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GREEN CORROSION INHIBITION OF MILD STEEL IN ACIDIC MEDIUM USING PSIDIUM GUAJAVA LEAF EXTRACT

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ABSTRACT

This study evaluates the corrosion inhibition potential of Psidium guajava (guava) leaf extract on mild steel in 1 M HCl solution. The extract was prepared by aqueous reflux method and characterized for its phytochemical content. Corrosion inhibition was assessed through weight loss measurements and electrochemical methods. Results revealed that inhibition efficiency increased with extract concentration, reaching a maximum of 69.15% at 500 ppm. The extract acted as a mixed-type inhibitor and followed the Langmuir adsorption isotherm, indicating spontaneous physical adsorption. The findings suggest that Psidium guajava extract is a promising eco-friendly corrosion inhibitor for industrial applications.

Keywords: *Green Corrosion, Mild Steel, Psidium Guajava, Eco-Friendly, Industrial Applications.*

Introduction

Corrosion of mild steel in acidic environments is a significant problem in industries like acid cleaning and oil-well acidification. Green inhibitors offer a sustainable and eco-friendly alternative to toxic commercial inhibitors. Psidium guajava is rich in flavonoids and phenolic compounds, which may effectively inhibit corrosion. This study explores the efficacy of Psidium guajava leaf extract as a corrosion inhibitor for mild steel in 1 M HCl.

Materials and Methods

Materials

- Mild steel specimens
- 1 M hydrochloric acid (HCl)
- Fresh Psidium guajava leaves

Preparation of Extract

Guava leaves were washed, dried, and powdered. 20 g of the powder was refluxed in 200 mL distilled water for 3 hours. The extract was filtered, concentrated, and stored at 4°C.

Weight Loss Method

Specimens were immersed in 1 M HCl with various concentrations of extract for 6 hours. Corrosion rate and inhibition efficiency were calculated.

Preparation of Acid Solution

By diluting analytical reagent grade concentrated hydrochloric acid with double distilled water in a 1000 mL standard measuring flask, a bulk solution of hydrochloric acid (2.5 N) was prepared, and their normalities were assessed by titrating with a standard sodium carbonate solution.

Preparation of Inhibitor Solutions

One Kg of fresh leaves from the plants selected for corrosion research were procured and dried for thirty days in the shade. The dried leaves were ground into a powder and left to soak for three days in 95% ethanol. To get the product with the green colour, the extract was reduced in vacuo and then filtered (30 g). The known amount of inhibitor was dissolved in 1.0 N HCl to create the inhibitor solutions.

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Results and Discussion

Weight Loss Analysis

Table 1: The corrosion inhibition performance of Psidium guajava leaf extract on mild steel in 1 M HCl was evaluated using weight loss measurements. The results are presented below:

(1 hrs Exposure, 7.75 cm², 298 ± 0.1 K)

S. No.	Inhibitor Concentration (ppm)	Weight Loss (ΔM) (mg)	Inhibition Efficiency (η%)	Corrosion Rate (mmpy)	Surface Coverage (θ)	log(θ/1−θ)
1	Blank	94	0.00	135.3507	0.0000	—
2	50	41	56.38	59.0360	0.5638	0.1115
3	100	37	60.64	53.2764	0.6064	0.1877
4	200	37	60.64	53.2764	0.6064	0.1877
5	500	29	69.15	41.7571	0.6915	0.3500

Table 2: The corrosion inhibition performance of Psidium guajava leaf extract on mild steel in 1 M HCl was evaluated using weight loss measurements. The results are presented below:

(6hrs Exposure, 7.75 cm², 298 ± 0.1 K)

S. No.	Inhibitor Concentration (ppm)	Weight Loss (ΔM) (mg)	Inhibition Efficiency (η%)	Corrosion Rate (mmpy)	Surface Coverage (θ)	log(θ/1−θ)
1	Blank	573	0.00	137.5106	0.0000	—
2	50	348	39.27	83.5143	0.3927	-0.1894
3	100	365	36.30	87.5940	0.3630	-0.2442
4	200	162	71.73	38.8773	0.7173	0.4043
5	500	95	83.42	22.7984	0.8342	0.7017

Table 3: The corrosion inhibition performance of Psidium guajava leaf extract on mild steel in 1 M HCl was evaluated using weight loss measurements. The results are presented below:

(24hrs Exposure, 7.75 cm², 298 ± 0.1 K)

S. No.	Inhibitor Concentration (ppm)	Weight Loss (ΔM) (mg)	Inhibition Efficiency (η%)	Corrosion Rate (mmpy)	Surface Coverage (θ)	log(θ/1−θ)
1	Blank	409	0.00	24.5383	0.0000	—
2	50	273	33.25	16.3789	0.3325	-0.3026
3	100	242	40.83	14.5190	0.4083	-0.1611
4	200	223	45.48	13.3791	0.4548	-0.0788
5	500	194	52.57	11.6392	0.5257	0.0446

Adsorption Isotherm

Surface coverage and log(θ/1−θ) data suggest that the adsorption of Psidium guajava extract obeys the Langmuir adsorption isotherm, indicating monolayer adsorption. The negative ΔG_ads values confirm spontaneous and physical adsorption.

Thermodynamic and Activation Parameters

Table 4: Activation and thermodynamic parameters are summarized in the following table:

Concentration (ppm)	Ea (kJ/mol)	Qads (kJ/mol)	ΔH⁰ (kJ/mol)	TΔS⁰ (J/mol)	ΔGads (kJ/mol)
0	74.6	—	71.9	-52.13	-19.77
50	82.6	-24.5	76.4	-51.45	-24.95
100	80.9	-25.8	77.8	-53.14	-24.66
200	84.5	-25.4	80.7	-56.29	-24.41
500	91.7	-31.5	91.2	-66.4	-24.8

Effect of Temperature on Corrosion Inhibition

Table 5: The influence of temperature on the corrosion rate (CR) and inhibition efficiency (%IE) of Psidium guajava leaf extract was studied at three different temperatures: 303 K, 313 K, and 333 K.

Concentration (ppm)	CR (303K)	%IE (303K)	θ (303K)	CR (313K)	%IE (313K)	θ (313K)	CR (333K)	%IE (333K)	θ (333K)
Blank	1458	-	-	1682	-	-	1921	-	-
50	320	70	0.70	460	51	0.51	1028	46	0.46
100	275	75	0.75	418	56	0.56	1002	49	0.49
200	264	80	0.80	300	65	0.65	955	55	0.55
500	190	83	0.83	256	80	0.80	498	71	0.71

Corrosion rate increases with temperature, suggesting a temperature-sensitive corrosion process. The decreasing inhibition efficiency with rising temperature indicates that the adsorption is primarily physical in nature.

Potentiodynamic Polarization Study

Table 6: To investigate the corrosion inhibition mechanism of Psidium guajava leaf extract, potentiodynamic polarization measurements were carried out at various acid concentrations with and without the inhibitor (500 ppm).

HCl Conc. (N)	Extract (ppm)	Ecorr (mV)	icorr (mA/cm²)	βa (mV/dec)	−βc (mV/dec)	η (%)
1.00	0	-476	15.46	223	270	-
1.00	500	-490	0.58	190	204	90.12
0.50	0	-504	12.61	222	263	-
0.50	500	-562	0.67	160	188	87.54
0.10	0	-476	3.15	254	295	-
0.10	500	-534	0.88	129	146	90.16
0.01	0	-480	37.82	182	240	-
0.01	500	-566	0.96	148	180	72.70

Significant reduction in corrosion current density and shifts in Ecorr confirm that Psidium guajava acts as a mixed-type inhibitor, mainly through physisorption.

Comparative Inhibition Efficiency at Room Temperature

Table 7: To evaluate the performance of Psidium guajava leaf extract more clearly, corrosion parameters were studied at room temperature (298 ± 0.1 K) for varying concentrations. The weight loss method was used, and parameters such as mass loss, inhibition efficiency, corrosion rate, surface coverage, and adsorption behavior were calculated.

Concentration (ppm)	Mass Loss (mg)	η (%)	CR (mmpy)	θ	log(θ/1−θ)	Inhibitor
Blank	573	0.00	137.5106	0.0000	-	Psidium guajava
50	348	39.27	83.5143	0.3927	-0.1894	Psidium guajava
100	365	36.30	87.5940	0.3630	-0.2442	Psidium guajava
200	162	71.73	38.8773	0.7173	0.4043	Psidium guajava
500	95	83.42	22.7984	0.8342	0.7017	Psidium guajava

The results show a clear improvement in inhibition efficiency with increasing concentration of the extract, reaching a maximum of 83.42% at 500 ppm. The positive values of log(θ/1−θ) at higher concentrations indicate favorable adsorption of inhibitor molecules on the mild steel surface.

24-Hour Corrosion Study at Room Temperature

To understand the long-term performance of Psidium guajava leaf extract as a corrosion inhibitor, corrosion data were recorded after 24 hours of immersion at room temperature (298 ± 0.1 K). The weight loss technique was used, and inhibition parameters were calculated accordingly.

Compared to the 6-hour results, the 24-hour immersion results show consistent inhibition trends with increasing extract concentration. The highest inhibition efficiency of 52.57% was achieved at 500 ppm. This indicates the stability and prolonged activity of Psidium guajava extract as a corrosion inhibitor over extended exposure time.

Langmuir Adsorption Isotherm

The adsorption of Psidium guajava leaf extract on mild steel surface in 1N HCl medium at 303 K was analyzed using the Langmuir adsorption isotherm model. The model assumes monolayer adsorption on a uniform surface with a finite number of adsorption sites. The isotherm equation was used to compute parameters such as the slope (B), adsorption equilibrium constant (Kads), and correlation coefficient (R^2) for 1 hour, 6 hours, and 24 hours immersion times.

Table 8

Concentration (ppm)	B (1h)	Kads (ppm^{-1})	R^2 (1h)	B (6h)	Kads (ppm^{-1})	R^2 (6h)	B (24h)	Kads (ppm^{-1})	R^2 (24h)
50	-6.91	360.1	0.93	-6.32	352.3	0.97	-7.12	370.17	0.96
100	-5.97	320.5	0.95	-7.55	399.6	0.98	-8.03	418.06	0.97
200	-5.56	290.8	0.94	-8.41	378.4	0.96	-9.12	446.7	0.97
500	-9.56	339.6	0.97	-10.61	334.0	0.95	-11.98	411.19	0.98

The data fit well with the Langmuir model as indicated by the high correlation coefficients (R^2), suggesting monolayer adsorption. The increase in Kads values with time implies stronger interaction of the inhibitor with the metal surface over prolonged exposure.

Conclusion

The present study confirms that the leaf extract of Psidium guajava is an effective green corrosion inhibitor for mild steel in 1N HCl solution. The inhibition efficiency increases with extract concentration and decreases with temperature, suggesting a physisorption mechanism. Thermodynamic parameters support the spontaneous nature of adsorption, and potentiodynamic polarization studies reveal that the extract functions as a mixed-type inhibitor. Thus, Psidium guajava extract can be considered an environmentally benign and cost-effective alternative to toxic corrosion inhibitors in acidic environments.

Psidium guajava leaf extract is an effective green inhibitor for mild steel corrosion in 1 M HCl. Its inhibition efficiency increases with concentration, with maximum efficiency of 69.15% at 500 ppm. Thermodynamic and activation parameters confirm spontaneous, physical adsorption following the Langmuir isotherm.

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