode surface [39]. Also, the value of the proportional factor A of CPE varies in a regular manner with inhibitor concentration. It can be supposed that a protective layer covers the C38 steel surface. At low concentration, no film was observed at the steel surface. Upon increasing the concentration of *Annona squamosa* extract, the film formation becomes much higher. Addition of plant extract increases n value indicating a reduction of surface inhomogeneity due to the adsorption of extract molecules on the most active adsorption sites of the C38 steel surface. On the other hand, the calculated value of the time constant (τ) obtained in the absence of the extract was found to be 0.0268 s. The addition of *Annona squamosa* extract in acid solution results in an increase in τ value at 5 mg l^{-1} ($\tau = 0.0446$ s). Upon increasing the concentration of *Annona squamosa* extract, the time of adsorption process becomes much higher which means slow adsorption process [40, 41]. It is obvious from the results that the *Annona squamosa* extract inhibits the corrosion of C38 steel in 1 M HCl solution at all concentrations. The *IE* (%) was seen to increase continuously with increasing additive concentration at 25 °C (Table 2). The inhibition efficiencies, calculated from ac impedance study, show the same trend as those obtained from polarisation curves measurements.

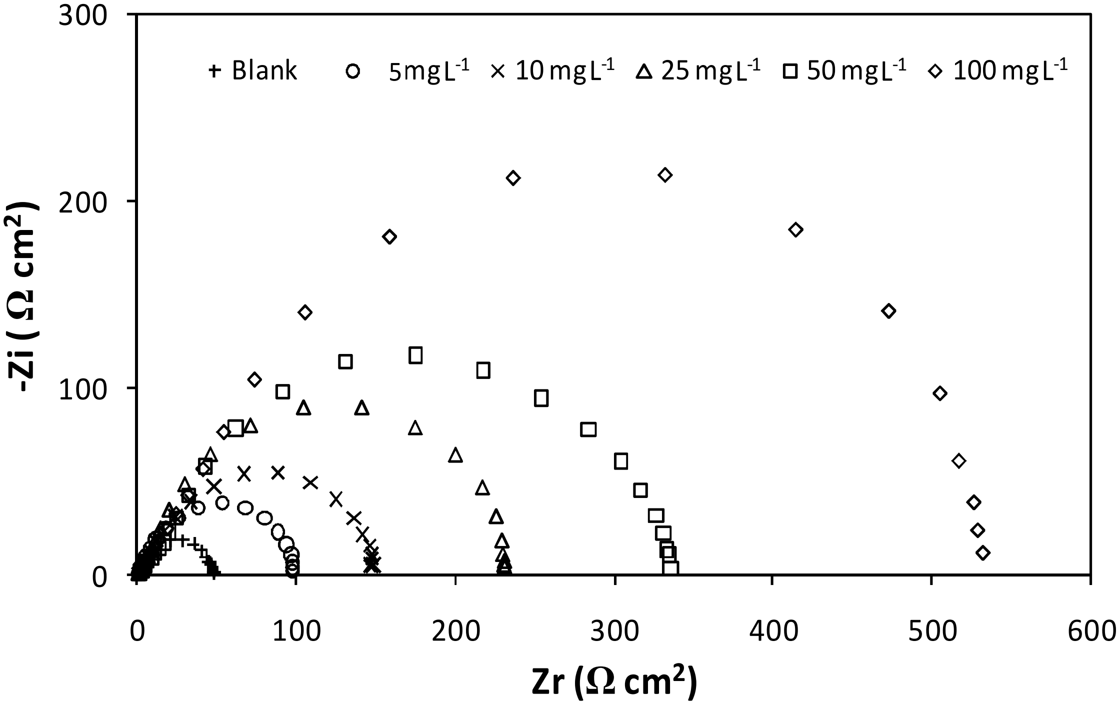

Figure 2. Nyquist plots for C38 steel in 1 M HCl in the absence and presence of different concentrations of *Annona squamosa* extract.

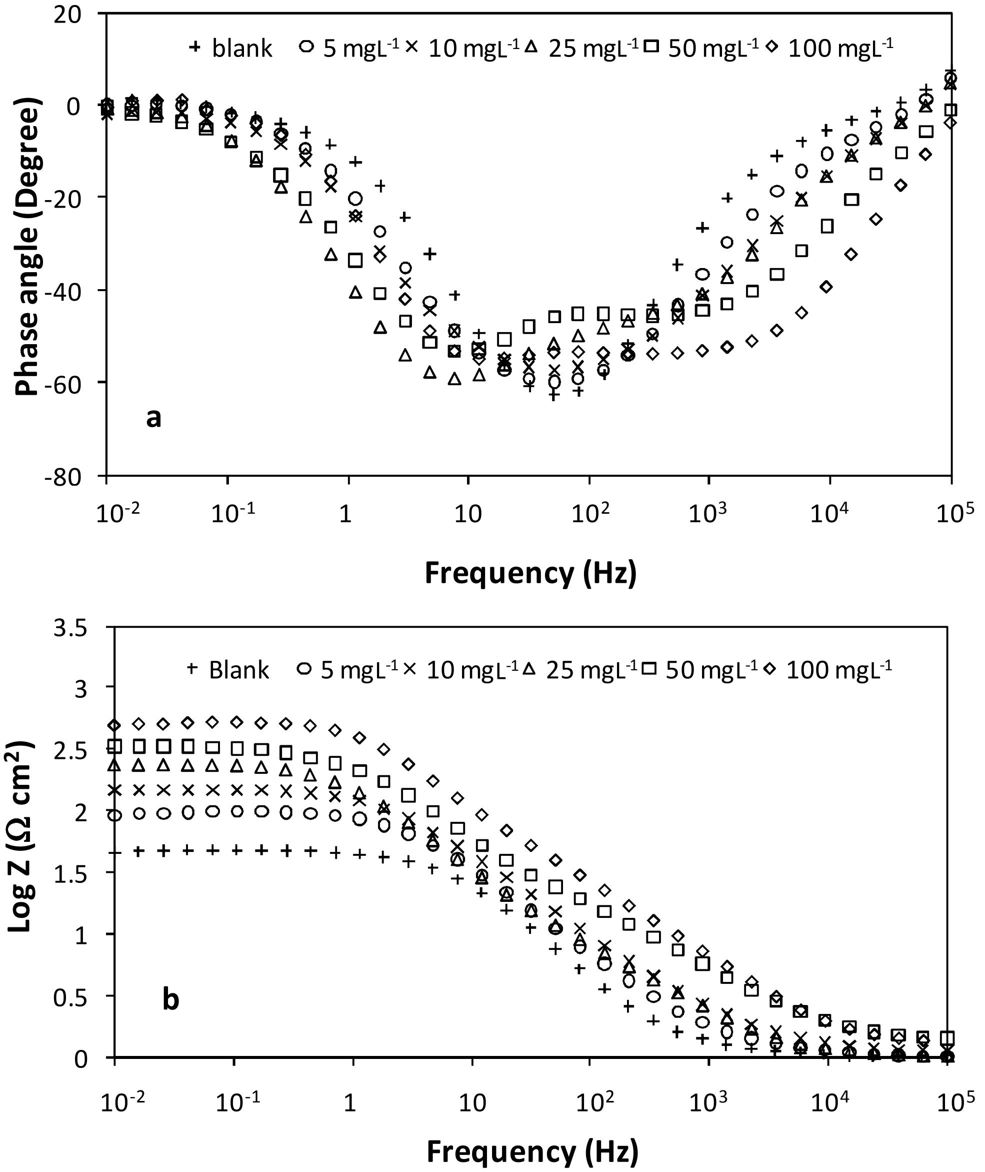

Figure 3. Bode plots, phase angle vs. freq (b) and LogZ vs. freq (a), for C38 steel in 1 M HCl in the absence and presence of different concentrations of *Annona squamosa* extract.

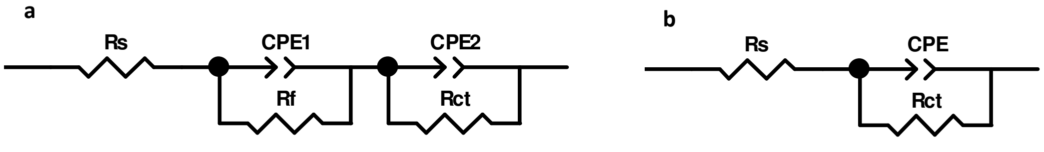

Figure 4. The equivalent circuit used to fit the impedance data exhibiting two capacitive loops (a) and one capacitive loop (b).

Table 2. Values of the elements of equivalent circuit required for fitting the EIS for C38 steel in 1 M HCl in the absence and presence of different concentrations of *Annona squamosa* extract and the corresponding inhibition efficiency.

Concentration (mg l^{-1})	R_f	$10^4 A$	n	R_{ct}	$10^4 A$	n	C_{ct}	τ_d	IE
	(Ω cm^2)	(Ω^{-1} s^n cm^{-2})		(Ω cm^2)	(Ω^{-1} s^n cm^{-2})		(μF cm^{-2})	(s)	(%)
1 M HCl	—	—	—	49 ± 0.02	9.50 ± 0.73	0.853 ± 0.014	546	0.0268	—
Annona squamosa									
5	—	—	—	95 ± 0.59	7.55 ± 1.75	0.853 ± 0.058	479	0.0446	49
10	—	—	—	148 ± 0.56	6.53 ± 0.46	0.868 ± 0.520	458	0.0677	67
25	13 ± 0.68	7.58 ± 0.12	0.809 ± 0.079	222 ± 6.74	4.98 ± 0.18	0.877 ± 0.531	366	0.0812	79
50	28 ± 0.79	5.37 ± 0.03	0.821 ± 0.008	335 ± 7.61	4.07 ± 0.93	0.881 ± 0.042	311	0.1042	87
100	65 ± 3.12	3.77 ± 0.92	0.824 ± 0.068	486 ± 1.86	2.82 ± 0.15	0.886 ± 0.058	218	0.1061	92

3.3. Effect of temperature

The effect of temperature on the various corrosion parameters E_{corr}, I_{corr} and R_{ct} was studied in 1 M HCl at temperature range 25 – 55 °C in the absence and presence of 50 mg l^{-1} of *Annona squamosa* extract by potentiodynamic polarisation curves and electrochemical impedance spectroscopy. We note that the high-frequency loop corresponding to the film formation at the steel surface, which was observed at 25 °C, was disappeared at temperature range 35 – 55 °C in the presence of extract. The results obtained from these studies were listed in Table 3, the double layer capacitance values were calculated using the Eq. (2). An inspection of Table 3 shown that, as the temperature increased, the values of E_{corr} shift in the negative direction and the values of I_{corr} increase. Also, the temperature rise leads to a decrease of R_{ct} values. This is due on one hand to the increase of the rate of metal dissolution, and on the other hand to the shift of the adsorption/desorption equilibrium towards the extract's desorption and hence to the decrease of surface coverage degree. The values of inhibition efficiency decrease with temperature increase. A decrease in inhibition efficiencies might be due to weakening of physical adsorption. We were interested in exploring the activation energy of the corrosion process and the thermodynamics of adsorption of *Annona squamosa* extract. This was accomplished by investigating the temperature dependence of the corrosion current, obtained using Tafel extrapolation method.

The activation energies (E_a) for the corrosion of C38 steel in the absence and presence of different concentrations of *Annona squamosa* extract were calculated using Arrhenius-type equation:

$$I_{corr} = k \exp(-\frac{E_a}{RT}) \quad (4)$$

where E_a is the apparent activation corrosion energy, T is the absolute temperature, k is the Arrhenius pre-exponential constant and R is the universal gas constant. Arrhenius plots for the corrosion rate of steel in 1 M HCl are shown in Fig. 5. Values of E_a for C38 steel in 1 M HCl in the absence and presence of *Annona squamosa* extract were calculated from the slope of ln i_{corr} vs. $1/T$ plots and given in Table 4. The enthalpy of activation (ΔH_a) and the entropy of activation (ΔS_a) for the corrosion of C38 steel in HCl were obtained by an alternative formulation of Arrhenius equation [42]:

$$I_{corr} = \frac{RT}{Nh}\exp\left(\frac{\Delta S_a}{R}\right)\exp\left(-\frac{\Delta H_a}{RT}\right) \tag{5}$$

where h is Planck's constant and N is Avagadro's number. Fig. 6 shows a plot of ln (i_{corr}/T) against $1/T$. Straight lines are obtained with a slope of $\Delta H_a/R$ and an intercept of ln $R/Nh + \Delta S_a/R$ from which the values of ΔS_a and ΔH_a are calculated and are given in Table 4. In 1 M HCl solution, the addition of Annona squamosa extract leads to an increase in the apparent activation energy to value greater than that of the uninhibited solution. The results show that the addition of *Annona squamosa* extract decreases metal dissolution in 1 M HCl medium. On the other hand, the increase in the apparent activation energy may be interpreted as physical adsorption that occurs in the first stage [43]. Szauer and Brand explained that the increase in activation energy can be attributed to an appreciable decrease in the adsorption of the inhibitor on the C38 steel surface with increase in temperature. The value of E_a is larger than the analogous value of ΔH_a indicating that the corrosion process must involved a gaseous reaction, simply the hydrogen evolution reaction, associated with a decrease in the total reaction volume [44]. Moreover, the average difference value of the $E_a - \Delta H_a$ is 2.61 kJ mol^{-1}, which is approximately equal to the average value of RT (2.63 kJ mol^{-1}). Therefore, it is indicated that the corrosion process is a unimolecular reaction as it is characterized by the following equation [45]:

$$E_a - \Delta H_a = RT \tag{6}$$

Table 3. Corrosion parameters obtained from potentiodynamic polarisation curves and EIS for C38 steel immersed in 1 M HCl and 1 M HCl + 50 mg l^{-1} of *Annona squamosa* at different temperatures.

	***Temp* (°C)**	***Polarization curves***			***EIS***		
		E_{corr} vs SCE (mV)	I_{corr} (mA cm^{-2})	*IE* (%)	R_{ct} (Ω cm^2)	C_{ct} (μF cm^{-2})	*IE* (%)
Blank	25	-460	232	—	49 ± 0.02	546	—
	35	-454	843	—	23 ± 0.64	934	—
	45	-451	1092	—	15 ± 0.94	1102	—
	55	-450	1872	—	4 ± 0.96	1819	—
Annona Squamosa	25	-470	51	78	335 ± 7.61 R_f = 28 ± 0.79	311	87
	35	-472	242	71	144 ± 1.6	462	84
	45	-484	513	53	49 ± 1.2	609	69
	55	-482	1029	45	11 ± 0.53	1124	63

The entropy of activation (ΔS_a) in the absence and presence of extract has negative values. This indicates that the activated complex in the rate determining step represents an association rather than dissociation, meaning that, a decrease in disordering takes place on going from reactants to the activated complex [46].

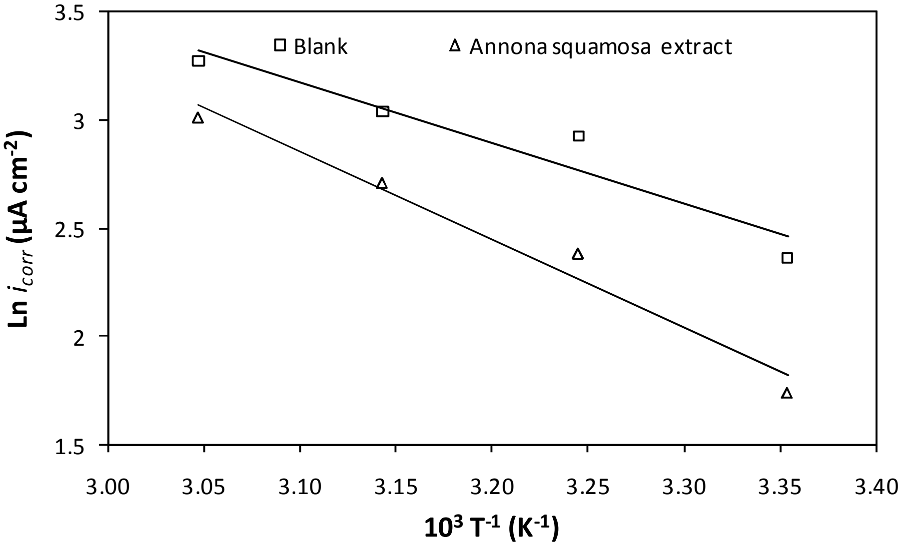

Figure 5. Arrhenius plots of corrosion ln i_{corr} vs. 1/T of 1 M HCl and 1 M HCl + 50 mg l^{-1} of *Annona squamosa* extract.

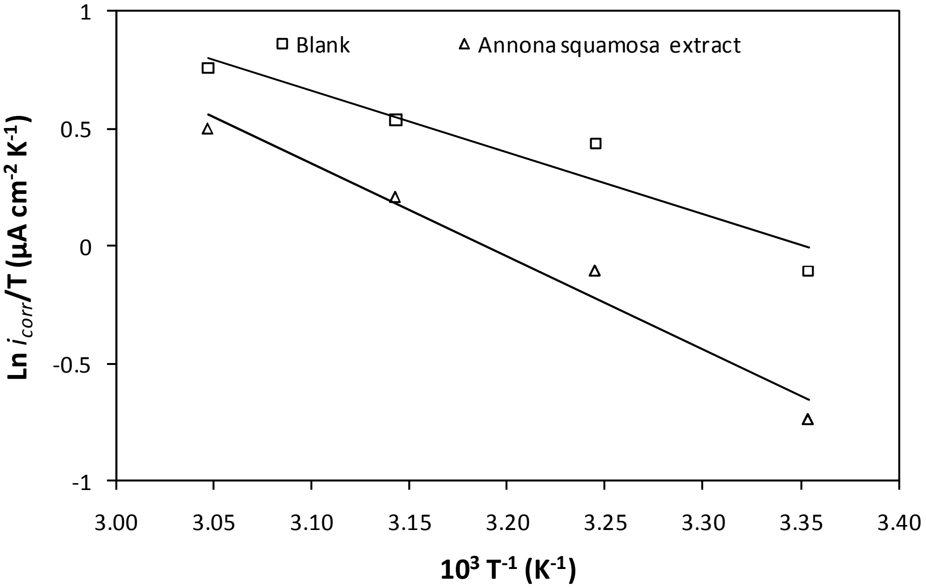

Figure 6. Arrhenius plots of corrosion ln (i_{corr} /T) vs. 1/T of 1 M HCl and 1 M HCl + 50 mg l^{-1} of *Annona squamosa* extract.

3.4. Adsorption Isotherm

The interactions between the extract and the C38 steel surface can be examined by the adsorption isotherm. The degree of surface coverage values (Θ) for various concentrations of the extract in 1 M HCl solution have been evaluated from the AC impedance study. Suitable adsorption isotherm was obtained, using these calculated values.

Table 4. Thermodynamic parameters for the adsorption of *Annona squamosa* extract in 1 M HCl on the C38 steel at different temperatures.

Inhibitor	E_a (kJ mol^{-1})	ΔH_a (kJ mol^{-1})	ΔS_a (J mol^{-1} K^{-1})
1 M HCl	24.24	23.29	-119.48
Annona Aquamosa	33.85	31.24	-89.43

The linear relationships of C/Θ vs. C, depicted in Fig. 7, suggest that the adsorption of *Annona squamosa* extract on the C38 steel obeyed the Langmuir adsorption isotherm. This isotherm can be represented as:

$$\frac{C_{inh}}{\Theta} = \frac{1}{K} + C_{inh} \tag{7}$$

The strong correlation (R^2 = 0.9997) of the Langmuir adsorption isotherm for *Annona squamosa* extract was observed. Langmuir adsorption isotherm assumes that the adsorption of organic molecule on the adsorbent is monolayer. The free energy of adsorption ΔG_{ads} of the *Annona squamosa* extract on C38 steel surface can be determined using the following equation [47]:

$$K = \frac{1}{55,5}\exp\left(\frac{-\Delta G_{\text{ads}}}{RT}\right) \tag{8}$$

Where R is the universal gas constant and T is the absolute temperature. The value 55.5 in the above equation is the concentration of water in solution in mol l^{-1}.

The ΔG_{ads} value of *Annona squamosa* extract was found -23.25 kJ mol^{-1}. The negative value of the ΔG_{ads} indicates the spontaneously adsorption of these molecules from HCl solution to the metal surface. This value of ΔG_{ads} is around -20 kJ mol^{-1} consist the electrostatic interaction between charged organic molecules and the charged metal surface (physisorption). Earlier studies on the some plant extracts have shown the same tendency (physisorption) [48, 49].

3.5. Mechanism of inhibition

The potentiodynamic polarisation curves and electrochemical impedance spectroscopy confirms the inhibiting character of *Annona squamosa* extract in acid solution. However, the inhibition efficiency increases with extract concentrations. This result suggests that increase in plant extract concentration increases the number of extract molecules adsorbed onto steel surface and reduces the surface area that is available for the direct acid attack on the metal surface.

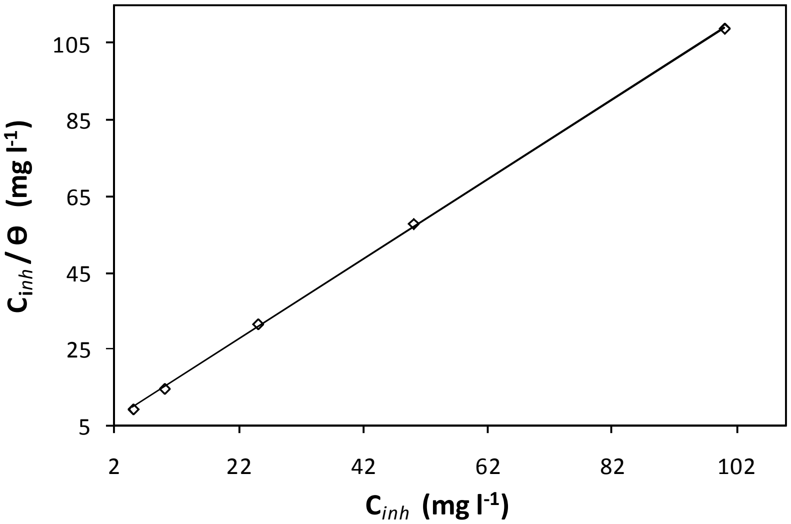

Figure 7. Langmuir adsorption plots for C38 steel in 1 M HCl containing different concentrations of *Annona squamosa* extract.

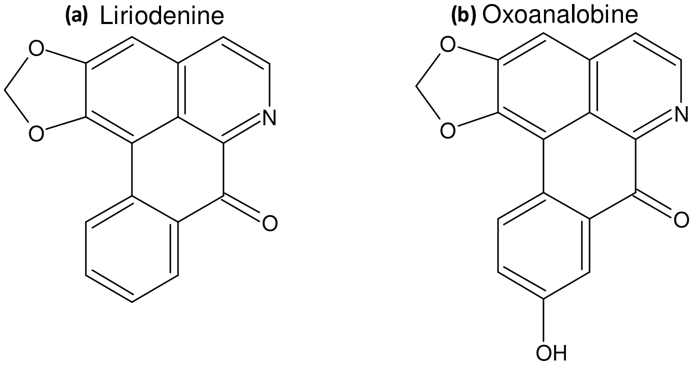

Figure 8. Chemical structures of two major alkaloids from *Annona squamosa* plant; (a) Liriodenine and (b) Oxoanalobine.

The inhibitive effect of *Annona squamosa* extract is ascribed to the presence of organic compounds in the extract. Studies on the phytochemical constituents of the alkaloids from *Annona squamosa* plant show the presence of two major alkaloids, liriodenine and oxoanalobine as shown in Fig. 8 [50]. As it is mentioned in sections 3.4, the adsorption mechanism of extract on C38 steel surface involves a physisorption. Its means that the alkaloids extract are able to electrostatically adsorb on the steel surface. Even the acidity of the medium, these compounds do not remain in solution as free bases. Therefore, it may be assumed that, the first contact between the metal surface and alkaloids extract is between metal and protonated form of the compounds (cationic form). However, a synergistic or antagonistic effect of these molecules may play an important role on the inhibition efficiency of *Annona squamosa* extract. As, these compounds contain heteroatoms (oxygen, nitrogen) and aromatic rings, which allow adsorption on the metal surface. We suppose that the adsorption of alkaloids extract could be also occurred due to the formation of a links between the d-orbital of iron atoms, involving the displacement of water molecules from metal surface, and the lonely electron pairs present on the N and O atoms of the heterocyclic rings.

3.6. Viability Test

The cytotoxicity of these inhibitors was determined using the human carcinoma buccal epithelial KB cell lines. The KB cells were exposed up to two concentrations of *Annona squamosa* dissolved in DMSO, simulating a worst-case situation of experiments. The results are expressed by the inhibition of cell proliferation as descript in the experimental method. *Annona squamosa* extract showed inhibition against KB cell with values of 3% and 73% for 1 and 10 µg ml^{-1}, respectively. However, the *Annona squamosa* extract exhibited less cytotoxicity at the highest quantities.

4. CONCLUSION

Annona squamosa extract inhibits the corrosion of C38 steel in 1 M HCl solutions and their inhibiting properties increase with increasing the concentration of the extract. Polarisation studies showed that *Annona squamosa* extract was mixed-type inhibitor in 1 M HCl and its inhibition efficiency increased with the extract concentration. The inhibition efficiency of *Annona squamosa* extract was temperature-dependent and its addition led to an increase of the activation corrosion energy revealing a physical adsorption between the extract and the metal surface. Data obtained from ac impedance technique show a frequency distribution and therefore a modelling element with frequency dispersion behaviour, a constant phase element (CPE) has been used. The adsorption of *Annona squamosa* extract on the C38 steel in 1 M HCl solution obeys Langmuir adsorption isotherm. The inhibitive effect of *Annona squamosa* is ascribed to the presence of organic compounds in the extract. The cytotoxicity of the *Annona squamosa* extract using the human carcinoma buccal epithelial KB cell lines indicates that this extract is considered as non-cytotoxic substance.

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