Evaluation of *Phytolacca americana* L. extract as green corrosion inhibitor for mild steel: a study of the solution phase

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Editor's note: Green corrosion inhibitors are gaining popularity, particularly those derived from plants, due to their non-toxic nature, affordability, and accessibility. Sheydaei conducted a study on the extract of *Phytolacca americana* L. (also known as American pokeweed), assessing its effectiveness in preventing mild steel corrosion. The findings indicated that the plant extract successfully inhibited corrosion, as it contains compounds such as betacyanins, flavonoids, and polyphenols.

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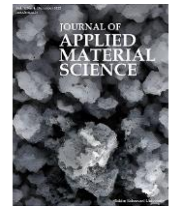

Communication

Evaluation of *Phytolacca americana* L. extract as green corrosion inhibitor for mild steel: a study of the solution phase

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Abstract

Corrosion is undoubtedly the most serious threat to metals. The behavior of this phenomenon is silent and slow, yet continuous, causing the destruction of metal structures and resulting in huge financial losses, as well as environmental pollution. This process is often regarded as a slow behavior, but in environments like oceans, it can be extremely violent and rapid. Researchers are continually seeking solutions to prevent and delay this process. It can be said that in the past decades, chemical corrosion inhibitors have been very popular among researchers and many industries. However, it must be admitted that many of them are toxic and cause great damage to the environment. In recent years, green corrosion inhibitors have been widely studied, and among them, plant-based ones are perhaps the most popular. In this study, *Phytolacca americana* L. extract was prepared, and its inhibition corrosion efficiency on mild steel was evaluated. For this evaluation, electrochemical impedance spectroscopy (EIS) and polarization test were used. The results showed that the extract is effective in inhibiting corrosion. The results showed that the charge transfer resistance (R_{ct}) for mild steel decreased significantly with increasing immersion time, but in the presence of the extract, this decrease was surprisingly less.

Keywords: Green chemistry; Inhibition efficiency; Protection.

1. Introduction

Polymer coatings can always be considered a suitable candidate for corrosion prevention [1]. To improve the performance of these coatings, chemical inhibitors as well as nanomaterials can be used [2, 3]. The use of nanomaterials often increases the cost of coatings, but chemical inhibitors still have their own fans based on their amazing performance [4]. However, chemical inhibitors cause serious problems for the environment because most of them are very toxic [5]. In recent years, research on the use of green corrosion inhibitors has become very popular, and plants are one of the candidates being studied because, in addition to being non-toxic, they are very cheap and available [6]. Some literature has reported inhibition efficiency of up to 99% for some plants [7, 8]. In general, it can be said that the inhibition efficiency depends on many parameters, such as the active phytochemical compounds of the plant, the solvent, the temperature, and the corrosive medium [9].

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Among plants, *Phytolacca americana* L. (Figure 1) is a well-known tropical plant native to North and South America but also distributed in Africa, Europe, and Asia [10]. This plant is used in traditional medicine in South and Central America for its antimicrobial and anti-inflammatory effects [11]. This plant also has the capacity to accumulate the heavy metal cadmium (10,700 mg/kg), which can be hazardous, as this plant will contain high levels of cadmium if grown in cadmium-contaminated soils [12]. Therefore, before using plants, one must make sure that they are not contaminated, because otherwise there is a possibility of contaminating the environment and causing many diseases, such as cancer and kidney damage, through heavy metals [13-16]. In this study, *Phytolacca americana* L. extract was prepared using ethanol, and its inhibitory efficacy in a saline medium was evaluated for mild steel.

Figure 1. *Phytolacca americana* L. plant.

2. Experimental

2.1. Materials

Sodium chloride and mild steel were obtained from Merck and Mobarakeh Steel Company, respectively. The *Phytolacca americana* L. plant was obtained from a local farm (Chalus city, Mazandaran province, Iran).

2.2. Preparation of extract, mild steel substrate, and electrochemical tests

The *Phytolacca americana* L. fruits were washed with distilled water. Then, the fruits were added to ethanol and heated for 30 min at 50°C. The extract was then separated by filtration and cooled to ambient temperature. Surface images were obtained using a Zitazy digital microscope (Insight Pro). A potentiostat-galvanostat (CorrTest CS350) was used to evaluate EIS and the polarization test. The substrates were coated with a mixture of Beeswax melt and colophony resin, and only a 1×1 cm^2 area was selected to contact the sodium chloride solution. 100 mL of *Phytolacca americana* L. extract was mixed with 1 L of sodium chloride solution (3.5 wt.%) under magnetic stirring, and then the substrates were immersed in it. Also, a sodium chloride solution (3.5 wt.%) was used as a reference solution. The inhibition efficiency (η) for the EIS test was obtained using equation (1) [17]. The polarization test was performed after 24 h of immersion of the substrate in the solution at a scan rate of 0.5 mV/s and within the range of ±200 mV. The percentage Inhibition efficiency (IE%) was calculated, with I_{corr} as the corrosion current density, using equation (2) [18, 19]:

$$\eta\,(\%) = 100 \times \left(1 - \frac{R_{ct\,without\,extract}}{R_{ct\,with\,extract}}\right) \quad (1)$$

$$IE\,(\%) = \frac{I_{corr\,(without\,extract)} - I_{corr\,(with\,extract)}}{I_{corr\,(without\,extract)}} \times 100 \quad (2)$$

3. Results and discussion

The corrosion inhibition of the extract was evaluated by electrochemical impedance spectroscopy test results, as shown in Figure 2 and Table 1. Figure 2 shows the Nyquist plots of the samples at different immersion times, indicating that mild steel is degrading in the absence of the extract, as evidenced by the changes in the diameter of the plots. In fact, the diameter of the curve shows that the Rct decreases with increasing immersion time [17]. This decrease in diameter indicates that the corrosive species penetrate the mild steel with increasing immersion time. On the other hand, the Bode plots (see Figure 2d) also show a decreasing trend with increasing immersion time. However, in the presence of the extract, the results are quite different (see Figure 2 b and d). As can be seen in the results, there is an increase in the diameter of the Nyquist plots, as well as a significant increase in the Bode plots.

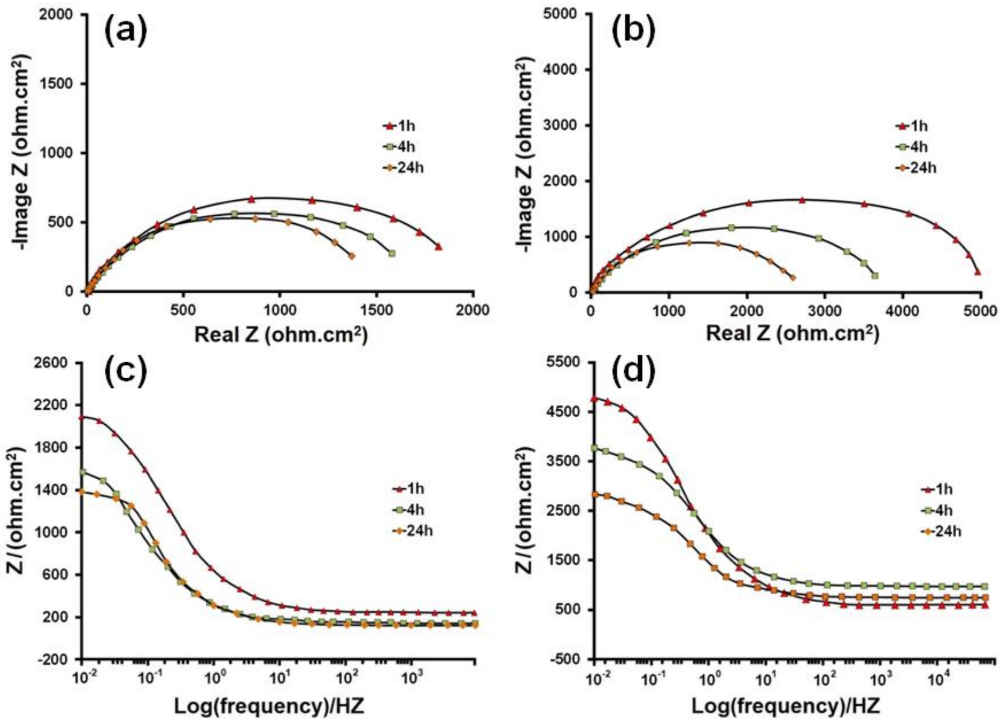

Figure 2. Nyquist plots (a and b) and Bode plots (c and d) of mild steel at different immersion times: in the absence of extract (a and c) and in the presence of extract (b and d).

Although there is a decreasing trend in both Nyquist and Bad plots with time. But the sample containing the extract shows better resistance even after 24 h than the sample in the absence of the extract after 1 h. Although these types of inhibitors are very popular, their effectiveness decreases significantly with increasing immersion time, a concern that can be largely addressed by encapsulation [4, 17, 20].

Phytolacca americana L. contains betacyanins, flavonoids, phenolic acids, phytosterols, esculentosides A and B, saponins, and polyphenolic compounds [10, 21]. These compounds in *Phytolacca americana* L. can adsorb onto metal surfaces. In fact, this ability is related to the π-electron transfer between oxygen atoms and aromatic rings of compounds with vacant d-orbitals on the surface [4, 17, 20]. This process causes the anodic regions to be blocked and a protective layer to form [17, 20]. In fact, it can be said that the surface is passivated, which is why the Bode plots increase in the presence of the extract [4, 17, 20].

Figure 3a shows the equivalent circuit that best matches the impedance results. Also, Figure 3b shows the potentiodynamic polarization test curves, and various parameters calculated from these curves are reported in Table 2. The results show that the effect of adding the extract to the solution on the anodic half-reaction is greater and ultimately causes E_{corr} to shift towards positive values. In fact, this change indicates the

Table 1. Parameters obtained from electrochemical impedance spectroscopy results

Samples	Time (h)	R_{ct} (ohm.cm²)	R_s (ohm.cm²)	log |z| (ohm.cm²)	η (%)
Without extract	1	1807.27	6.9	1911.17	-
	4	1597.07	7.6	1503.24	-
	24	1372.19	7.4	1318.16	-
With Extract	1	4960.79	11	4727.56	64
	4	3644.86	13	3348.71	56
	24	2592.76	12	2294.32	47

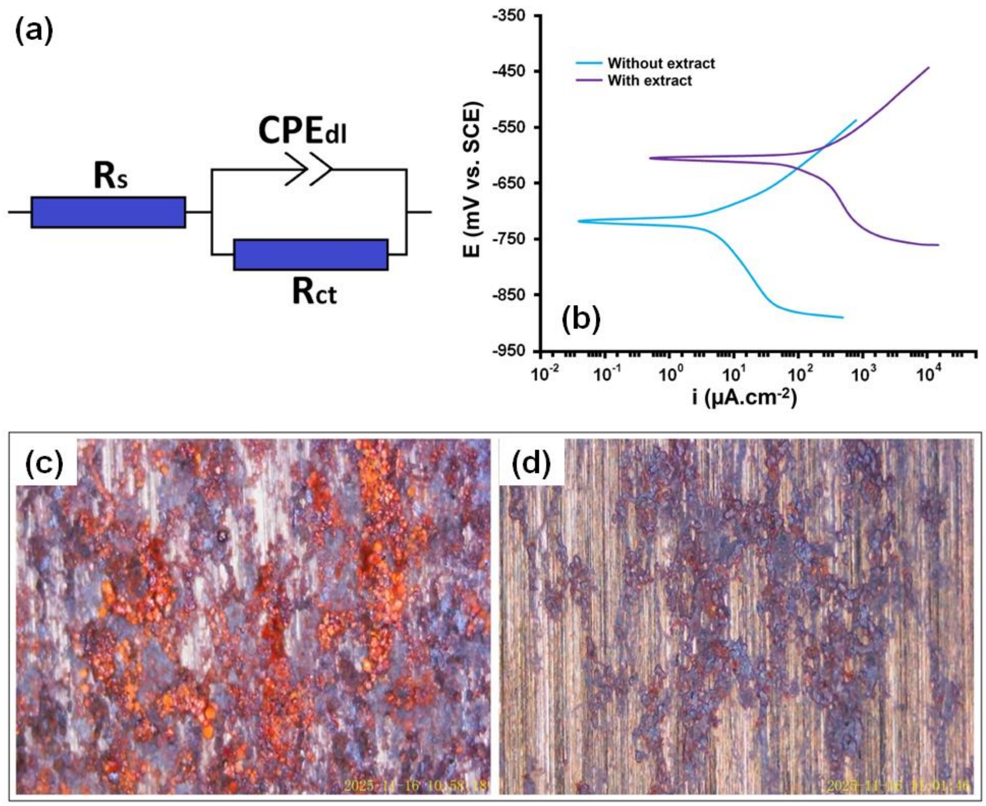

Figure 3. Equivalent circuit to describe the results (a), The polarization curves of samples immersed for 24 h (b), and images of the mild steel surface immersed in the saline solution, without extract (c), and with extract (d).

formation of a protective layer on the substrate surface that provides protection. It can be said that due to the overall E_{corr} shift of more than +85 mV, this extract can be classified in the group of anodic inhibitors. The addition of the extract also caused a significant decrease in i_{corr}, indicating better corrosion behavior [17-19].

Figure 3 also shows images of the mild steel surface after 24 h of immersion (panels c and d). The images show that the entire surface of the blank sample is filled with rust and corrosion products, but the surface of the sample that used the extract as an inhibitor contains far fewer corrosion products. In the blank sample, corrosion has caused the formation of numerous grooves and pores on the surface, and the presence of irregular and porous deposits on the steel surface indicates the formation and deposition of corrosion products on the surface, but the surface of the sample that used the extract as an inhibitor had far fewer roughness and pores. These images show the inhibitory role of the compounds in the extract, which prevents surface degradation by creating a protective layer with low permeability against corrosive ions.

4. Conclusions

In summary, a corrosion inhibitor was prepared using *Phytolacca americana* L. extract and ethanol. This plant

Table 2. Electrochemical parameters obtained from the polarization test on mild steel immersed in the saline solution after 24 h

Samples	Ecorr vs. SCE (mV)	icorr (A/cm²)	βα (V/dec)	βc (V/dec)	IE (%)
Without extract	-715	2.561×10^{-6}	0.07	0.322	-
With extract	-605	9.76×10^{-7}	0.067	0.179	61.88

Note: Corrosion potential (E_{corr}), the anodic Tafel slope (βα), and the cathodic Tafel slope (βc).

contains compounds such as betacyanins, flavonoids, and polyphenolic compounds, which are responsible for the corrosion inhibition potential of this extract because these compounds can adsorb onto the metal surface. Plant-based inhibitors are always very tempting due to their low cost, but it should be kept in mind that their effectiveness decreases with increasing temperature and immersion time, although this problem can be largely solved with solutions such as encapsulation.

Conflict of Interest

The author declares no conflict of interest.

References

1. G.P.V. Dalmora, et al. Methods of corrosion prevention for steel in marine environments: A review. *Results in Surfaces and Interfaces*, **2025**, *18*, 100430.

2. A. Yadav, S. Panjikar, and R.K. Singh Raman. Graphene-Based Impregnation into Polymeric Coating for Corrosion Resistance. *Nanomaterials*, **2025**, *15*, 486.

3. F. Alasmari, et al. A review on the application of various nanotechnologies for corrosion prevention. *Nanotechnology for Environmental Engineering*, **2024**, *10*, 3.

4. M. Sheydaei, M. Edraki, and F.S.-J. Abad. Matcha-modified clay polyurethane coating: improving thermal, mechanical, antimicrobial, and anticorrosion performance. *Iranian Polymer Journal*, **2023**, *32*, 1643.

5. M. Yeganeh, et al. Corrosion Inhibitor of API Pipeline Steels: A Review. *Journal of Bio- and Tribo-Corrosion*, **2025**, *11*, 44.

6. M. Talha. Biomacromolecules as green corrosion inhibitors: a review based on mild steel corrosion in acidic media. *Corrosion Reviews*, **2024**, *43*, 409.

7. H. Li, S. Zhang, and Y. Qiang. Corrosion retardation effect of a green cauliflower extract on copper in H2SO4 solution: Electrochemical and theoretical explorations. *Journal of Molecular Liquids*, **2021**, *321*, 114450.

8. Q. Liu, et al. A novel green reinforcement corrosion inhibitor extracted from waste Platanus acerifolia leaves. *Construction and Building Materials*, **2020**, *260*, 119695.

9. C.A. Barbu, et al. Critical Review Regarding the Application of Plant Extracts as Eco-Friendly Corrosion Inhibitors—A Sustainable Interdisciplinary Approach. *Molecules*, **2025**, *30*, 3722.

10. I.D. Veleşcu, et al. Valorization of Betalain Pigments Extracted from Phytolacca americana L. Berries as Natural Colorant in Cheese Formulation. *Agriculture*, **2025**, *15*, 86.

11. J.K. Patra, et al. Antibacterial effect of crude extract and metabolites of Phytolacca americana on pathogens responsible for periodontal inflammatory diseases and dental caries. *BMC Complementary and Alternative Medicine*, **2014**, *14*, 343.

12. M. Sheydaei. Investigation of Heavy Metals Pollution and Their Removal Methods: A Review. *Geomicrobiology Journal*, **2024**, *41*, 213.

13. M. Sheydaei. Heavy Metals Contamination in Soil and Rice and their Removal Processes: A Brief Review. *Geomicrobiology Journal*, **2024**, *41*, 721.

14. M. Sheydaei. Cancer and Polymeric-Carriers. *Biomedical Journal of Scientific & Technical Research*, **2020**, *31*, 24107.

15. M. Sheydaei. Breast Cancer and the Role of Polymer-Carriers in Treatment. *Biomedical Journal of Scientific & Technical Research*, **2021**, *34*, 27057.

16. M. Sheydaei and E. Alinia Ahandani. Cancer and the role of polymeric-carriers in diagnosis and treatment. *Journal of Advanced Biomedical Sciences*, **2020**, *10*, 2408.

17. M. Edraki and M. Sheydaei. Investigation of date seed powder as green corrosion inhibitor for mild steel: A study of solution and coating phases. *Hybrid Advances*, **2024**, *6*, 100238.

18. M. Edraki, et al. Enhanced mechanical, anticorrosion, and antimicrobial properties of epoxy coating via pine pollen modified clay incorporation. *Iranian Journal of Chemistry and Chemical Engineering*, **2023**, *42*, 2775.

19. M. Edraki and M. Sheydaei. Investigation of the Dual Active/Barrier Corrosion Protection, Mechanical and Thermal Properties of a Vinyl Ester Coating Doped with Ginger Modified Clay Nanoparticles. *Russian Journal of Applied Chemistry*, **2022**, *95*, 1481.

20. E. Milad, et al. Protective Nanocomposite Coating Based on Ginger Modified Clay and Polyurethane: Preparation, Characterization and Evaluation Anti-Corrosion and Mechanical Properties. *Polymer Science, Series B*, **2022**, *64*, 756.

21. N.M. Fahmy, et al. Chemical exploration of different extracts from Phytolacca americana leaves and their potential utilization for global health problems: in silico and network pharmacology validation. *Journal of Biomolecular Structure and Dynamics*, **2024**, *43*, 5178.