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Madhuca Longifolia Corrosion Inhibition in Acid Medium-An Overview

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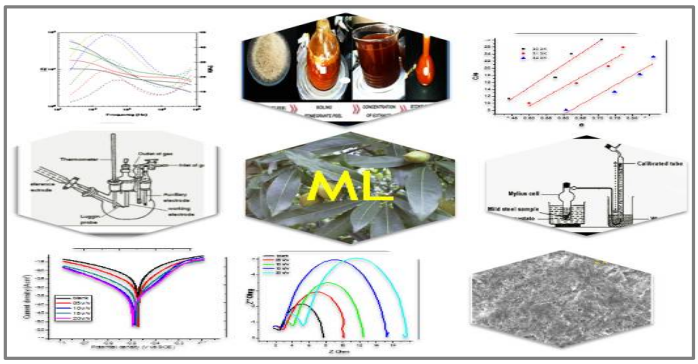
ABSTRACT

The corrosion inhibition and adsorption behaviour of aqueous extract of plant select namely like as Madhuca longifolia mild steel surface in 1N HCl solution were investigated by mass loss with different time of contact, various temperature and evaluated by electrochemical impedance and Tafel studies. Polarization method indicates that the plant extract which was as mixed type inhibitor with predominately control of anodic reaction. EIS study showed a decrease in C_{dl} as the adsorption of inhibitor lead to structural change at electrode solution interface thereby controlling the mild steel dissolution by C_{dl} mechanism. The nature of Protective film formed on the MS surface has been confirmed by SEM analysis. The surface coverage values were test graphically to fitting of a suitable adsorption isotherm. The result indicates that the plant extract was efficient natural corrosion inhibitor in the acid medium.

Graphical abstract



Keywords: Metals, Corrosion test, EIS, SEM.

INTRODUCTION

Mild steel is world widely used in many application in industries like metallurgical process, chemical cleaning, fertilizer, desalination plants, nut bolts, screw industry, storage tank, petroleum refineries, pharmaceutical industry, thermal power point, construction material, and gas industry, sugar, paper, textile, boilers, automobiles, steam boilers, engineering purpose, mechanical purpose, chain, hinges, knives, magnets, military equipment, armour, vehicles (ships and cars) and pickling process etc., due to their stability, high strength, weld ability and good corrosion resistance [**1-10**]. Corrosion is only

nature's method, inevitable and serious problem, because it definitely contributes to the depletion of our natural resource and non - stop. That problem faced by almost all alloys and industries, can be considered as one of the worst environmental calamite of our time. Most metals are commonly unstable in the atmosphere, both dangerous and costly [**11-15**]. Once corrosion initiates, it propagates rapidly, most dangerous is the loss of strength by corrosion, but it can be considerably reduced using various effects have been made corrosion control and prevention to environmental degradation in aqueous and open atmosphere. Hydrochloric acid and Sulphuric acid which are used to clean up the scales and rusts of the mild steel articles cause corrosion of the exposed metal after the scale have been removed [**16-20**]. Sea water is another corrosive environment which causes drastic environmental degradation of various mild steel structures. Among the various method of mitigation of corrosion of steel, application of corrosion inhibitors is one of the best methods. For inhibition in aqueous and alcoholic system are organic compounds with a lone pair of electron, pi electron with multiple bonds. They are generally heterocyclic organic compound with presence of S, O or N atoms in the molecules. The polar function is usually regarded the reaction centres' for the establishment of adsorption process. But most of the inhibitor are toxic and harmful to human and living system. Since earliest 1990's in different areas of the world where platform in the sea used to extract oil, environmental situations arise that challenge the use of corrosion inhibitor. This inhibitor may cause temporary or permanent damage to organ system, viz-leaver or to disturb a bio - chemical or enzyme system at some sites on the body **[21-30]**. The toxicity may be manifested by either the synthesis of the compound or its applications. To combat such lethal global problem, advent of green inhibitor which are eco- friendly naturally occurring product of mostly plants of micro – Organisms, have taken place. They decrease the rate of aqueous corrosion of metallic system without causing any harm of the environments, human and leaving system **[31-42]**. In the present investigation, corrosion inhibition of mild steel in HCl has been studied in presence of few green inhibitors mainly *Madhuca longifolia*, to be used as corrosion inhibitors in alcoholic extract, there is no reports in the literature on the use these plants as corrosion inhibitors.

MATERIALS AND METHODS

Preparation of mild steel specimen: Mild steel strips were mechanically cut into strips of size 4 cm x 2 cm x 0.1 cm containing the composition of C- 0.030 %, Mn- 0.169 %, Si- 0.015 %, P- 0.031 %, S - 0.029 %, Cr- 0.029 %, Ni- 0.030 %, Mb- 0.016 %, Cu- 0.017 % and the remainder Fe and provided with a hole of uniform diameter to facilitate suspension of the strips in the test solution for weight loss method. For electrochemical studies, mild steel strips of the same composition but with an exposed area of $1cm^2$ were used. Mild steel strips were polished by using emery paper of 400, 600, 800, 1000 and 1200 grade, subsequently degreased with acetone and finally washed with deionized water, and stored in the desiccator. Accurate weight of the metal was taken using four digital electronic balance (shimadzu ay 220 model).

Alcoholic extract preparation: The leaves, barks, fruits and seed peel of the medicinal plants ML were taken and cut into small pieces, and dried in room temperature and ground well into powder. 500 g of the powder from each was refluxed with alcohol in soxlet apparatus for 24 h kept overnight. After completion of extraction, the extract was filtered the suspended or impurities are removed. The excess of alcohol was removed by distillation method. The resulting residue was dark green in colour and had a pleasant smell. The crude was boiled with little amount of activated charcoal to removes impurities, the pure plant extract after completed drying was collect and stored in a desiccator. The refluxed solution was then filtered carefully, the filtrate volume was made up to 250 ml using double distilled water which was the stock solution, and the concentration of the stock solution was expressed in term of v/v. From the stock solution, 5-20 v/v concentration of the extract was prepared using double distilled water. Similar kind of preparation has been reported in studies using aqueous plant extract in the recent years [**43**].

Weight loss method: Mild steel specimens were immersed in 200 mL of 1N HCl solution without and with various concentrations of the inhibitors using glass hooks and rods for a predetermined time period (24 h) at room temperature. The weights of the specimens before and after immersion were determined using four digit electronic balance (shimadzu ay 220 model).

From the weight loss measurements, the corrosion rate was calculated using the following relationship.

$$CR\ (mmpy) = \frac{\mathbf{K} \times \text{Weight Loss}}{D \times A \times t\ (\text{in hours})} \quad \ldots (1)$$

Where, K = 8.76 x 10^4 (constant), D is density in gm/cm^3 (7.86), W is weight loss in grams and A is area in cm^2.

The inhibition efficiency (%) was calculated using equation (2)

$$IE\ \% = \frac{W_0 - W_i}{W_0} x100 \quad \ldots (2)$$

Where, W_0 and W_i are the weight loss in the absence and presence of the inhibitor respectively.

FTIR measurements: FTIR spectra were recorded in a Bruker ALPHA 8400 S spectrophotometer. The film was carefully removed, mixed thoroughly with KBr made into pellets and FTIR spectra were recorded.

Pontetiodynamic polarization methods: Potentiodynamic polarization measurements were carried out using CHI660E electrochemical analyzer. The polarization measurements were made to evaluate the corrosion current, corrosion potential from Tafel slope. Experiment were carried out in a conventional three electrode cell assembly with mild steel specimen of $1cm^2$ area which was exposed and the rest being covered with red lacquer, was used as working electrode, a rectangular Pt foil as the counter electrode, and a saturated calomel electrode as standard reference electrode. A time interval of 15 minutes was given for each experiment to attain the steady state open circuit potential. The polarization was carried from a cathodic potential of -800 mV (vs SCE) to an anodic potential of -200 mV (vs SCE) at a sweep rate of 1 mV per second. From the polarization curves, Tafel slopes, corrosion potential, and corrosion current were calculated. The inhibitor efficiency was calculated using the formula:

$$IE\ \% = \frac{I_{Corr} - I_{*Corr}}{I_{Corr}} x\ 100 \quad \ldots (3)$$

Where I_{corr} and I_{*corr} are corrosion current in the absence and present of inhibitors.

Electrochemical impedance method: The electrochemical AC-Impedance measurements were also performed using CHI660E electrochemical analyzer. Experiments were carried out in a conventional three electrode cell assembly as that used for potentiodynamic polarization studies. A sine wave with amplitude of 10 mV was superimposed on the steady state open circuit potential. The real part (Z') and the imaginary part (Z") were measured at various frequencies in the range of 100 KHz to 10 MHz. A plot of Z' versus Z" was made. From the plot, the charge transfer resistance (R_{ct}) was calculated, and the double layer capacitance (C_{dl}) was then calculated using formula:

$$C_{dl} = \frac{1}{2\pi} f_{max} R_{ct} \quad \ldots (4)$$

Where R_{ct} is charge transfer resistance, and C_{dl} is double layer capacitance. The experiments were carried out in the absence and presence of different concentration of inhibitor.

$$IE\% = \frac{R_{ct} - R^0_{ct}}{R_{ct}} \times 100 \qquad \ldots (5)$$

Where, R_{ct} and R^0_{ct} are the charge transfer resistance values in the inhibited and uninhibited solution respectively.

Phytochemical analysis: Phytochemical screening were performed to assess the qualitative chemical composition of the different samples of plants extract using commonly employed precipitation and coloration reactions to identify the major secondary metabolites like alkaloids, flavonoids, glycosides, proteins, phenolic compounds, saponins, starch, steroids, tannins and terpenoids.

Scanning electron microscopy: The mild steel specimen immersed in blank and in the inhibitor solution for a period of one day was removed, rinsed with double distilled water, dried and observed in a scanning electron microscope to examine the surface morphology. The surface morphology measurements of mild steel were examined using (JEOL) computer controlled scanning electron microscope.

Effect of immersion time: The prepared mild steel coupons were immersed in 100 mL of the test solution without and with the ML extract of various concentrations for 1h, 3 h, 5 h, 7 h and 12 h at room temperature. The weight of the coupons before and after immersion was determined. Inhibition efficiency of the mild steel was calculated.

Effect of temperature: The polished and pre – weighed specimens were suspended in 100 mL of the test solution without and with the addition of various concentration of the ML extract for 1h in the temperature range of 303-323 K using water thermostats. The specimens were removed from the test solution after 1 h and washed with distilled water, dried and weighed. The inhibition efficiency was calculated from the weight loss.

RESULTS AND DISCUSSION

Weight loss methods: Alcoholic extract of ML plants corrosion parameters obtained in the weight loss method are listed in Table 1. From the values indicates that the plant extract could as effective corrosion inhibitor for mild steel in acid solution. The result indicates that the addition of inhibitor increase the inhibition efficiency of ML extract on mild steel surface in 1N HCl medium through adsorption and protect against corrosion. The order of inhibition effect among the ML plant extract on the mild steel in acid medium is found to be ML leaves >fruits> seed peels > barks.

FTIR Measurement: The alcoholic extract of IR spectrum of the compound showed (figure 1) a band around 3408 cm^{-1} indicating the presence of hydroxyl group and a strong band around 1738 cm^{-1} which reveals the presence of carbonyl stretching vibration. Since there is complete coordination between Fe^{2+} - organic constituent, the band due to the formation of the complex gets vanished in the FTIR spectrum of the film formed on the metal surface by alcoholic extract [**44-52**].

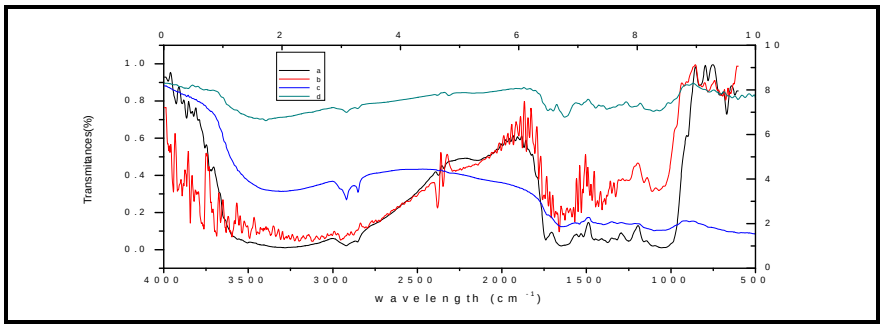


Figure 1. FTIR Spectra of *Madhuca Longifolia* leaves, barks, fruits and seeds peels Extracts.

Table 1. Percentage of inhibition efficiency (IE %) and corrosion rate (CR) at different concentration of inhibitor in 1N HCl medium

Alcoholic extracts				
Parts of Madhuca Longifolia plant	**Conc. of the extract (v/v)**	**Weight loss (g)**	**Corrosion rate (mmpy)**	**IE (%)**
madhuca longifolia	Blank	0.1147	44.008	-
leaves	5	0.0111	6.628	55.45
	10	0.0717	3.326	62.05
	15	0.213	1.234	75.22
	20	0.0115	0.070	92.95
madhuca longifolia	Blank	0.0445	9.030	-
barks	5	0.0046	2.117	57.91
	10	0.0040	0.918	64.48
	15	0.0001	0.416	78.29
	20	0.0035	0.131	85.16
madhuca longifolia	Blank	0.0350	10.610	-
fruits	5	0.0083	2.817	60.12
	10	0.0002	0.716	75.82
	15	0.0005	0.216	82.17
	20	0.0040	0.042	91.02
madhuca longifolia	Blank	0.0849	14.001	-
seed peel	5	0.0089	`1.006	65.19
	10	0.0003	0.100	72.04
	15	0.0120	0.085	86.39
	20	0.0110	0.055	90.34

Potentiodynamic polarization studies: The displayed data (Table 2 and Figure 2) clearly show that the corrosion current density (I_{corr}) values decreased in the presence of alcoholic extract indicating that the corrosion process of steel was supported in the presence of plant extract. However, the lowest (I_{corr}) values were observed in the presence of extract possess strongest inhibitive properties and suggesting that alcoholic extract could serve as effective green corrosion inhibitor. Theoretically, no shift in the corrosion potential should be observed after addition of the inhibitor if the geometric

Table 2. Electrochemical parameters from polarization measurement and calculated values of inhibition efficiency

Alcoholic extract of ML plants						
Parts of plant	**Conc. (v/v)**	**E_{corr}/ mV/ SCE**	**I_{corr}/ mA/cm^2**	**b_c mV/de**	**b_amV/de**	**IE (%)**
	Blank	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.468	$1.2x10^{-5}$	64	66	92.04
ML **Leaves**	10	-0.453	$4.7x10^{-5}$	147	68	96.87
	15	-0.455	$2.4x10^{-5}$	134	68	90.68
	20	-0.458	$2.0x10^{-5}$	129	69	90.70
	Blank	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.444	$1.5x10^{-5}$	265	90	23.90
ML **Barks**	10	-0.456	$2.7x10^{-5}$	135	67	57.89
	15	-0.459	$2.1x10^{-5}$	130	69	65.16
	20	-0.460	$1.8x10^{-5}$	127	71	78.90
	Blank	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.462	$2.4x10^{-5}$	120	70	90.45
ML **Fruits**	10	-0.460	$1.8x10^{-5}$	115	70	93.58
	15	-0.460	$1.4x10^{-5}$	114	72	94.89
	20	-0.461	$1.2x10^{-5}$	112	75	96.80
	Blank	-0.504	$1.5x10^{-4}$	128	87	*
	5	-0.460	$1.3x10^{-5}$	115	74	95.88
ML **Seed peels**	10	-0.462	$1.2x10^{-5}$	115	76	96.99
	15	-0.463	$1.1x10^{-5}$	116	77	96.99
	20	-0.464	$1.0x10^{-5}$	116	80	97.00

blocking effect is stronger than the effect. As can be seen from Table no shift in the values of corrosion potential E_{corr} were observed for the alcoholic extract indicating that the geometric blocking

effect is stronger. On the other hand, in case of rest of the plant extract the energy effect is stronger, although the blocking effect cannot be ignored as only a slight change was observed in the corrosion potential values upon addition plant extract. Also, it is clear that the addition of alcoholic extract of plant in aggressive media can be classified as mixed type corrosion inhibitor [**53-65**].

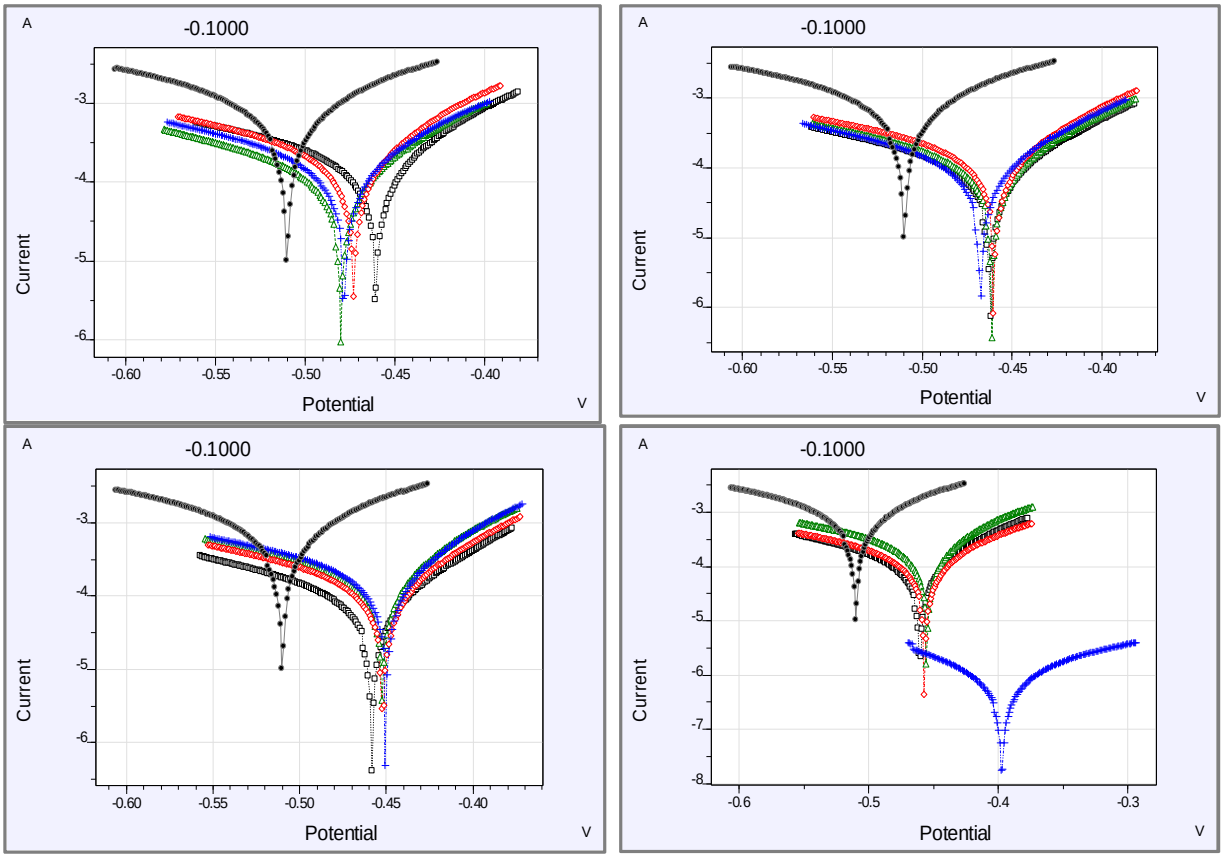


Figure 2. Potentiodynamic polarization (Tafel) curves for mild steel in 1N HCl solution in the absence and presence of different concentration of Madhuca Longifoliaextracts of (a) leaves (b) barks (c) fruits (d) seed peels.

Electrochemical impedance studies: The different corrosion parameters derived from EIS measurement are presented as Table 3.The nqyuist plot in the absence and presence of alcoholic extract of plant extract is shown in fig 3. it is worth noting that the presence of extract did not alter the profiles of impedance diagrams and it was found to be plant extract and composed of one semi circles indicating that a charge transfer process on the mild steel. However, deviation from slightly depressed nature of semicircles (which has the center below the x axis) indicates that extract inhomogeneity of roughness of the mild steel. It is evident from the data shown in Table that the values of R_{ct} values are increased and C_{dl} values are decreased in the presence of plant extract could be attributed to the adsorption of the phytochemical present in the plant extract over the mild steel surface as organic compounds adsorption process on the metal surface is characterized by decrease in C_{dl} values [**66-71**].

Surface analysis: The observation of the mild steel specimen was carried out using scanning electron microscope. Figure 4 shows the SEM image of mild steel surface after immersed in 1NHCl in the absence and presence of selected ML plant extract for 24 h. Closely observed very strong corroded (pits and crack) and uneven (heavy damage) metal surface obtained when the metal was kept immersed in 1N HCl for absence of inhibitor. In presence of inhibitor the metal surface shows smoother lager with clearly different morphology (surface covered means no pits and cracks). The protective film formed on the mild steel surface confirmed by SEM also supported the optimum inhibition efficiency.

Table 3. Impedance parameter for mild steel in 1 N HCl acid solution in the absence and Presence of varied concentration of ML inhibitor

Alcoholic extract of ML plants				
Parts of *Madhuca Longifolia* plant	**Conc (v/v)**	**R_{ct} (ohm cm^2)**	**C_{dl} (µF/cm^2)**	**IE (%)**
Madhuca Longifolia **leaves**	Blank	20.70	$1.5x10^{-5}$	*
	5	52.30	$9.1x10^{-5}$	60.42
	10	49.63	$2.1x10^{-5}$	58.29
	15	59.32	$5.3x10^{-1}$	65.10
	20	60.00	$1.0x10^{-6}$	65.55
Madhuca Longifolia **barks**	Blank	20.70	$1.5x10^{-5}$	*
	5	21.95	$4.6x10^{-5}$	05.69
	10	60.18	$8.1x10^{-5}$	65.60
	15	70.60	$1.2x10^{-4}$	70.67
	20	68.40	$1.4x10^{-4}$	69.73
Madhuca Longifolia **fruits**	Blank	20.70	$1.5x10^{-5}$	*
	5	73.20	$6.6x10^{-5}$	71.72
	10	99.30	$6.2x10^{-5}$	79.15
	15	113.7	$5.9x10^{-5}$	81.79
	20	124.6	$5.4x10^{-5}$	83.38
Madhuca Longifolia **seed peels**	Blank	20.70	$1.5x10^{-5}$	*
	5	31.10	$5.9x10^{-5}$	33.44
	10	67.60	$1.0x10^{-5}$	69.37
	15	74.67	$8.2x10^{-5}$	72.27
	20	98.81	$5.1x10^{-6}$	79.05

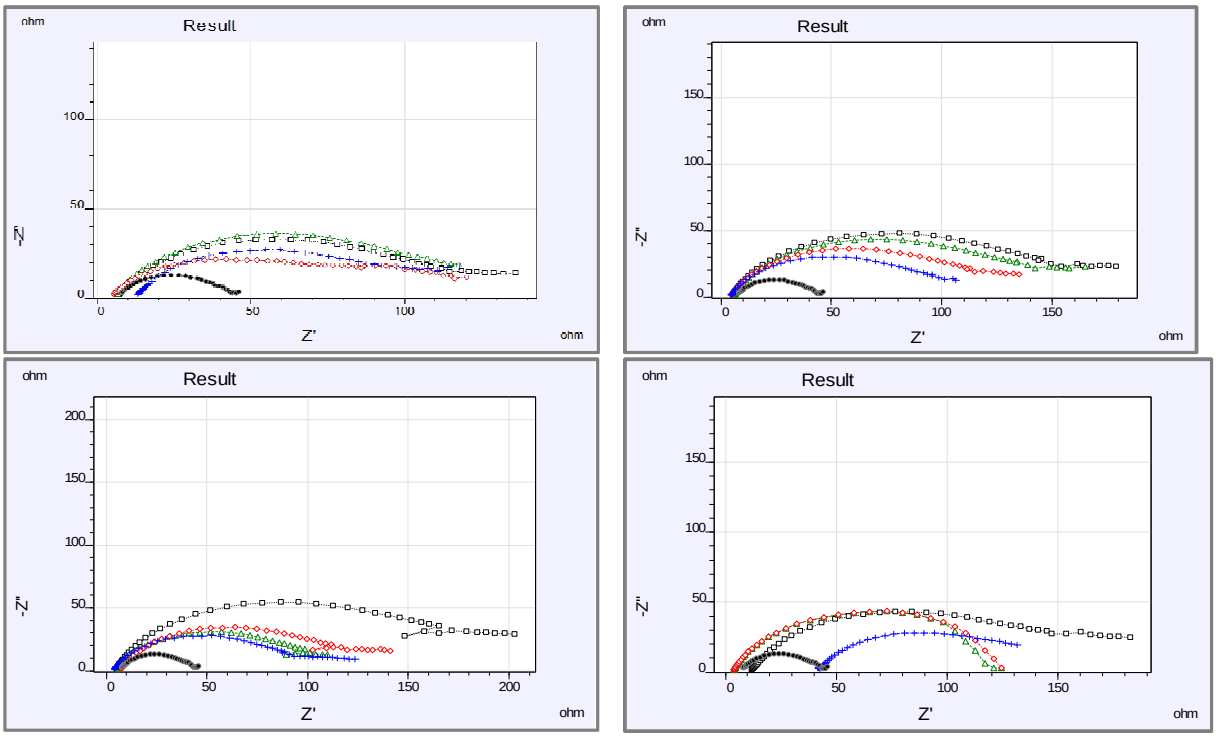


Figure 3. Nyquist plots for mild steel in 1N HCl acid solution without and with presence of different concentration of Madhuca Longifoliaextract of (a) leaves (b) bark (c) fruits (d) seed peels.

EDAX Measurement: The goal of this section was to confirm the results obtained from chemical and electrochemical measurement that a protective surface film of inhibitor is formed on the electrode surface. The corresponding energy dispersive EDAX profile analysis is presented in figure 5. The EDAX survey spectra were used to determine which elements of extract components were exposure to acid solution and inhibitor treatment. It is noticed the existence of the EDAX spectra in the case of

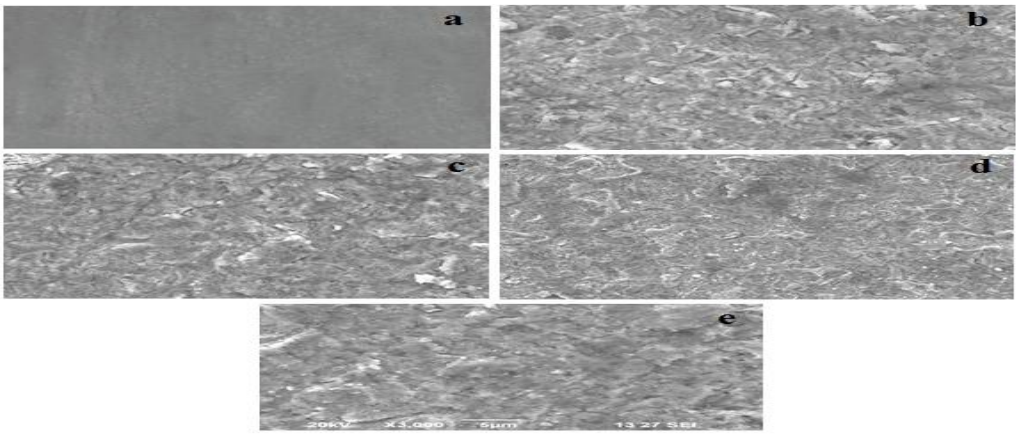


Figure 4. SEM image of the surface of mild steel after immersion for 24 hours in 1N HCl solution (a) blank and in the presence of optimum concentration of the plant extracts from (b) Stem, (c) Leaves, (d) Flowers and (e) Tubers.

the sample exposed to the extract, could be attributed to the adsorption of organic molecules at the mild steel surface. The figure shows that the Fe peaks are considerably suppressed relative to the samples prepared in 1N HCl solution, and this suppression increases with increasing extract concentration and immersion time. The suppression of the Fe lines occurs because of the overlying extract film. These results confirm those from polarization measurement which suggest that a surface film inhibited the metal dissolution, and hence retarded the hydrogen evolution reaction. This surface film also increase the charge transfer resistance of the anodic dissolution of mild steel and down the corrosion rate. Therefore, EDAX examination of the electrode surface supports the results obtained from chemical and electrochemical methods that the plants extract is a good inhibitor for acid solution.

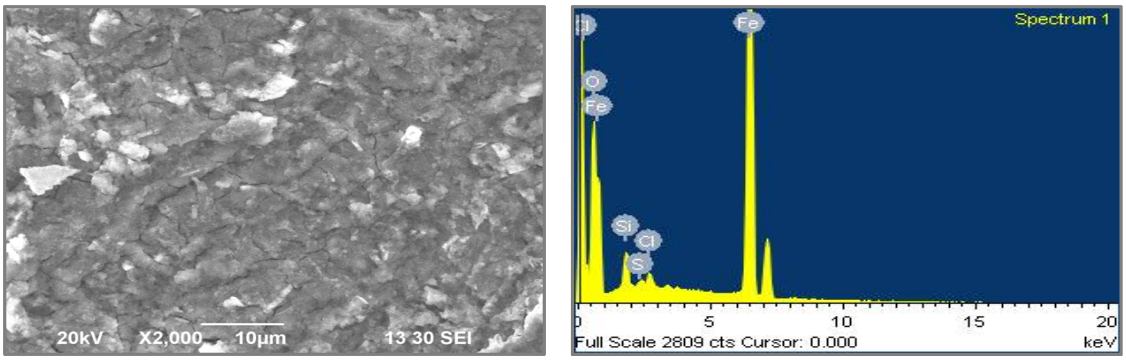
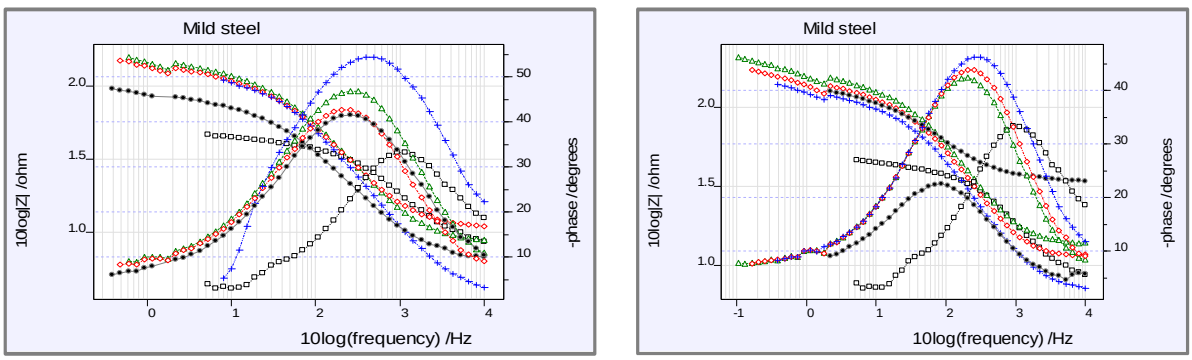


Figure 5. SEM image of the surface of mild steel and EDAX.

Bode measurement:



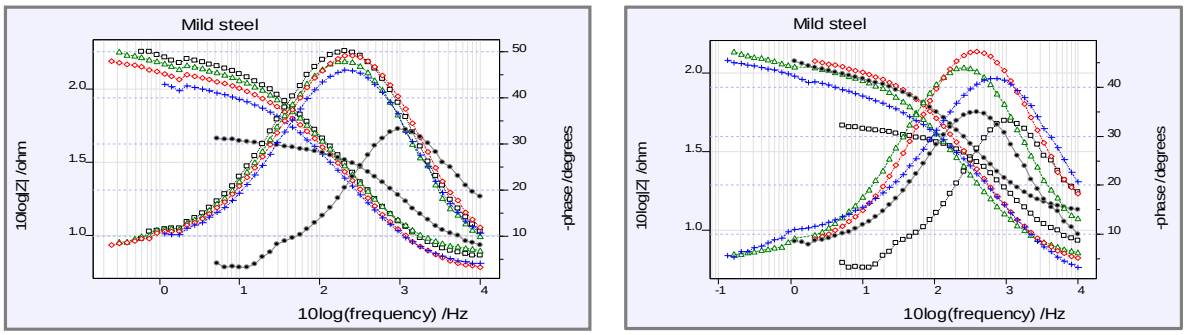


Figure 6. Bode plots of mild steel in alcoholic solution.

Effect of immersion time: The variation of inhibition efficiency for different concentration of plant aqueous and alcoholic extract of ML was listed in the table 4. Highest inhibition efficiency of alcoholic extract for 1N HCl was found to be 96.91 % at 12 h with 20 v/v concentration of the inhibitor respectively. This behavior may be attributed to the increase of the surface coverage by the extract, which retards the corrosion of mild steel.

Table 4. Inhibition efficiency as a various immersion time

Parts of *Madhuca Longifolia* plant	Conc. of the extract (v/v)	Inhibition efficiency (%)					
		1h	3h	5h	7h	9h	12h
	Blank	*	*	*	*	*	*
Madhuca longifolia **leaves**	5	68.10	71.53	66.76	64..39	54.32	45.56
	10	78.10	80.25	78.54	76.76	60.12	68.72
	15	87.50	89.99	86.16	87.96	82.49	86.95
	20	90.2	92.16	93.15	90.37	91.30	94.10
Madhuca longifolia **barks**	5	70.31	74.90	80.33	86.16	85.78	90.12
	10	75.08	86.59	87.88	87.72	86.88	94.78
	15	78.85	88.90	89.19	89.15	87.22	95.92
	20	84.93	92.03	93.05	94.09	90.78	96.91
Madhuca longifolia **fruits**	5	72.81	78.90	76.14	74.21	83.89	78.90
	10	75.95	80.16	85.33	76.78	87.28	89.13
	15	78.84	84.56	87.60	82.59	87.99	92.98
	20	93.21	91.89	92.69	90.17	93.89	94.16
Madhuca longifolia **seed peel**	5	78.90	74.93	80.23	83.78	86.87	89.21
	10	86.98	80.54	85.33	84.98	88.96	90.56
	15	87.98	83.44	86.59	88.98	89.18	92.21
	20	92.62	90.34	94.25	92.09	91.54	94.60

Effect of temperature: The effect of temperature on the corrosion inhibition properties of ML extract was studied by exposing the mild steel to 1 N HCl containing 5, 10, 15, 20 v/v of the ML extract in the temperature range of 303-323K. The data in Table 5 indicate that the leaves extract is effective as inhibitor for mild steel in 1N HCl upto 303K and increase thereafter. Uppermost inhibition efficiency of alcoholic extract for 1N HCl was found to be 97.10 % at 12 h with 20 v/v concentration of the inhibitor respectively.

Phytochemical Screening: Phytochemical screening was carried out on the ML extract freshly prepared according to the common phytochemical method described earlier by [73-74]. The different chemical constituent tested included Alkaloids, Terpenoids, Sterols, Triterpenes, Anthraquinones and Flavonoids etc are given in table 6.

Adsorption isotherm: The information on the collaboration between inhibitor molecules (organic adsorbate) and mild steel surface can be provided by adsorption isotherm. In order to evaluate the

Table 5. IE at various temperatures

Alcoholic extract				
Parts of *Madhuca Longifolia* plant	**Conc. of the extract (v/v)**	**IE (%)**		
		303K	**313K**	**323K**
	Blank	*	*	*
Madhuca Longifolia **leaves**	5	50.64	65.15	66.66
	10	68.83	72.72	73.01
	15	79.22	77.27	80.95
	20	90.90	86.36	88.88
Madhuca Longifolia **barks**	5	45.90	28.39	33.80
	10	52.45	56.79	56.33
	15	68.85	72.83	78.87
	20	91.80	93.82	92.95
Madhuca Longifolia **fruits**	5	14.92	59.96	6.34
	10	58.20	72.15	26.98
	15	91.04	93.67	92.06
	20	80.59	77.21	55.55
Madhuca Longifolia **seed peels**	5	25.97	20.25	27.63
	10	75.32	62.02	65.78
	15	84.41	78.48	75.00
	20	92.20	89.87	92.10

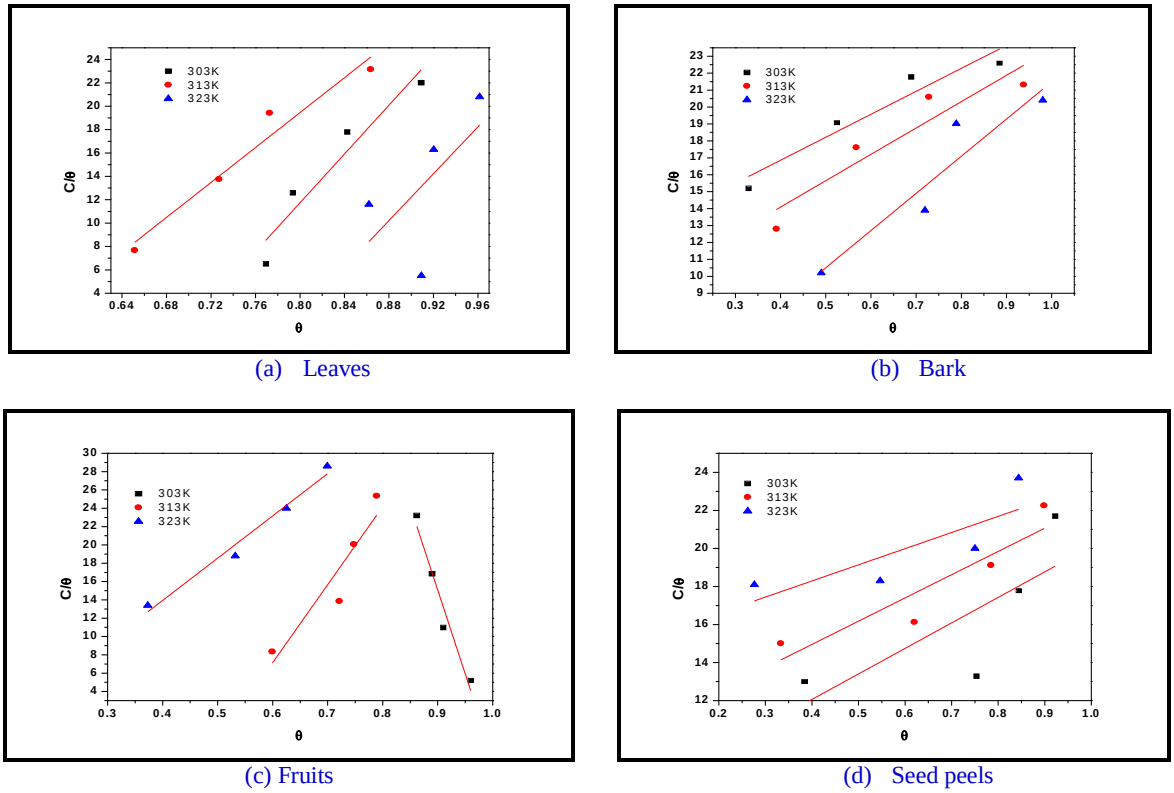
Table 6. Phytochemical screening test of extract of ***Madhuca longifolia* (ML)** plant

Alcoholic extract				
Phytochemical test	**leaves**	**Barks**	**Fruits**	**Seed peel**
Alkaloids	+	+	-	-
Carbohydrates	+	+	+	+
Proteins	-	+	+	+
Saponins	+	-	-	-
Thiols	-	+	-	-
Tannins	+	-	+	-
Flavanoids	-	+	_	+
Phenol	-	+	-	-
Glycosides	-	-	-	-

(+).. Presence (-)... Absence

adsorption process of selected ML plant extract on the metal surface Temkin, Langmuir, Frumkin were made to find the best isotherm which describes in this study. According this isotherm related to surface coverage area and inhibitor concentration shown in figure 7-9. The isotherm assumed that the metal surfaces contain a fixed number of adsorption sites and each site hold one adsorbate. Since the linear regression coefficient or correction factor (R^2) are almost unities or 1. The literature shows that the adsorptions of heterocyclic (Organic) compounds usually contains polar function with hetero atom such as N, S, O, and P and have double or triple bond or aromatic ring. Which these group are more electron donor and possibility of centre of adsorption. These isomerism are very important in determining the mechanism of Organo-electrochemical reaction and it's provides important clues to the nature of the metal-inhibitor interaction. The metal /solution interface is due to the formation of either electrostatic or covalent bonding between the adsorbates and the metal surface atom [72-78]. Good correlation between plant water and alcoholic soluble constituent and suggest physical adsorption mechanism was obtained.

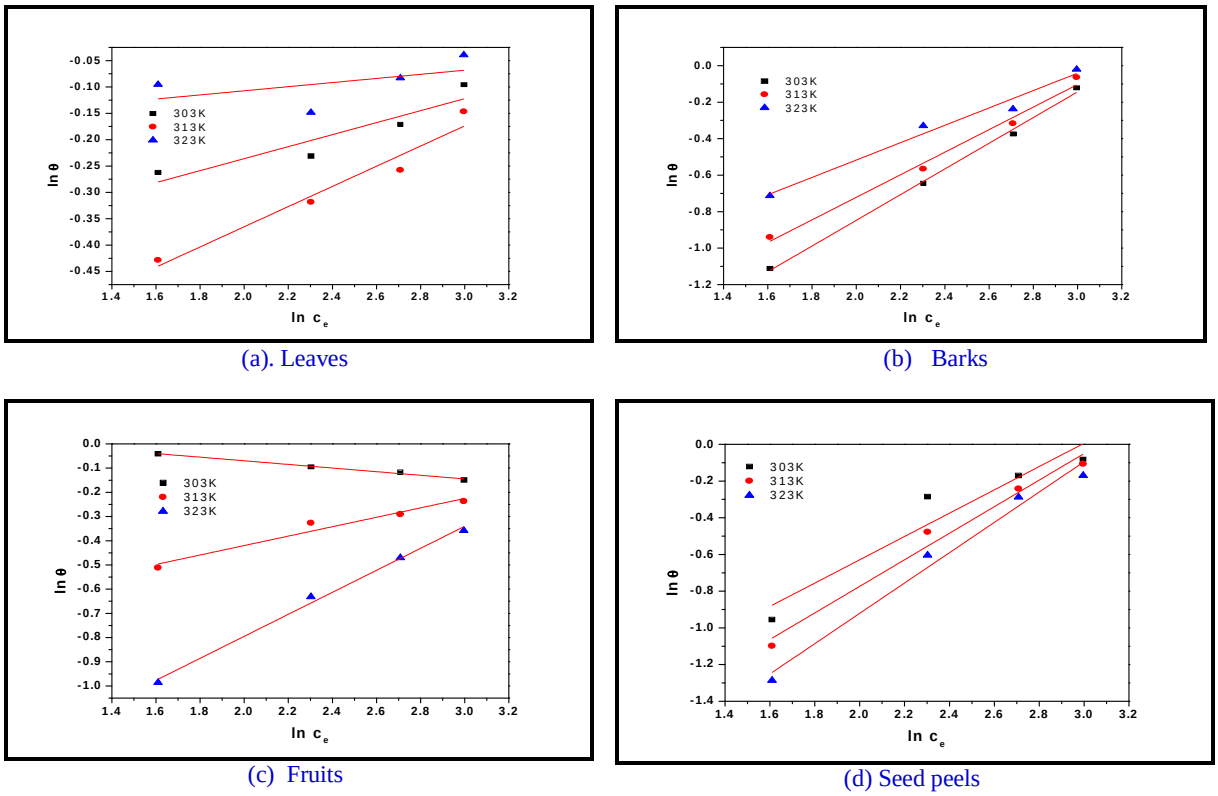
Mechanism of inhibition: The possible mechanism of inhibition can be described on the center of adsorption method and the structure of the components present in the ML plant extracts. The leading constituent of ML plant extract is whose structures are given in figure 10 having multiple bonds though which they get adsorbed on the metal surface. The compounds have to block the vigorous corrosion positions on the MS surface and hence the adsorption occurs by the bonding of the free



(a) Leaves (b) Bark

(c) Fruits (d) Seed peels

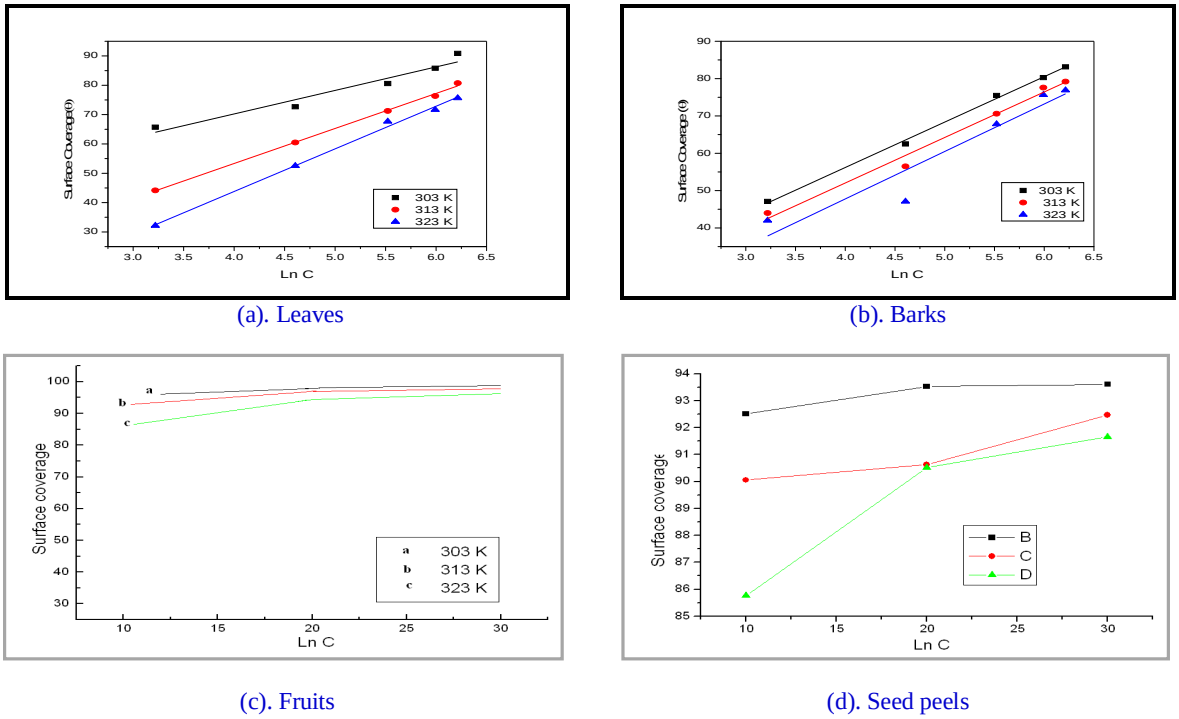
Figure 7. Langumir adsorption isotherm plot for mild steel in 1N HCl containing different concentration of ML plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds peels.



(a). Leaves (b) Barks

(c) Fruits (d) Seed peels

Figure 8. Hasley adsorption isotherm plot for mild steel in 1N HCl containing different concentration of ML plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds peels.



(a). Leaves (b). Barks

(c). Fruits (d). Seed peels

Figure 9. Temkin adsorption isotherm plot for mild steel in 1N HCl containing different concentration of ML plant alcoholic extracts (a) leaves (b) barks (c) fruits and (d) seeds peels.

electron of inhibitor with the metal. Phytochemical analysis showed the presence of glycosides, flavonoids, saponins, steroids, tannins, and alkaloids. Above Organic fragments grows adsorbed on the metal surface developing a protecting film and difference in inhibitory properties of inhibitor is closely related to the difference in molecular structure. The following component with structure contains electron rich oxygen and nitrogen that could serve as good active ingredients which are responsible for corrosion inhibition in plants.

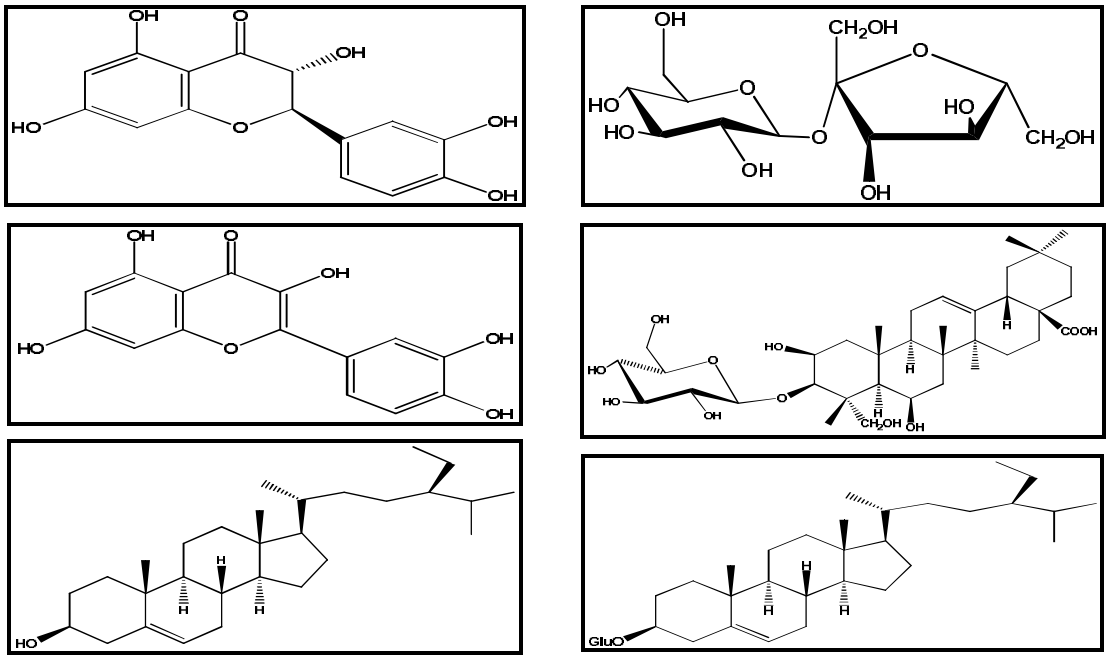


Figure 10. Phytoconstituents of ML plants.

CONCLUSION

Selected plant ML extract served as potential benign inhibitor for the corrosion of mild steel in 1N HCl acid media. Tafel studies, and impedance studies revealed that the inhibitor act as mixed type inhibitor. FTIR studies conducted on corrosion product confirm the formation of Fe complex. SEM studies prove the adsorption of the select plant extracts on the mild steel surface. In the presence of efficient inhibitors, FT-IR, SEM, indicate the development of a smooth, thick protective layer.

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