RASĀYAN *J. Chem.*
Vol. 19 | No. 2 | 1139-1149| April-June | 2026
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

ELECTROCHEMICAL EVALUATION OF LEAF AND BARK EXTRACTS OF *Chrozophora Plicata* AS GREEN CORROSION INHIBITORS FOR MILD STEEL IN HYDROCHLORIC ACID: ADSORPTION, THERMODYNAMIC, AND MECHANISTIC STUDIES

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ABSTRACT
Metals and alloys frequently undergo corrosion, a destructive process that reduces their durability, reliability, and service performance, resulting in significant material and economic losses. This study aims to identify and validate low-cost, environmentally benign corrosion inhibitors sourced from indigenous plant materials found in Coimbatore, Tamil Nadu, India. Bioactive constituents were extracted using ethanol from the leaf and bark tissues of *C. plicata*. The extracts were subsequently subjected to phytochemical evaluation, which verified the presence of key secondary metabolites, including flavonoids and phenolic compounds. Qualitative screening further confirmed the occurrence of polyphenolic constituents. Electrochemical performance was assessed employing potentiodynamic polarisation, and electrochemical impedance spectroscopy techniques were employed to assess inhibition performance on steel surfaces. The leaf and bark extracts demonstrated notable protection efficiencies of 87.1% and 69.6%, respectively. PDP measurements uncovered that both extracts act as mixed-type inhibitors, while EIS fallouts indicated an upsurge in polarisation resistance and confirmed that adsorption on the metal surface adheres to the Langmuir adsorption isotherm, involving a combination of physical and chemical interactions. A insignificant reduction in inhibition efficacy with temperature elevation (298–328 K) further substantiated the thermodynamic adsorption trend. These outcomes highlight *C. plicata* as an environmentally benign source of inhibitory compounds, offering an alternative to synthetic commercial formulations. Future work may involve scaling up formulations, surface characterisation via microscopy techniques, and evaluating long-term performance in industrial conditions.
Keywords: *Chrozophora Plicata,* Green Corrosion Inhibitors, Mild Steel Corrosion, Plant Extracts, Potentiodynamic Polarisation, Electrochemical Impedance Spectroscopy, Langmuir Adsorption Isotherm, Thermodynamic Parameters.
RASĀYAN*J. Chem.*, Vol. 19, No.2, 2026

INTRODUCTION

Corrosion is a pervasive electrochemical phenomenon that occurs when metals interact with their surrounding environment, leading to gradual deterioration of their structural integrity, mechanical properties, and surface appearance. This degradation not only compromises the functionality and durability of metallic components but also results in significant economic losses and environmental impacts. Globally, the financial burden associated with corrosion has been estimated to range from 1 to 5 per cent of a developed nation's GDP, highlighting its importance as an industrial and societal challenge, mainly in countries such as the United States, Japan, China, and India.[1,2] Among metallic materials, mild steel is extensively utilized in countless engineering and industrial applications owing to its affordability, high ductility, malleability, and favourable mechanical strength.[3,4] However, its widespread use is counterbalanced by its susceptibility to corrosion, necessitating proactive protective measures. Conventional practices, such as chemical treatments with concentrated hydrochloric acid, are commonly employed to remove rust and surface scales before deployment, yet these approaches do not address long-

term protection and often involve environmentally hazardous chemicals.[5,6] In recent years, extensive research has been devoted to developing corrosion inhibitors to reduce metal deterioration. Special emphasis has been placed on organic compounds that contain heteroatoms such as sulfur, nitrogen, oxygen, and phosphorus. These atoms are capable of interacting with the vacant d-orbitals of iron atoms present on metal surfaces, resulting in the formation of a stable adsorbed protective film that significantly slows down the corrosion process.[6,7] Additionally, organic molecules that possess polar functional groups or aromatic systems, including carbonyl, amide, and hydroxyl groups, can enhance protective performance through electrostatic interactions and π-electron conjugation with the metal substrate.[8,9] While these conventional inhibitors have demonstrated effectiveness, their practical application is often limited by factors such as elevated cost, harmful toxicity, and environmental safety concerns.[10-12] As a result, research has increasingly shifted toward green and sustainable alternatives that are both safe and cost-effective.[13–14] Botanical extracts, waste-derived pharmaceuticals, and Ionic liquids, in certain cases, have demonstrated strong potential as sustainable corrosion inhibitors. Plant-based extracts, in particular, are biodegradable, biocompatible, and often economically viable. These extracts are rich in bioactive compounds containing electron-donating groups, aromatic rings, and heteroatoms that can adsorb onto metal surfaces and reduce corrosion rates.[15–21] Studies have shown that extracts from leaves, fruits, and seeds can significantly improve the corrosion resistance of mild steel. For instance, *Valeriana wallichii* extracts have been reported to inhibit corrosion effectively,[22] while extracts derived from date palm residues in combination with gum arabic achieved protection efficiencies of 78–81 per cent.[23] Similarly, *Pongamia pinnata* extracts exhibited inhibition efficiencies as high as 95 per cent in acidic media.[24] Despite these promising findings, research has predominantly focused on widely available or commonly used plant species, leaving many potential sources unexplored. The effects of less-studied plants, such as *Chrozophora plicata*, on mild steel corrosion remain largely uninvestigated, representing a critical gap in the current understanding of green corrosion inhibitors. This research seeks to bridge the existing gap by evaluating the corrosion inhibition performance of *Chrozophora plicata* leaf and bark extracts on mild steel in acidic conditions. It is anticipated that the electron-donating constituents and heteroatom-containing compounds present in these extracts will adsorb onto the steel surface, leading to the formation of a protective layer that slows metal dissolution and increases resistance to corrosion. By investigating both leaf and bark extracts, the study also attempts to identify any synergistic interaction between them that could enhance the inhibition efficiency. The results of this investigation are expected to provide valuable insight for the development of cost-effective and environmentally sustainable methods for corrosion protection. The work is particularly novel because it examines an underutilised plant species with minimal prior investigation, broadening the scope of green corrosion inhibitors and providing insights that may inform future applications in industrial and engineering contexts. By combining eco-friendly approaches with practical performance evaluation, this research not only addresses a critical environmental and economic challenge but also supports the transition toward safer and more sustainable material protection methodologies.

EXPERIMENTAL

Botanical Trial Assortment

Leaves (CTL) and bark (CTB) of *C. plicata* were collected in May 2024 from different sites around Coimbatore, Tamil Nadu. The collected samples were thoroughly washed with tap water to remove adhering soil and other impurities, followed by rinsing with bi-distilled water. The bark was then cut into small pieces to facilitate further processing and left to dry in the shade at room temperature for about two weeks. After drying, the materials were finely powdered, yielding approximately 400 g of bark powder and 200 g of leaf powder.

Abstraction of Botanical Trial

The plant materials were soaked in 80% aqueous ethanol (v/v) and kept at room temperature for about 3–5 days, with occasional stirring to facilitate extraction. At intervals of approximately 36 hours, the extract was separated, and the remaining residue was treated again with fresh solvent. The combined filtrates were filtered through Whatman No. 1 filter paper and then concentrated to dryness at 40 °C under

reduced pressure using a rotary evaporator. The resulting dried extracts were weighed and preserved at −4 °C for subsequent analysis.

Examination and Validation of Extracts

Phytochemical Analysis of Crude Extracts

The crude extracts prepared using ethanol was examined to determine the presence of different classes of phytochemicals. Tests were carried out to detect compounds such as alkaloids, saponins, glycosides, flavonoids, tannins, triterpenes, anthraquinones, and phenolic substances using customary phytochemical screening procedures.[25]

Determination of Total Phenolic and Flavonoid Contents

The total phenolic content (TPC) in the plant extracts was estimated using a modified Folin–Ciocalteu colourimetric method.[26, 27] For the analysis, an extract solution of 1 mg/mL was prepared and mixed with 2.5 mL of 0.2 N Folin–Ciocalteu reagents, followed by an incubation period of 5 minutes. Subsequently, 2.0 mL of 7.5% sodium carbonate solution was added, and the reaction mixture was kept at room temperature for about 2 hours to allow full colour development. A spectrophotometer was used to measure the intensity of the ensuing blue tint, which correlated with the phenolic content. The calibration curve was created using E Gallic acid standards and then evaluated similarly; the total phenolic content of the botanical extract was expressed in terms of gallic acid equivalents.

Steel Trials

Most of the equipment used in desalination plants is fabricated from mild steel. The chemical composition of the mild steel used in this study is 0.187% carbon, 0.173% silicon, 0.570% manganese, 0.195% copper, 0.056% sulfur, with the remainder being iron. The specimens employed for all experimental tests had dimensions of 2.1 × 2.1 × 0.09 cm.

Corrosion Measurements

Mass Loss Method

Before each experiment, the surfaces of the test specimens were polished sequentially using emery papers of grades 180, 320, 800, and 1200 to obtain a smooth surface. The specimens were then thoroughly rinsed with bi-distilled water, degreased, and finally dried using acetone. Mass loss experiments were conducted at 298 K, and the weight of the samples was recorded after exposure periods of 5, 10, 15, and 20 hours.

Electrochemical Studies

Electrochemical experiments were performed using a Gamry Reference 1000 potentiostat (USA, No. 06094) operated with Framework 7.07 software. The measurements were carried out in a thermostatically controlled electrochemical cell with a three-electrode arrangement. A platinum electrode functioned as the counter electrode, while a saturated calomel electrode (SCE) was used as the reference electrode. The same mild steel material was used for both gravimetric and electrochemical analyses. Potentiodynamic polarisation (PDP) tests were conducted at a scan rate of 1.0 mV s^{-1}, and polarisation curves were recorded within the potential range of −1000 mV to +1050 mV. Electrochemical impedance spectroscopy (EIS) measurements were also performed using the Gamry Interface 1000 system. Initially, the steady-state current at the corrosion potential was determined. A sinusoidal voltage signal with an amplitude of 10 mV was then applied over a frequency range from 10^4 Hz to 10^{-3}Hz at the open-circuit potential. After maintaining the system for 1 hour at 298 K, the open-circuit potential measurements were automatically recorded using the instrument software. The impedance data were represented in the form of Nyquist plots. To examine the effect of temperature on inhibitor efficiency, experiments were conducted at temperatures between 298 K and 328 K. Each test was repeated three times to confirm the reproducibility and reliability of the results.

RESULTS AND DISCUSSION

Phytochemical Screening of the Crude Extract

C. plicata Leaves and *C. plicata* bark phytochemical screening revealed favourable results for flavonoids, glycosides, tannins, steroids, saponins, and phenolics, but pessimistic results for alkaloids and anthraquinones.

Determination of Total Phenolic and Flavonoid Contents

Polyphenolic compounds, including flavonoids and other phenolic substances, represent important groups of molecules known for their antioxidant and free radical scavenging properties. Their antioxidant behaviour arises mainly from their ability to donate hydrogen atoms to free radicals and from the stability of the resulting radical intermediates. Because of these redox properties, such compounds play a vital role in capturing and neutralising free radicals, suppressing singlet and triplet oxygen species, and decomposing peroxide compounds.[28] The samples' total phenolic content (TPC) was measured spectrophotometrically and expressed as gallic acid counterparts (GAC). The regression equation y=11.861x+0.0001y = 11.861x + 0.0001y=11.861x+0.0001 with a strong correlation coefficient (R2=0.9929R^2 = 0.9929R2=0.9929) entitles excellent linearity. A standard calibration curve was created using gallic acid. Measurements were taken in triplicate, and the consequences are articulated as mean ± standard deviation. The TPC analysis showed that *C. plicata* leaves contained 115.90 ± 0.25 mg GAE/g, while *C. Plicata* bark had a substantially higher amount of 263.03 ± 0.06 mg GAE/g, indicating a significant difference in their phenolic compositions. These findings suggest that *C. plicata* bark may possess higher antioxidant potential than *C. plicata* leaves, owing to the influence of phenolic constituents on overall bioactivity. Flavonoid content was assessed by means of the ordinary curve regression equation ($y = 28.5655x + 0.1608$, $R^2 = 9876$) and recounted in mg quercetin equivalents (QE) per gram of dried botanical extract. *Chrozophora Plicata* leaf extract comprises substantial flavonoid concentration (77.03 ± 0.12). While the barks of *Chrozophora Plicata* include only 3.28 ± 0.00 mg QE/g.

Mass Loss Measurements

The effects of introducing high doses of *C. plicata* Leaves and *C. plicata* Barks to the corrosive media were investigated by means of the mass loss process at 298 K. The weight loss of steel pieces in abandoned and suppressed saltwater has been determined. Equation (1) was used to express the corrosion rate in millimetres per year (mm y^{-1}).

$$C_{RM} = \frac{K x W}{A x t x \rho} \quad (1)$$

Where K= 8.76×10^4 was used as the constant. W and t are the mass loss (in grams) and contact time (in hours). Steel has a density of 7.86 g cm^{-3}, as per ASTM G1-03, typically.[29] Equation (2)[30] was used to compute the uncovered area, A (in cm2);

$$A = \frac{\pi}{2}(D^2 - d^2) + l\pi D + l\pi d \quad (2)$$

Where D, d, and l represent the diameter of the slight steel portions, the width of the holding hole, and the breadth, respectively. Equations 3 and 4 were used to compute inhibition effectiveness (%) and surface coverage (θ):

$$\eta_{WL}(\%) = C^0_{WL} - C_{WL} / C^0_{WL} \text{ X } 100 \quad (3)$$

$$\theta = C^0_{WL} - C_{WL} / C^0_{WL} \quad (4)$$

CWLs and CWLs are corrosion rates, not including and including inhibitor concentrations, respectively, while θ represents the degree of surface coverage of experienced inhibitors. Table-1 provides a summary of the findings. The inhibition effectiveness and corrosion rates of steel in the incidence of inhibitors were shown to rise constantly as the concentration increased. At the same concentration, *C. plicata* Leaves > *C. plicata* Barks in terms of inhibition effectiveness. The consequences support the idea that raising the concentration of inhibitors will progressively augment the adsorption of inhibitors, resulting in a full obstruction of corrosion of energetic spots, except for 1-θ of the uncovered surface area.

Stability of the Inhibitors

Weight loss investigations were performed in seawater using the best possible inhibitor dosage for varied immersion times to assess the stability of the inhibitors' inhibitive coating and decide how long it would acquire for the inhibitors to achieve their paramount IE%. Figure-1 depicts the outcomes. It is observable that as immersion extent surges, IE% decreases. The utmost effectiveness was observed amongst one and six hours of immersion. When the immersion phase was augmented to 24 hours, the efficacy decreased

noticeably. These consequences could result from the unsteadiness of the inhibitor coating or the biodegradability of the botanical extracts over time.[31,32]

Table-1: Weight Loss Data of Steel Samples in Uninhibited and Inhibited Conditions at 298K

Inhibitors	C (g/L)	C ($mg.cm^{-2}.h^{-1}$)	η_{WL} %	Θ
Plain	-	1.231	-	-
C. plicata Leaves	0.28	0.416	64.2	0.644
	0.55	0.351	72.5	0.722
	1.01	0.215	82.4	0.824
	1.52	0.127	88.5	0.885
	0.25	0.552	50.2	0.502
	0.50	0.478	59.3	0.593
	1.00	0.407	64.8	0.648
	1.50	0.339	70.6	0.706

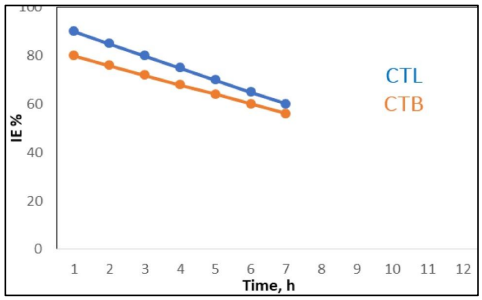

Fig.-1: The Upshot of Immersion Time on Inhibition Effectiveness in Slight Steel at 298K

Electrochemical Measurements

Potentiodynamic Polarization Curves

Figure-2 illustrates the Tafel polarization curves obtained at different concentrations of *C. plicata* leaf and bark extracts. The kinetic parameters derived from these curves are summarized in Table-2. These parameters include corrosion current density (Icorr), anodic Tafel slope (ba), cathodic Tafel slope (bc), and corrosion potential (Ecorr). The inhibition efficiency (EI%) values were calculated using Eqn.-5.

$$IE\ \% = I^0_{corr} - I_{corr} / I^0_{corr} x\ 100 \qquad (5)$$

Where I°corr and Icorr signify the corrosion current thickness of steel models, not including and including inhibitors, correspondingly.

The data presented in Table-2 indicate that the corrosion current density (Icorr) decreases as the concentration of the inhibitor increases. The anodic (ba) and cathodic (bc) Tafel slope values show noticeable changes, except at the lowest inhibitor concentration. This observation suggests that the presence of the inhibitor does not alter the mechanism of the proton discharge reaction.

Table-2: Steel Electrochemical Properties under different *C. plicata* Leaves and *C. plicata* Barks Concentrations in Seawater, as well as the Associated Inhibition Effectiveness

Inhibitors	Con. (g/L)	-Ecorr (mV/SCE)	Icorr (µA cm-2)	Ba ($mVdec^{-1}$)	-bc ($mV\ dec^{-1}$)	IE_Icorr
Plain	-	462	1426	154	222	----
C. plicata Leaves	0.25	472	574	175	212	59.4
	0.50	508	426	185	184	70.5
	1.00	519	268	169	190	80.9
	1.50	538	176	172	194	87.1
C. plicata Barks	0.25	481	731	170	175	49.6
	0.50	494	611	169	182	57.2
	1.00	512	529	187	196	63.9
	1.50	482	437	173	180	69.6

Figure-2 shows that the inhibitors reduce both anodic and cathodic current densities, confirming their behaviour as mixed-type inhibitors. As the concentration of the inhibitor increases, the inhibition efficiency (IE%) also rises, reaching maximum values of 87.1% for ATL and 69.6% for ATB.

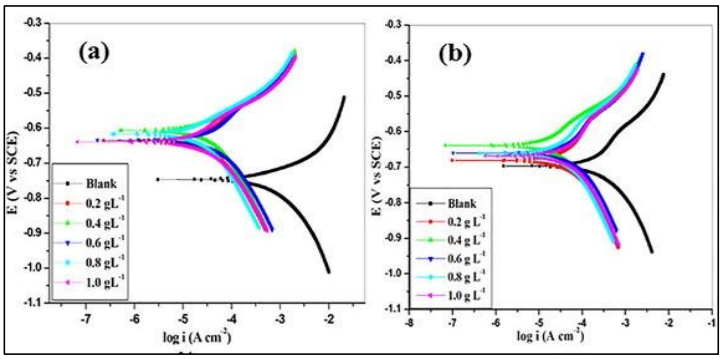

Fig.-2: Steel Potentiodynamic Polarisation Curves in the presence of Various Concentrations of (A) *C. Plicata* Leaves, (B) *C. Plicata* Barks

Electrochemical Impedance Spectroscopy (EIS)

Electrochemical Impedance Spectroscopy (EIS) trials were carried out in both uninhibited and inhibited saltwater solutions to acquire a better understanding of mild steel corrosion inhibition mechanisms. Figure 3 contains the matching Nyquist charts. The semicircles in the EIS spectra were marginally lower than those predicted by the ideal EIS model. Deviations from ideal semicircles are common and are often attributable to surface heterogeneity, frequency dispersion, and steel surface roughness.[33-34] The impedance curves were measured after immersing the electrodes in the inhibitor concentrations for 60 minutes. As shown in Fig.-3, all inhibitor systems had a lonely capacitive ring, demonstrating that the corrosion of slight steel in saltwater is primarily driven by the charge transfer progression that occurs at the metal/water contact. Table-3 summarizes computed inhibition efficiency based on impedance characteristics.

Table-3: Electrochemical Impedance Characteristics for Corrosion of the Steel Trials at different Inhibitor Doses at 298K

Inhibitors	Con. (g/L)	Rt (Ω.cm2)	Q x 10^{-4} ($S^n\Omega^{-1}cm^{-1}$)	(10^4) C_{dl} ($\mu F/cm^2$)	EI_{Rt} (%)
Blank	-	14	2.68	145.2	-
C. plicata Leaves	0.25	35	2.36	58.1	89.6
	0.50	38	1.96	36.5	62.4
	1.00	68	1.74	22.8	80.6
	1.50	109	1.64	6.7	87.1
C. plicata Barks	0.25	25	2.54	64.2	51.6
	0.50	29	2.36	45.2	56.3
	1.00	40	2.12	31.4	66.5
	1.50	49	1.95	11.8	72.4

Equation-6 exhibits that the elevated regularity impedance was deducted from the little regularity impedance to calculate Rt values.

$$R_t = Z_{re} \text{ (at short frequency)} - Z_{re} \text{ (at elevated frequency)} \quad (6)$$

Equation-7 was used to compute the Cdl values (electrochemical double layer) at the occurrence fmax, when the unreal component of the impedance has a highest value (-Zmax).

$$C_{dl} = 1\ 2\pi f_{max}/R_t \quad (7)$$

The inhibition effectiveness IE% (EIS) is resolved by means of Eqn.-8:

$$\%_(= R_t^o - R_t / R_t^o \times 100 \quad (8)$$

The charge relocate resistance values without and with the inhibitor are denoted by Rto and Rt, respectively. Table-3 clearly shows that resistance levels increase when all inhibitors are present. This can

be credited to the molecules' capability to preclude corrosion. Furthermore, it is obvious that Cdl levels reduce when the inhibitor is present. This could be attributed to a diminish in the local dielectric constant and/or an amplify in the depth of the electric double layer.[35,36] implying that inhibitor molecules adsorb at the metal contact.

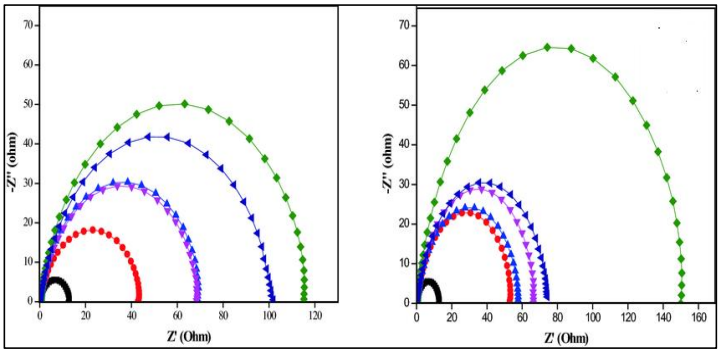

Fig.-3: Shows the Nyquist Plots Obtained for the Carbon Steel Electrode in the Absence and Presence of (A) *C. Plicata* Leaf Extract and (B) *C. Plicata* Bark Extract after 60 Minutes of Open Circuit Potential (OCP) Exposure

The decrease in double-layer capacitance (Cdl) and the increase in charge transfer resistance (Rt), which consequently lead to higher inhibition efficiency (IE %), can be attributed to the adsorption of inhibitor molecules on the steel surface. These molecules likely replace water molecules at the interface, thereby reducing the rate of iron oxidation.[37,38] The findings from the EIS analysis are in good agreement with the results obtained from the polarization measurements.

Adsorption study

The purpose of the adsorption study is to understand the interaction between the inhibitor molecules and the steel surface. The adsorption isotherm was evaluated by determining the surface coverage (θ) at different inhibitor concentrations at 298 K (Table-1). The values of θ were calculated using Eqn.-9.

$$\Theta = W_{corr}^{o} - W_{corr} / W_{corr}^{o} \quad (9)$$

Adsorption isotherms come in a variety of models, including the Freundlich, D-R, Temkin, and Langmuir isotherms. When Equation 10 was applied, linear plots were obtained with slope values of 1.044 for *C. plicata* leaves and 1.056 for *C. plicata* bark. In addition, a high correlation coefficient ($R^2 > 0.987$) was observed, indicating that the adsorption of inhibitor molecules from seawater onto the steel surface follows the Langmuir adsorption isotherm model.

$$C_{inh}/ \theta = 1/ k_{ads} + C_{inh} \quad (10)$$

$$\text{With } \Delta G_{ads} = -RTln\ (999) \quad (11)$$

Equation-11's ΔGads was calculated, while Equation 10's intercept was exploited to determine the equilibrium adsorption constant (Kads). Table-4 shows the outcomes.

Table-4: Values of K_{ads} and ΔG_{ads} for the Adsorption System of *C. plicata* Leaves and *C. plicata* Barks on Slight Steel at 298K

Inhibitor	K_{ads}	ΔG_{ads}
C. plicata Leaves	6.15	-21.5
C. plicata Barks	5.28	-21.3

The data presented in Table-4 indicate that the adsorption process is most likely spontaneous, as evidenced by the negative values of adsorption free energy (ΔGads). According to previously reported studies, adsorption is considered chemisorption when ΔGads is −40 kJ/mol or more negative, whereas values around −20 kJ/mol or less negative suggest physisorption. The results obtained in this study imply that the adsorption mechanism involves a combination of both chemical and physical interactions.[39-41]

Effect of temperature

Electrochemical Impedance Spectroscopy method was used to scrutinize the consequence of high temperature on the inhibition advancement and to acquire several corrosion-related thermodynamic

parameters. EIS tests were completed over a temperature assortment is 298-328 K, including the suitable inhibitor dose (Fig.-4).

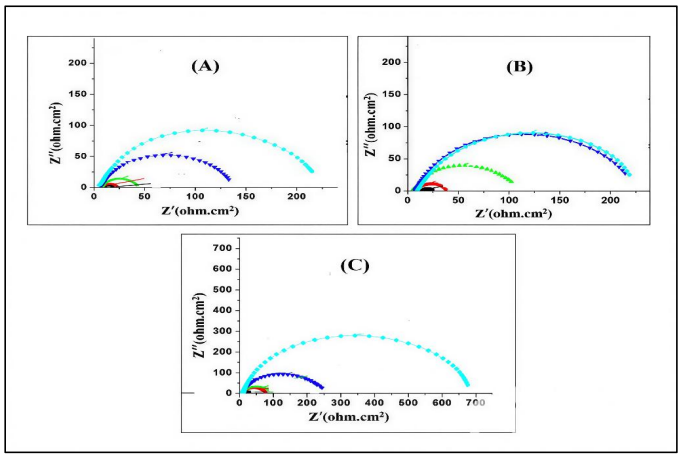

Fig.-4: Nyquist Figures for Slight Steel at Diverse Temperatures for (A) *C. plicata* Leaves, (B) *C. plicata* Barks, (C) Blank

Table-5: Temperature Influences the Adsorption of Several Inhibitors (1.50 g/L) in Carbon Steel at Several Temperatures

Inhibitors	T (K)	Rt (Ω.cm2)	Q x 10^{-4} ($S^n\Omega^{-1}cm^{-1}$)	C_{dl} (μF/cm^2)	EI_{Rt} (%)
Blank	298	12	2.68	142.2	-
	308	9	2.74	116	-
	318	6	2.94	128	-
	328	5	3.25	83	-
C. plicata Leaves	298	103	1.60	28	87.2
	308	58	1.87	42	80.4
	318	34	1.95	58	78.2
	328	18	2.24	73	73.5
C. plicata Barks	298	46	1.96	36	72.6
	308	26	2.24	48	67.5
	318	18	2.45	61	58.6
	328	12	2.72	86	54.1

Table-5 illustrates that, in both inhibited and abandoned media, charge transfer resistance (Rt) values reduce with escalating temperature. Furthermore, Table-5 divulges that as the temperature ascended, the IE% values in the occurrence of all inhibitors decreased legitimately. This is most likely owing to the probability of elevated temperatures throughout the desorption advancement. These conclusions display that *C. plicata* leaves are an efficient inhibitor across the temperature assortment underneath exploration. Its IE% has fallen to just 53% at 328 K, designating that *C. plicata* Barks' productivity is temperature dependent. This behaviour is widely established by botanical-derived inhibitors.[42,43]

CONCLUSION

Corrosion inhibition studies on mild steel were shown scientifically using two organic inhibitors, *C. plicata* Leaves and *C. plicata* Barks, to assess their efficacy in reducing metal degradation under corrosive environments. The assessment was performed by means of an assortment of electrochemical techniques, such as potentiodynamic polarisation and electrochemical impedance spectroscopy (EIS), together with traditional weight loss assessments to ensure full analysis and validation of the data. The evaluation study exposed a substantial variance in inhibition performance between the two compounds. *C. plicata* Barks'corrosion inhibition effectiveness was moderate to poor, indicating a relatively weak interaction with the metal outward and a limited competence to form a stable defensive coating. *C. plicata* Leaves, on the other hand, showed significantly higher inhibition efficiency, indicating a resilient

adsorption affinity for the slight steel surface as well as the improvement of a further dense and adherent defensive film that successfully reduced both anodic metal dissolution and cathodic hydrogen development reactions. Adsorption performance analysis exposed that both *C. plicata* Leaves and *C. plicata* bark molecules adsorb well on the slight steel surface, according to the Langmuir adsorption isotherm model. This finding suggests that a uniform monolayer of inhibitor species on the surface forms on the metal surface, with homogeneous adsorption sites and negligible lateral contact between the adsorbed species. Furthermore, the electrochemical results verified that each of the two inhibitors functioned as Dual-action inhibitors, credibly overpowering both anodic and cathodic corrosion progression. Nonetheless, as exposure time increased, the inhibition efficiency gradually decreased. This drop could be attributable to inhibitor molecules desorbing from the metal surface, the protective coating deteriorating due to destructive ion attack, or the inhibitor experiencing chemical renovation under sustained immersion environments. Overall, the study obviously validates that *C. plicata* leaves are a stronger and permanent corrosion inhibitor for mild steel than *C. plicata* Barks, while also emphasizing the inhibition procedure's time-dependent stability.

ACKNOWLEDGMENTS

The authors cordially welcome the support of the Department of Chemistry, LRG College of Arts and Sciences for Women, Tirupur.; Government Arts College, Coimbatore, for providing laboratory facilities and research assistance. The authors, in addition, expand their appreciation to the local authorities of Kanuvai, Tamil Nadu, for facilitating the collection of *Chrozophoraplicata* botanical materials used in this study.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

The present work is related to *SDG-12: Responsible Consumption and Production*. All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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Cite this article as: L. Madhanraj *et al.*, *Rasayan J. Chem.*, 19(2), 1139-1149(2026), https://doi.org/10.31788/RJC.2026.1929564.

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[RJC-9564/2026]