



Sesamum Indicum Leaves and *Sesamum Indicum* Stem Extract as a Potential Corrosion Inhibitor for Mild Steel in Acidic Media

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ABSTRACT

The influence of stem and leaves extract of *Sesamum indicum* (Ellu) on the corrosion of mild steel (MS) in 1M HCl and 0.5 M H₂SO₄ was measured by mass loss method and electrochemical techniques. Results revealed that the stem and leaves extract of *Sesamum indicum* act as an effective inhibitor for MS in the examined acidic media. Inhibition efficiency was found to increase with increase in concentration of the inhibitor but decrease with rise in temperature. The inhibitive effect could be attributed to the phytochemical constituents present in the inhibitor. The adsorption characteristics of the inhibitor were approximated by Langmuir adsorption isotherm and Temkin adsorption isotherm. Thermodynamic parameters revealed that the adsorption process is spontaneous. Electrochemical measurements revealed mixed mode of inhibition.

Keywords: *Sesamum indicum*, corrosion, inhibition, eco-friendly inhibitor

Introduction:

Corrosion is the damage of material resulting from exposure and interaction with the environment. Corrosion problems have received a considerable amount of attention because of their attack on materials. The environmental consequences of corrosion on metals are enormous and its inhibition has been deeply investigated. The use of inhibitors is one of the most practical methods for protection against corrosion, especially in acidic media¹. Inhibitors play an important role in controlling corrosion of metals². The use of naturally occurring substances as inhibitors for metals exposed to acid environment has continued to receive attention as replacement for synthesized organic inhibitors mainly due to its biodegradability and eco-friendliness.

Numerous naturally occurring substances such as natural oil extracted from *Pennyroyal mint*³, *Carica papaya* (seeds, leaves, heart wood and bark)⁴ *Ficus benghalensis* and sprouted seeds of *Phaseolus aureus*^{5,6} *Cyamopsis tetragonaloba*⁷, *Ervatamia coronaria*⁸, *Borassus flabellifer*⁹ have been documented as inhibitors. Due to their biodegradability and eco-friendliness the trend of using these green inhibitors are gaining momentum and in this direction, the present work has been undertaken to study the inhibitive action of stem and leaves extract of *Sesamum indicum* (SIS) & (SIL) on the corrosion of MS in acid medium.

Materials and methods:

Preparation of specimens

A rectangular steel bar was cut into pieces of area 5x1cm² and a wire brush was used to descale the test specimens. They were then ground with the silicon carbide abrasive paper, polished, degreased, thoroughly dried and kept in a desiccator for further weight loss tests. The locally produced MS specimens had the following percent nominal composition.

Carbon 0.143 Manganese 0.271 Silicon 0.041 Phosphorous 0.035 Sulphur 0.030 Chromium 0.002 Molybdenum 0.018 Nickel 0.006

Sesamum indicum plant was collected from the nearby field after the seeds were removed and the plant was air dried. The extract was prepared by refluxing 25g dry stem & leaves in 500ml of 0.5M sulphuric acid for 3 hours and kept overnight and filtered to get 5% extract.

Techniques

Weight loss Method

It is one of the oldest techniques of monitoring corrosion and is based on exposing the coupons of the metal onto the test media for a predetermined period of time and then removed and the weight loss of coupon is measured.

In the present work, weighted test pieces were immersed in triplicate in the test media (100ml), with varying concentration of the inhibitor and they were removed after a particular period of immersion, washed, dried and reweighed. The experiments were performed for various parameters such as

- Concentration variation from 0.05-0.5%
- Different time intervals – ½ h, 1h, 3h, 6h, 12h, & 24 h.
- Various temperature – 303,313,323, 333, & 338 K

(For temperature study the time of immersion was for ½ hr)

The corrosion rate has been calculated from the formula,

$$CR = \frac{534 * Wt. loss * 10000}{Density * time of immersion area of sample}$$

The inhibitor efficiency was obtained from the following formula,

$$IE (\%) = \frac{W_0 - W}{W_0} * 100$$

Where,

W_0 - Weight loss without inhibitor.

W - Weight loss with inhibitor.

From the weight loss measurements the thermodynamic parameters and the kinetics of the reaction can be carried out to arrive at a suitable mechanism

Electrochemical Methods:

Tafel plot techniques

In the Tafel plot technique, a controlled potential scan was applied, extending in both the anodic and the cathodic directions of corrosion potentials for a few hundred millivolts. The linear region of the plot (applied potential vs. log current) is projected to intersect. This defines corrosion potential (E_{corr}) and the slope of the linear region is the tafel slope (ba and bc).

I.E was calculated by applying the formula,

$$IE = \frac{I_{corr} (blank) - I_{corr} (Inhibited) * 100}{I_{corr} (blank)}$$

Impedance spectroscopic techniques:

In this method an AC signal of 5-10 mv of frequencies 10 KHZ to 10 MHZ is applied to the system. Impedance data can be presented in the form of Nyquist or Bode plot.

The I.E can be calculated using the equation.

$$IE = \frac{\text{Corrosion rate (without inhibitor)} - \text{corrosion rate (with inhibitor)}}{\text{Corrosion rate (without inhibitor)}} * 100$$

Results and Discussion:

Effect of concentration and Immersion time of the inhibitor:

The effect of the inhibitor on the dissolution of MS in 0.5 M H_2SO_4 media has been investigated by conducting the tests with various concentration and immersion time of the extract (0.5% extract). The results are illustrated in table 1(a,b). The data showed that the corrosion rate of MS decreased with increase in concentration and the maximum enhancement of inhibition is noted with 0.5% of the extract. The increase in inhibition efficiency with increase in concentration of the extract may be attributed to the increase in the number of molecules adsorbed over the MS surface. This blocks the active sites in which direct acid attack proceed there by effectively protecting the metal from corrosion. ⁽¹²⁾

Table 1.a- Effect of concentration & Time on inhibition efficiency of SIL Extract in 0.5 M H₂SO₄

Conc (%)	IE (%)					
	1/2 h	1 h	3 h	6 h	12 h	24 h
0.05	20.83	46.42	51.44	58.19	69.06	91.89
0.1	26.23	48.70	58.59	61.73	72.37	90.07
0.15	32.81	47.88	60.75	62.31	77.19	91.12
0.2	33.32	50.32	64.10	63.57	79.77	91.84
0.25	40.62	50.48	65.72	69.81	79.77	92.28
0.3	43.74	51.21	67.35	73.40	81.71	93.46
0.35	51.56	52.32	72.64	75.92	81.85	93.58
0.4	54.16	54.26	73.64	77.24	82.05	93.67
0.45	57.86	57.27	74.20	79.11	84.41	93.86
0.5	59.19	58.30	76.43	80.45	86.75	94.05

Table 1.b - Effect of concentration & Time on inhibition efficiency of SIS extract in 0.5 M H₂SO₄

Conc (%)	IE (%)					
	1/2 h	1 h	3 h	6 h	12 h	24 h
0.05	20.5	6.4	49.1	61.8	72.9	90.5
0.1	30.7	48.6	50.9	63.1	79.8	91.3
0.15	31.9	50	50.8	69.6	79.7	91.7
0.2	39.1	50.7	51.8	73.2	82.2	92.2
0.25	40.1	51.5	56.2	73.6	83.9	92.4
0.3	41.0	52.9	56.7	74.4	84.3	92.6
0.35	41.8	54.7	57.4	75.2	84.7	92.9
0.4	45.1	55.7	58.2	76.2	84.8	93.3
0.45	46.3	56.3	60.3	77.6	85.5	94.07
0.5	47.9	56.9	62.1	78.8	86.2	94.65

From the tables, it can also be seen that inhibition efficiency increases with increasing concentration of the inhibitor at all periods of immersion. From the results, it can be inferred that as the time of immersion increases, the inhibitor molecules gets coated on the surface of mild steel thereby decreasing the MS dissolution effectively. A maximum of 94.65% & 94.05% of inhibition was obtained at 0.5% of 5% of the leaf and stem extract under study respectively. In the present investigation it is also observed that the extract behaved as an excellent one at all periods of immersion. This proves the inhibitive nature of the adsorbed molecules on the surface of MS

Effect of temperature:

Temperature can influence the interaction between MS and the acid in the presence and absence of the inhibitors. To determine the activation energy and the energy of adsorption of the corrosion process, weight loss studies were conducted using SIL & SIS extract at various temperatures ranging from 303K to 353K. Inhibition efficiency of MS at various temperatures are listed in the table 2, and depicted in figure 1.

From the figure, it can be seen that the IE increased unto 313K and then a gradual decrease was observed for both extracts in H₂SO₄ medium. A maximum efficiency of 81.5% was observed at 313K for SIL extract and 75.1% was observed at 313K for SIS extract. According to N.S Rawat and A.K Singh (1987), the above observation can be explained on the following basis adsorption and desorption of inhibitor molecules continuously occur at the metal surface and an equilibrium exists between these two processes at a particular temperature. With the increases of temperature the equilibrium between

adsorption and desorption processes is shifted leading to a high desorption rate until equilibrium is again established at a different value of equilibrium constant. It explains the lower inhibition efficiency at higher temperatures.

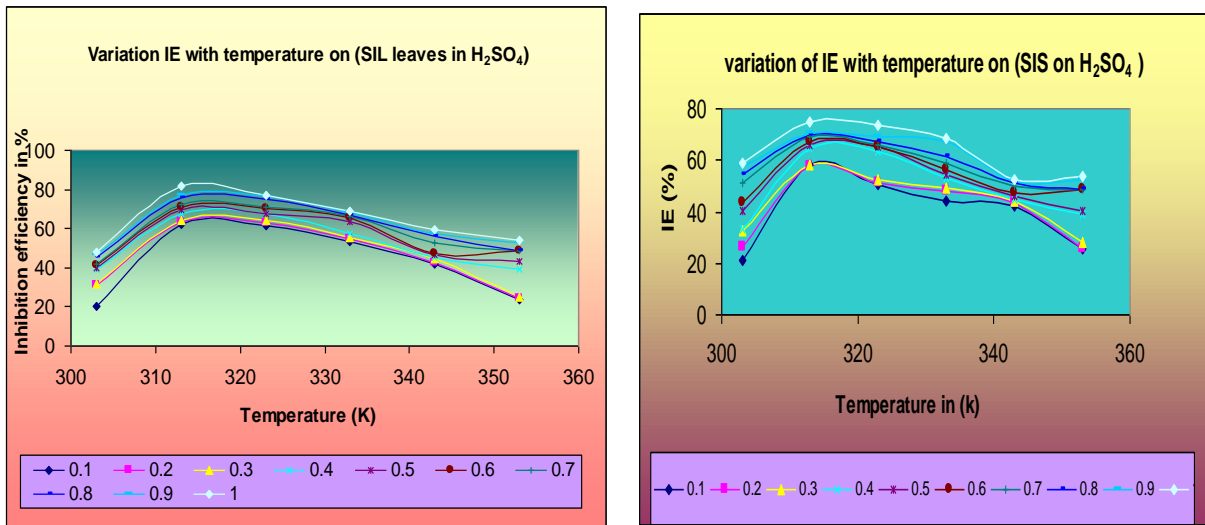


Figure-1 Inhibition efficiency of MS at various temperatures of SIL & SIS Extracts

Adsorption behaviour

The nature of inhibitor interaction on the corroding surface during corrosion inhibition of metal has been deduced in terms of adsorption characteristic of the inhibitor. The inhibition data are used for constructing experimental adsorption isotherms. Adsorption isotherms provide a clue to the mode and mechanism of adsorption. It is assumed that the inhibition efficiency is comparable to the degree of surface coverage of the inhibitor on the metal surface.

The surface coverage (θ) values for different concentration of the inhibitor in acid medium were evaluated from the weight loss data. Attempts were made to fit the data obtained from weight loss measurement into different adsorption isotherms like Langmuir and Temkin. An assumption of Langmuir adsorption isotherm relate concentration of inhibitor in the bulk electrolyte and the degree of surface coverage by the following equation,

$$\text{Log } [\theta/(1-\theta)] = \text{log K} + \text{log C}$$

From the above equation, if the assumptions of Langmuir are obeyed, a plot of $\text{log } (\theta/(1-\theta))$ Vs log C should give a straight line. Langmuir plots for the corrosion reaction of MS in the presence of SIL & SIS are shown in figure 2. It is clear from the linear plot that the inhibitors follow Langmuir adsorption isotherm with r^2 values of 0.95 and 0.91.

A straight line was obtained when the surface coverage was plotted against log C for the inhibitor. This shows that the adsorption of the inhibitor at the MS acidic solution interface obeys Temkin adsorption isotherm. The plots of θ Vs log C for the inhibitor SIL & SIS is shown in fig 3.

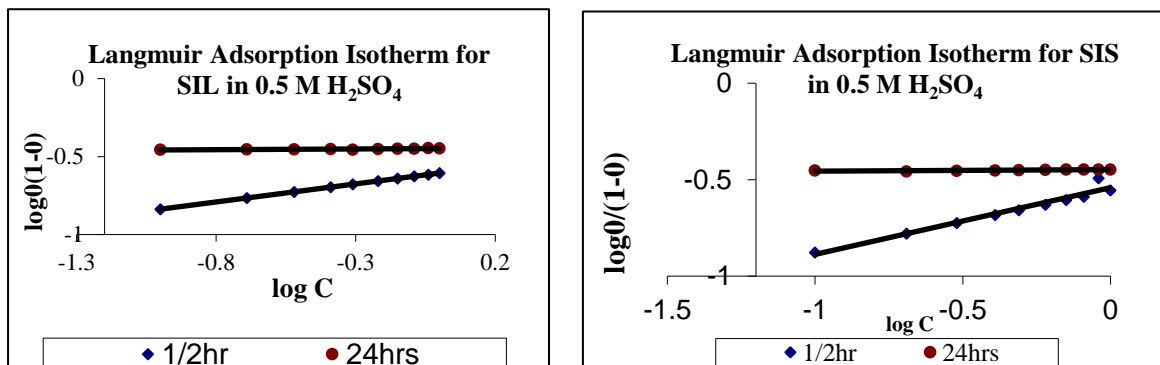


Figure-2 Langmuir plots for the corrosion reaction of MS in the presence of SIL & SIS

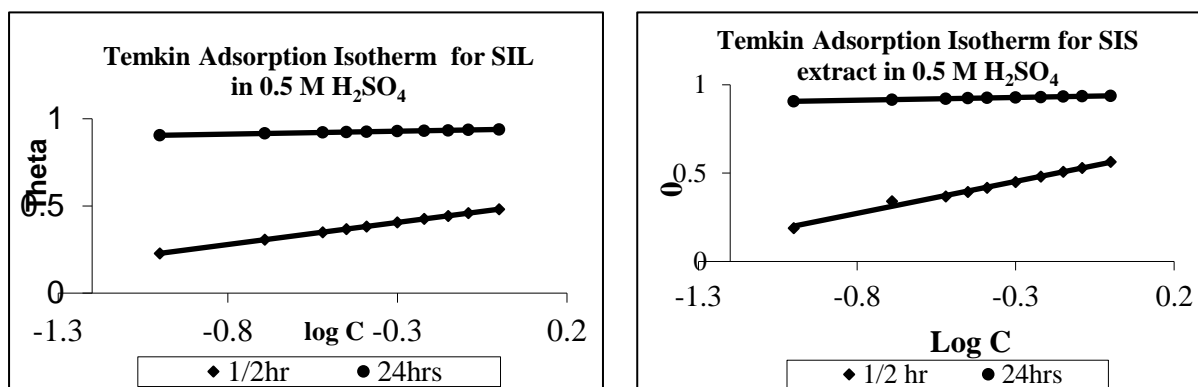


Figure-3 Temkin adsorption isotherm for the inhibitor SIL & SIS

From the intercepts of the straight lines on the C_{inh}/θ -axis (fig. 2), K_{ads} can be calculated which is related to free energy of adsorption ΔG_{ads}^* , as given by equation (3)

$$\Delta G_{\text{ads}}^* = -RT \ln (55.5 K_{\text{ads}}) \quad (3)$$

The values of the free energy of adsorption, ΔG_{ads}^* was obtained from equation (3) and are given in table (2). Results presented in the table indicate that the values of ΔG_{ads}^* are negative in all cases and lies between -10.2 and -14.2 KJmol^{-1} . The negative values signify a spontaneous adsorption of the inhibitors molecules via physical adsorption mechanism. It is also seen that values of ΔG_{ads}^* decreased with an increase in temperature, a phenomenon which indicates that the adsorption of the inhibitor onto MS surface was unfavorable with increasing experimental temperatures as a result of desorption of adsorbed inhibitors from the metal surface. Generally, values of $\Delta G_{\text{ads}}^* \leq -20 \text{ KJmol}^{-1}$ (as obtained in this study) signify physisorption, and values more negative than -40 KJmol^{-1} signify chemisorption, physisorption is consistent with electrostatic interaction between charged molecules and charged metal while chemisorption is consistent with charge sharing or transfer from the inhibitors components to the metal surface to form a co-ordinate type of bond

Table 2- Adsorption Parameters calculated from Langmuir and Temkin Adsorption Isotherm

S. No	Temp in K	Langmuir				Temkin			
		Slope	logK	ΔG_{ads}^* (KJmol^{-1})	R^2	A	logK	ΔG_{ads}^* (KJmol^{-1})	R^2
1	303	0.52	0.091	-10.34	0.98	0.17	0.68	-11.83	0.96
2	313	0.88	0.11	-10.74	0.99	0.07	0.76	-12.44	0.91
3	323	0.83	0.09	-11.04	0.99	0.10	0.77	-12.87	0.93
4	333	0.81	0.13	-11.48	0.99	0.10	0.71	-13.10	0.94
5	343	0.90	0.26	-12.19	0.99	0.04	0.54	-13.00	0.91
6	353	1.16	0.04	-11.91	0.97	0.77	0.08	-12.03	0.95

Activation energy (E_a)

Energy of activation for different concentration of the inhibitor in H_2SO_4 was calculated by plotting $\log C.R$ Vs $1/T$ (fig 4). The dependence of logarithm of the C.R on the reciprocal values of the absolute temperature gives a straight line. The values of the slope of these straight lines permit the calculation of activation energy E_a by the application of following equation.

$$C.R = A.e^{(-E_a/RT)}$$

Where,

A is the frequency factor for the reaction, R is the universal gas constant, T is the temperature (Kelvin). Thus E_a can be evaluated from the rate constant at any temperature. The estimated values of E_a for MS in extract of SIL & SIS in $0.5 \text{ M H}_2\text{SO}_4$ are listed in the table 3. From the table, it can be understood that energy of activation changes in the presence of the inhibitors. The estimated E_a in the presence of inhibitors infer that the interaction between the metal surfaces is strong enough to prevent corrosion.

This may seem surprising and paradox, but in the presence of the inhibitor, the dissolution of the metal proceeds with two distinct processes corresponding to the covered area and the bare metal surface concluded that at high degree of coverage the dissolution process is not only determined by

the reaction of the metal from the bare surface but also involves the adsorbed inhibitor and consequently the E_a can assume values greater or smaller than those calculated in the absence of the inhibitor (16).

As far as the present study is concerned the above said explanation aptly suits the result obtained for the extract of SIS.

It was also found that the activation energy of the acid medium in the presence of the inhibitor were lower than the values of the media in the absence of the extract there by confirming that the adsorption of the extract of SIS occurred through the mechanism of physical adsorption.

ΔH and $-\Delta S$

A plot of ΔG Vs T is a straight line which is depicted in fig 5. The values of ΔH and ΔS are taken from intercept & slope respectively. The values of ΔH and ΔS indicate that the system is enthalpic and entropic controlled. From table, the extract of SIS on MS shows positive value for ΔH suggesting that the dissolution process is an exothermic phenomenon & that the dissolution of steel is difficult which in turn proves the corrosion inhibition effect of the plant extract. Also the entropy ΔS widely decrease with the content of the inhibitor. This means the formation of an ordered stable layer of inhibitor on the steel surface.

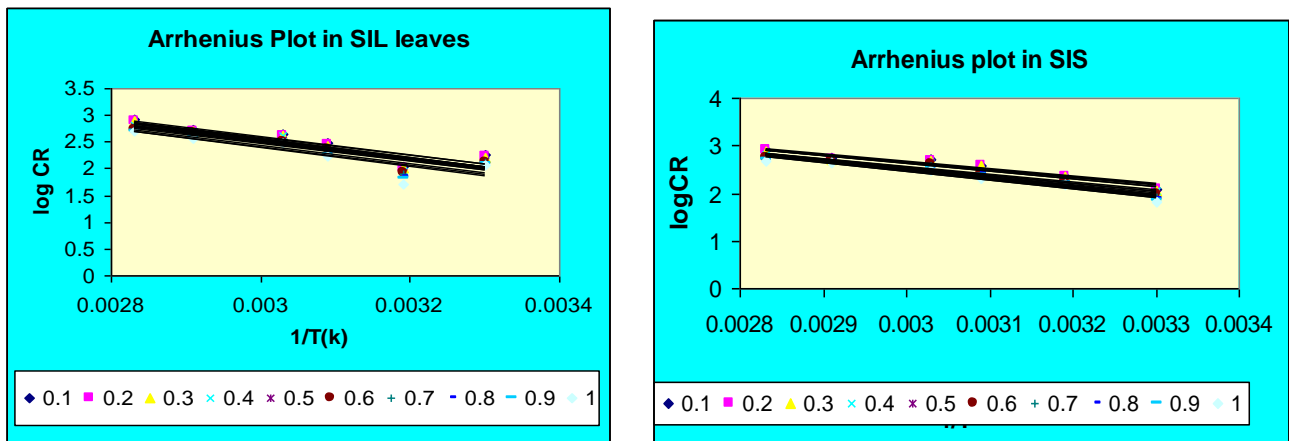


Figure-4 Energy of activation for different concentration of the inhibitor in H_2SO_4

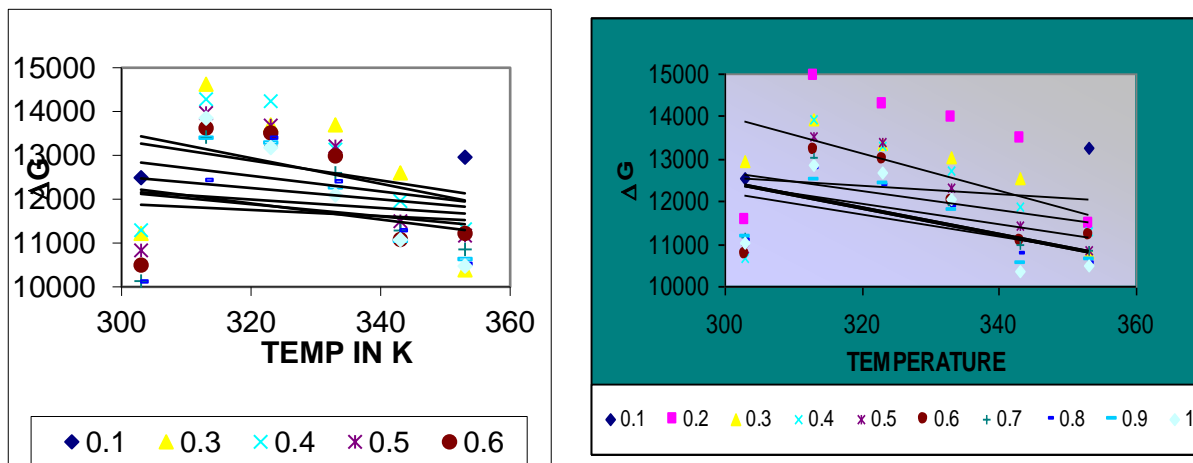


Figure-5 ΔG as a function of temperature for SIL & SIS

Table-3.a- Variation of Thermodynamic and Kinetic Parameters with Concentration and Temperature (SIL in 0.5 H₂SO₄)

Conc. (%)	Ea KJ/mol	ΔG values at various Temperature KJ/mole						ΔS J/mol	ΔH K J/mol
		303 K	313 K	323 K	333 K	343 K	353 K		
Blank	-12.12	-	-	-	-	-	-	-	-
0.05	-12.54	-12.49	-17.13	-16.25	-16.25	-15.05	-12.95	18.67	-11.12
0.1	-12.92	-14.14	-15.51	-14.64	-14.64	-13.40	-11.31	33.13	-58.51
0.15	-13.77	-11.22	-14.62	-13.69	-13.69	-12.60	-10.38	22.29	-29.23
0.2	-13.33	-11.29	-14.27	-14.23	-13.13	-11.95	-11.31	20.14	-22.70
0.25	-12.87	-10.83	-13.96	-13.68	-13.20	-11.49	-11.17	18.22	-17.77
0.3	-12.59	-10.49	-13.61	-13.51	-12.98	-11.08	-11.21	16.38	-12.91
0.35	-12.16	-10.12	-13.42	-13.20	-12.59	-11.28	-10.85	15.10	-9.71
0.4	-13.01	-10.12	-12.44	-13.40	-12.40	-11.29	-10.52	13.99	-6.99
0.45	-12.81	-99.92	-13.40	-13.29	-12.27	-11.05	-10.63	16.31	-13.84
0.5	-13.44	-98.82	-13.84	-13.17	-12.09	-11.07	-10.47	7.80	-18.44

Table-3.b- Variation of Thermodynamic and Kinetic Parameters with Concentration and Temperature (SIS in 0.5 H₂SO₄)

Conc. (%)	Ea KJ/mol	ΔG values at various Temperature KJ/mole						ΔS J/mol	ΔH K J/mol
		303 K	313 K	323 K	333 K	343 K	353 K		
Blank	- 12.1	-	-	-	-	-	-	-	-
0.05	- 12.20	-12.54	-16.75	-15.95	-15.27	-15.13	-13.24	-5.75	16.70
0.1	- 12.10	-11.54	-14.94	-14.28	-13.95	-13.48	-11.47	-14.48	18.03
0.15	- 12.10	-12.94	-13.93	-13.36	-13.03	-12.54	-10.78	-43.76	27.12
0.2	- 12.14	-10.65	-13.91	-13.81	-12.73	-11.89	-11.29	-9.81	15.52
0.25	- 12.35	-10.88	-13.52	-13.41	-12.31	-11.43	-10.83	-21.74	19.20
0.3	- 12.33	-10.74	-13.19	-12.97	-12.02	-11.09	-11.22	-13.89	16.43
0.35	- 13.28	-11.15	-13.04	-12.66	-11.91	-10.99	-10.84	-24.04	19.65
0.4	- 13.53	-11.07	-12.74	-12.37	-11.86	-10.77	-10.51	-26.38	20.21
0.45	- 14.03	-11.15	-12.50	-12.41	-11.77	-10.54	-10.61	-26.43	20.17
0.5	- 14.24	-11.03	-12.87	-12.66	-12.03	-10.37	-10.50	-30.75	21.66

Electrochemical measurements

Electrochemical studies will be helpful to predict the nature of the inhibitor -anodic, cathodic or mixed type inhibitor and to predict a suitable mechanism for the inhibition process. The values of corrosion kinetic parameters corrosion current (E_{corr}), corrosion current density (I_{corr}), Tafel slopes (b_a and b_c), linear polarization resistance (R_p) are recorded in table 4 (a,b).

The results indicated a considerable reduction in I_{corr} values in the presence of the inhibitor. This confirms the inhibitive nature of the extract and also the adsorption of the plant extract on metal surface. The values of IE are found to be increasing with increase in concentration of inhibitor. A maximum

of 93.68% inhibition was obtained with 0.5% concentration. No significant change in E_{corr} values in the presence of inhibitor indicating the mixed nature of the inhibitor Tafel constant b_a and b_c are found to be changing with the concentration of the inhibitor.

Table-4.a- Tafel Polarization and Impedance Measurements of MS in SIL Extract In 0.5M H₂So₄

Conc. (%)	$I_{corr} \times 10^{-4}$ (amp/cm ²)	E_{corr} (V/dec)	b_a (mV/dec)	b_c (mV/dec)	IE (%)	R_{ct} (Ohm cm ²)	IE (%)	R_p (Ohm cm ²)	IE (%)	$C_{dl} \times 10^{-5}$ (F cm ²)	(θ)
Blank	6.75	5.27	236.1	192.8	-	29.49	-	5.00	-	0.000084	-
0.1	1.15	5.24	244.8	125.8	82.83	65.95	64.58	28.98	82.72	0.00014	42.52
0.2	7.87	5.26	287.9	127.5	88.34	95.35	69.06	45.13	88.90	0.00010	22.41
0.3	5.33	5.34	173.4	112.1	84.60	124.02	63.38	34.37	90.12	0.00013	37.81
0.4	7.54	5.24	250.1	126.1	88.83	64.57	54.32	46.74	89.28	0.00009	31.20
0.5	1.04	5.25	203.2	119.9	92.10	80.56	76.21	50.77	85.43	0.000125	58.95

Table-4.b - Tafel Polarization and Impedance Measurements of MS in SIS Extract in 0.5M H₂So₄

Conc. (%)	$I_{corr} \times 10^{-4}$ (amp/cm ²)	E_{corr} (V/dec)	b_a (mV/dec)	b_c (mV/dec)	IE (%)	R_{ct} (Ohm cm ²)	IE (%)	R_p (Ohm cm ²)	IE (%)	$C_{dl} \times 10^{-5}$ (F cm ²)	(θ)
Blank	6.7	5.37	236.1	192.8	-	29.5	-	5.83	-	0.000084	-
0.1	1.48	5.26	239.9	126.7	78.0	34.47	14.4	23.90	79.05	0.000115	26.74
0.2	1.61	5.27	229.6	134.0	78.2	45.97	35.8	22.40	77.64	0.00024	65.70
0.3	1.47	5.30	240.3	147.4	80.3	59.66	50.0	27.31	81.66	0.00031	61.48
0.4	1.25	5.32	201.9	136.2	81.4	51.78	43.0	26.50	81.10	0.00034	75.45
0.5	1.59	5.26	238.1	149.5	93.7	70.13	57.9	27.22	81.59	0.00021	73.09

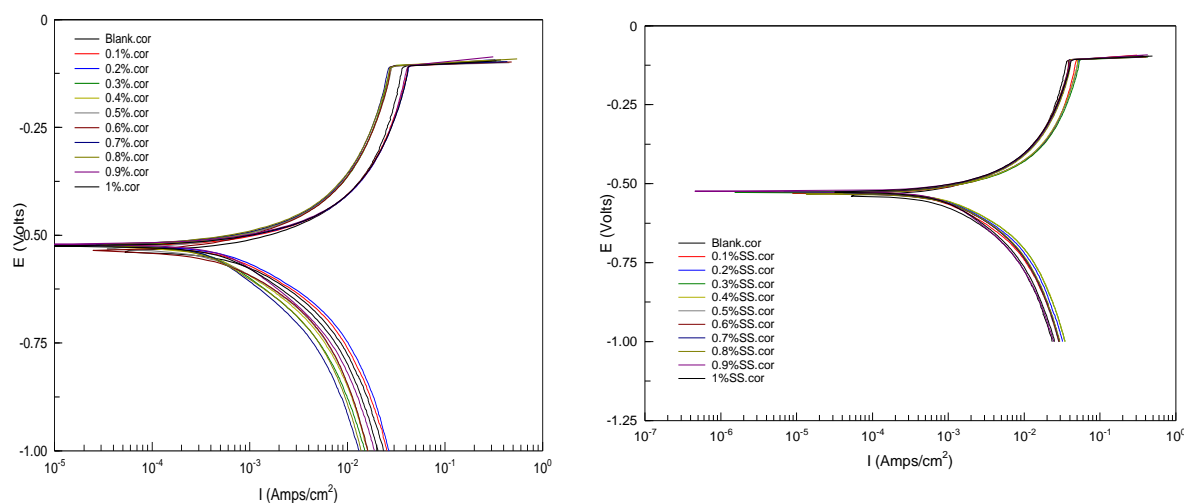


Figure-6.a Potentiodynamic Polarization Curves of SIL& SIS Extract 0.5 M H₂So₄

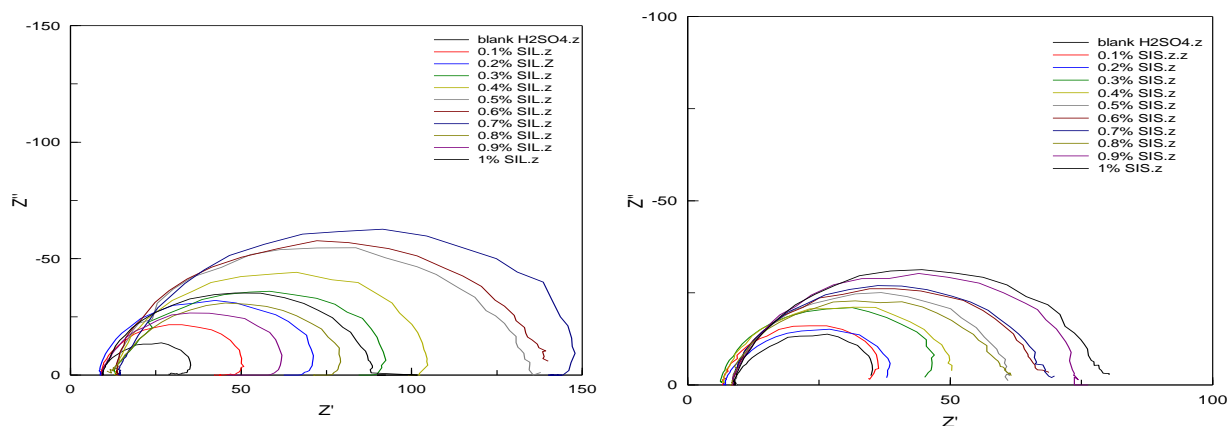


Figure-6.b Impedance Curves of MS in the presence of SIL & SIS Extract in 0.5M H₂SO₄

Impedance Spectroscopy:

The Nyquist plot of the impedance behaviour of MS in 0.5 M H₂SO₄ in the presence of various concentrations of the inhibitor is shown in fig 6.a&b.

It can be seen that the impedance spectra are not perfect semicircle. A clean electrode without a passive film especially in the case of corroding electrode immersed in acid solutions gives rise to an impedance spectrum consisting of perfect semicircle. The depressed semicircle is either due to the presence of pores on the electrode surface or due to the adsorption of the inhibitor⁽¹⁷⁾. In the presence case it may be due to the adsorption of the inhibitor. The diameter of the semicircle gives the charge transfer resistance (R_{ct}). This is taken as the measure of corrosion rate as the charge transfer resistance is inversely proportional to the rate of corrosion. From the impedance spectral data it is evident that R_{ct} values increase with increase in concentration of the inhibitor. This may be attributed to the adsorption of the active constituents of the inhibitor species on the metal/solution interface. This increase is in accordance with the results obtained by weight loss measurements.

The C_{dl} value was found to decrease with increase in concentration of the inhibitor which can result from decrease in dielectric constant due to adsorption of phytochemical constituents of the extract onto the metal surface^(19, 20).

Comparison of Weight loss and electrochemical methods

The values of inhibition efficiency calculated from electrochemical measurements are lower than those obtained from weight loss data. Nevertheless in general, the polarization data confirms the results of steel dissolution measurements. The difference in inhibition efficiency by different techniques can be attributed to the fact that weight loss method gives average corrosion rates, while electrochemical measurements give instantaneous corrosion rate. The difference may be expected to arise because of the difference in time required to form an adsorbed layer, which brings down corrosion.

Mechanism of Inhibition:

Most organic inhibitors contain at least one polar group with an atom of Nitrogen or Sulphur or in some cases Selenium and Phosphorus. The inhibiting properties of many compounds are determined by the electron density at the reaction center⁽¹⁾. With increase in electron density in the center, the chemisorption between the inhibitor and the metal are strengthened.^(18, 19, 20)

From the literature survey it was found that the major phytochemical constituent's present in SIL, SIS are, Arachidic, Arginine, Ash, Aspartic-acid, Calcium, Chlorogenic-acid, Fat, Fiber, Gadoleic-acid, Glutamic-acid, Glycine, Isoleucine, Linoleic-acid, Magnesium, Methionine, Oleic-acid, Phenylalanine, Phosphorus, Potassium, Proline, Protine, Serine, Starch, Stearic-acid, threonine, Tyrosine, Valine, Water^(21, 22).

It can be seen that the SIS extract has a large number of amino acids present in acidic medium these amino group are protonated them yield to NH₃⁺ from complex at the iron surface, there by retarding corrosion.

The above behaviour also can be discussed on the fact that the substitution of hydrogen atom for example, in glycine, by nucleophilic groups such as methyl or isopropyl would lead to an increase in the electron density on -NH₃. This might lead to more convenient electron transfer from the functional group to the metal, with subsequent coordination, hence greater adsorption and inhibition efficiency^(23, 34). Substitution of hydrogen atom by nucleophilic group as OH- or phenyl group, which has inductive effects, would reduce the electron density at the functional group, leading to an increase in protection efficiency.

CONCLUSION

Corrosion control methods, especially the use of inhibitors, have gained monumental importance in the present scenario of expunging corrosion and the quest for natural products as inhibitors for ecofriendly reasons continues. Green corrosion inhibitors are biodegradable and do not contain heavy metals or other toxic compounds and so they are environmentally friendly. In the current investigation the *Sesamum indicum* leaves & stem extract play a major role in reducing the metal dissolution as well as hydrogen evolution and protect the MS surface from corrosion.

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