International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

DiEffense: Efficacy of dumb cane (*Dieffenbachia seguine (Jacq.) Schott*) extract as plant–based inhibitor for mild steel corrosion

Alyxa Mae Condeza Rara [1,*], Rhiane Jade Yongco Quiapo [1], Penelope Naaliatan Vallar [1] and Christian James Llubit Castro [2]

[1] *Gingoog City Comprehensive National High School, Gingoog City, Misamis Oriental Philippines.*
[2] *Department of Education - Gingoog City Comprehensive National High School, Gingoog City, Misamis Oriental, Philippines.*

International Journal of Science and Research Archive, 2026, 18(03), 1367-1380

Publication history: Received on 13 February 2026; revised on 20 March 2026; accepted on 23 March 2026

Article DOI: https://doi.org/10.30574/ijsra.2026.18.3.0584

Abstract

Corrosion of mild steel in marine environments causes significant material degradation and economic losses, creating a need for sustainable and environmentally friendly corrosion inhibitors. This study investigated the effectiveness of Dumb Cane (*Dieffenbachia seguine* (Jacq.) Schott) extracts as a plant-based corrosion inhibitor for mild steel in natural seawater. Ethanolic extracts from the leaves, stems, and roots were prepared and tested at concentrations of 0.2, 0.4, 0.6, and 0.8 g/L. Corrosion inhibition performance was evaluated using weight loss measurements and surface image analysis, while Fourier Transform Infrared (FTIR) spectroscopy was employed to identify functional groups associated with corrosion inhibition. The results showed a clear concentration-dependent reduction in corrosion, with weight loss decreasing significantly as extract concentration increased. At 0.8 g/L, near-complete protection was achieved, with inhibition efficiencies reaching 100% for the stem/leaf extract and 97.10% for the root extract. Statistical analysis confirmed that inhibitor concentration had a significant effect on corrosion reduction, while differences between plant parts were not statistically significant. FTIR analysis revealed the presence of hydroxyl, carbonyl, and aromatic functional groups attributed to phytochemicals such as flavonoids, tannins, and alkaloids, which facilitate adsorption onto the mild steel surface. Surface image analysis further confirmed reduced rust coverage and improved surface morphology in treated samples. These findings demonstrate that Dumb cane extracts act as effective, eco-friendly corrosion inhibitors through an adsorption-controlled mechanism, offering a sustainable alternative to conventional synthetic inhibitors for mild steel protection in seawater environments.

Keywords: Corrosion inhibition; Mild steel; Dumb cane; Plant-based inhibitor; Seawater

1. Introduction

Corrosion is the gradual deterioration of metals through chemical and electrochemical reactions, causing significant economic, environmental, and safety impacts, accounting for 1–5% of a nation's GNP annually [1]. Mild steel, widely used in construction, transportation, and marine applications for its low cost and favorable properties, is especially vulnerable in aggressive environments like seawater, where chloride ions accelerate metal dissolution [2,3]. Effective corrosion control is essential to extend steel service life and reduce costs.

Plant extracts can act as corrosion inhibitors due to organic constituents such as phenols and flavonoids, which form protective films that shield the metal surface and slow corrosion [4,5]. Dumb Cane (*Dieffenbachia seguine* (Jacq.) Schott) contains flavonoids, saponins, oxalates, alkaloids, tannins, phytic acid, and cyanogenic glycosides [6], and has known antimicrobial and antioxidant properties.

* Corresponding author: Alyxa Mae Condeza Rara

This study explores Dumb Cane extract as a green corrosion inhibitor for mild steel. Its key features, renewability, low toxicity, and biodegradability, distinguish it from conventional inhibitors like chromates, phosphates, and nitrites, which are efficient but toxic and environmentally persistent [7]. Rich in phytochemicals, the extract adsorbs onto steel surfaces, forming a protective film that interrupts electrochemical reactions responsible for corrosion [8,9,4].

Although widely available in tropical regions, Dumb Cane's use as a corrosion inhibitor is still limited. This study evaluates its effectiveness in seawater, developing an anti-corrosion solution, DiEffense, which interferes with rust-forming oxidation, minimizes metal degradation, and enhances the environmental durability of mild steel.

2. Materials and Methods

2.1. Identification and Classification of Dumb Cane

For the identification and classification of Dumb Cane (*Dieffenbachia seguine* (Jacq.) Schott), the researchers sought assistance from the Far Eastern University (FEU) Herbarium. This step was necessary to ensure that the collected samples were correctly identified and taxonomically classified. Verification by a recognized herbarium also ensured that the plant organism did not require any special permits and was not subject to conservation measures. The confirmed classification is as follows: Family: Araceae and Species name: *Dieffenbachia seguine* (Jacq.) Schott (Certification Authentication No. 2025-187).

2.2. Collection and Preparation of Dumb Cane

After identifying Dumb Cane (*Dieffenbachia seguine* (Jacq.) Schott), samples were collected from Saa Estate, Barangay 26, Gingoog City (Figure 1). Using a shovel and gloves, the researchers carefully excavated the plant and handled the stems. A total of 1 kg of plant material—including leaves, stems, and roots—was collected to ensure sufficient material for producing 150 g of powdered extract.

Figure 1 Location map of the sampling area (Source: Google Map, 2025)

2.3. Collection and Preparation of Carbon Steel

Mild steel was bought from the local hardware store in Gingoog City. The dimension of the mild steel sample is 137 cm long, 5 cm in diameter. The researchers used sandpaper to clean the samples, then washed them with distilled water and acetone [10] to remove impurities and dust from the surface of the carbon steel alloy. Mild steel is composed of 0.08% C, 0.018% P, 0.013% S, 0.09% Si, 0.004% Al, 0.34% Mn, and the remaining is Fe.

2.4. Extraction of Plant-based Inhibitor

Leaves, stems, and roots were cleaned with distilled water to remove dust and debris, minimizing contamination. The leaves were cut into small pieces and dried in an oven at 80 °C for 5.5 hours, as [11] noted that short drying at high temperatures preserves antioxidant compounds better than prolonged exposure to light, oxygen, and heat.

After drying, the plant material was ground into a fine powder to produce Dumb Cane powder. A 150 g portion was macerated in 1500 mL of 96% (v/v) ethanol, which preserves the stability and potency of delicate phytochemicals [12]. After six days of maceration, when compound concentration reaches its third-highest level [13], the extract was filtered using filter paper. Evaporation of the solvent was then performed for two hours in a water bath with a magnetic stirrer at 60 °C. This method maintains Total Polyphenol Content (TPC) and Total Antioxidant Activity (TAA) effectively, as reported by [14].

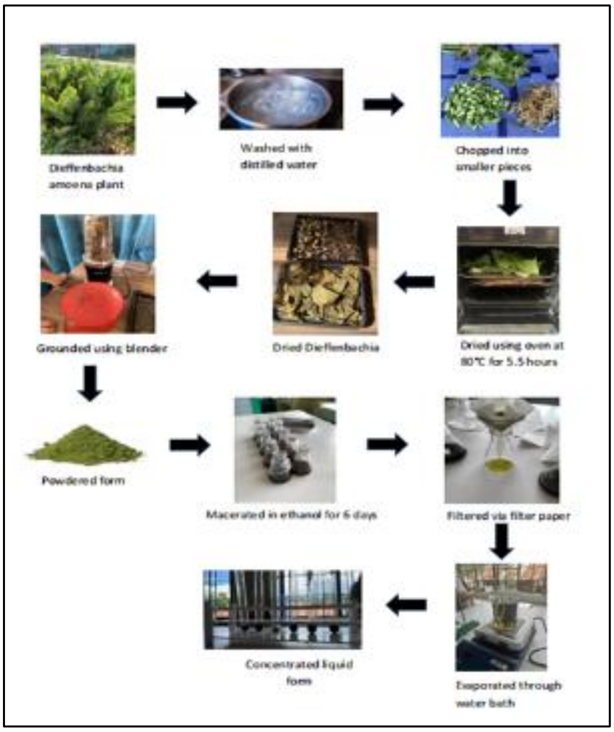


Figure 2 Schematic diagram of the collection of plant material and extraction.

2.5. Experimental Procedure

Seawater was collected following a modified method from [15]. Natural seawater from Talisay, Gingoog City (8.8779° N, 125.1846° E) was used, selected for its representative environmental conditions suitable for evaluating corrosion inhibitors.

The experiment began with the preparation of Dumb Cane (*Dieffenbachia seguine* (Jacq.) Schott) extract. Mild steel samples were submerged in three media: seawater only (blank), 95%(v/v) ethanol (negative control), and seawater with the bio-inhibitor at concentrations of 0.2, 0.4, 0.6, and 0.8 g/L [16]. Samples were exposed for one week with cycles of 12 hours submerged in seawater followed by 12 hours of air exposure. Under these conditions, the corrosion rate of mild steel reaches 0.76 mpy in the first week [17].

2.6. Data Gathering Methods

2.6.1. Determination of the Corrosion-Inhibiting Efficacy of Dumb Cane through the Weight Loss Method

To evaluate the corrosion-inhibiting effect of Dumb Cane (*Dieffenbachia seguine*) extract on mild steel in seawater, the researchers performed physical analyses using the weight loss method. Pre-weighed steel samples were treated with different inhibitor concentrations using cotton balls and then immersed in seawater in a beaker. Samples were exposed in cycles of 12 hours submerged and 12 hours in air for 10 days. After this period, the samples were cleaned, dried, and reweighed to determine material loss.

Corrosion rate was calculated from the difference between pre- and post-immersion weights, providing a quantitative measure of inhibitor effectiveness. The procedure was repeated for all concentrations, and corrosion rates ($g/cm^2 \cdot h$) were computed for both the presence and absence of inhibitors, following the method described by [18].

$$W = W_i - W_f$$

W_i is the weight before immersion and W_f is the weight after immersion. The percentage inhibition efficiency (% IE) was calculated by the following equation as reported by Satapathy *et al*. (2009) as cited in [19]:

$$IE\ \% = (W1 - W2)/W1 \times 100$$

W_i is the weight loss in *g* of mild steel in inhibited solutions and W_b is the weight loss in *g* of mild steel in uninhibited solutions.

2.6.2. Image Analysis

Image analysis using the ImageJ (NIH, USA) program was conducted to further evaluate the surface condition of the mild steel samples. Photographic images of the specimens after immersion in the seawater. Methods outlined by [20] were utilized with minor modifications. Surface rust coverage (%) was quantified from digital photographs analyzed with ImageJ (NIH, USA). Rusted regions were identified through color thresholding, and their pixel areas were measured. The percentage of rust coverage was then calculated using the following equation:

$$\text{Rust coverage } \% = (A_{rust} / A_{tot}) \times 100$$

Where A_{rust} and A_{tot} represent the rusted and total surface areas, respectively.

2.6.3. FTIR Analysis

Powdered stem, leaf, and root samples of Dumb Cane (*Dieffenbachia seguine* (Jacq.) Schott) were sent to the Center for Natural Products Research, Development, and Extension at Central Mindanao University, Musuan, Bukidnon. Fourier-transform infrared (FTIR) spectroscopy was used to identify naturally occurring compounds such as flavonoids, tannins, saponins, terpenoids, and phenolics. These compounds contain functional groups with heteroatoms like nitrogen, oxygen, and sulfur, which are known to facilitate adsorption onto metal surfaces [21].

2.7. Statistical Analysis

Collected data were exported and analyzed in Microsoft Excel. Descriptive statistics (mean and standard deviation) and inferential statistics were calculated, including inhibition efficiency (%) and rust coverage (%). Experiments were conducted in three trials, and statistical analysis was performed using IBM SPSS Version 25.0. Data followed a normal distribution; therefore, two-way ANOVA was used, along with linear regression analysis. A p-value < 0.05 was considered statistically significant.

3. Results and Discussion

Bioactive compounds were extracted from the stem, leaves, and roots of *Dieffenbachia seguine* to isolate organic constituents responsible for corrosion inhibition on mild steel surfaces. Plant-based inhibitors typically contain diverse phytochemicals, including alkaloids, flavonoids, tannins, saponins, and polyphenols, which possess electron-rich functional groups that form protective adsorption films on metal substrates [22,18].

Ethanol was selected as the extraction solvent because its high polarity enables dissolution of both hydrophilic and moderately hydrophobic compounds, facilitating efficient recovery of oxygen- and nitrogen-containing species capable of coordinating with iron surfaces through lone-pair electron donation or π-bond interactions [23]. By comparing extracts from different plant parts, this study aimed to determine whether the phytochemical composition of the stem, leaves, and roots affects inhibitory efficiency. This comparative approach provides insight into which plant portion contains the highest concentration of active molecules contributing to corrosion protection, consistent with findings from previous studies of other green inhibitors such as *Azadirachta indica* and *Glycyrrhiza glabra* [24,25].

3.1. FTIR Analysis

Fourier Transform Infrared (FTIR) spectroscopy was utilized to identify functional groups in the ethanolic extracts of *Dieffenbachia seguine* stems, leaves, and roots that contribute to corrosion inhibition. The obtained spectra, shown in Figures 2 and 3, and corresponding absorption band assignments, summarized in Tables 1 and 2, indicate the presence of organic functional groups associated with phytochemicals, including alcohols, phenols, carbonyls, and aromatic compounds. These groups contain electron-donating heteroatoms, such as oxygen and nitrogen, which can coordinate with the vacant *d*-orbitals of iron atoms on the mild steel surface [22]. Identification of these active sites is crucial for elucidating the adsorption mechanism of the inhibitor molecules, as the interaction between these functional groups and the metal surface facilitates the formation of a protective organic film that reduces corrosion [23,18]

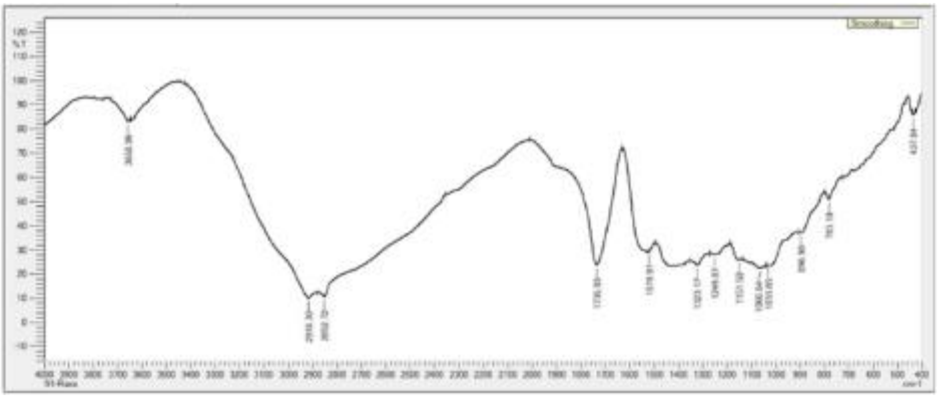


Figure 3 Image of the IR spectrum of *D. seguine* (Jacq.) Schott Leaf and Stem at 400-4000 cm^{-1}

Table 1 FTIR Spectral Interpretation of *Dieffenbachia seguine* (Jacq.) Schott Leaf and Stem Extract (Sample 1)

Wavenumber (cm^{-1})	**Functional Group**	**Intensity**	**Interpretation**	**Potential Phytochemical Class**
3656.96	O–H stretch (hydroxyl group)	Weak, Broad	Free/weakly bonded hydroxyl	Alcohols, Phenols, Sterols
2918.30	C–H stretch (asymmetric) (alkane group)	Strong	Alphatic CH_2 / CH_3 aliphatic or fatty/waxy material on the leaves	Lipids, Steroids
2852.72	C–H stretch (symmetric) (alkane group)			
1735.93	C=O stretch (carbonyl group)	Strong, Sharp	Ester, Ketone, or Carboxylic Acid Dimer	
1519.91	H–H bend/aromatic C=C	Medium to Strong, Sharp	Amide II (Protein/Alkaloids), Polyphenolic structures	Alkaloids, Flavonoids, Tannins

The FTIR spectrum of Dumb Cane leaves and stem (Sample 1) revealed several characteristic absorption bands corresponding to different functional groups and phytochemical constituents. The broad and weak peak observed at 3656.96 cm^{-1} corresponds to the O–H stretching vibration, indicating the presence of hydroxyl groups commonly found in alcohols, phenols, and sterols.

The strong peaks observed at 2918.30 cm^{-1} and 2852.72 cm^{-1} correspond to the asymmetric and symmetric C–H stretching vibrations of aliphatic $-CH_2$ and $-CH_3$ groups. These bands indicate long-chain hydrocarbons commonly found in fatty acids, lipids, and steroids. [26] reported that aliphatic compounds with long hydrocarbon chains form hydrophobic films over metal surfaces, minimizing direct contact between the metal and corrosive medium.

A sharp intense peak at 1735.93 cm^{-1} was assigned to C=O stretching vibrations, confirming the presence of carbonyl compounds such as esters, ketones, and carboxylic acid dimers. [22] noted that such carbonyl, containing phytochemicals, especially flavonoids and tannins, can strongly coordinate with iron ions on the metal surface, forming a stable complete that inhibits corrosion. Additionally, the band at 1519.91 cm^{-1} corresponds to aromatic C=C stretching or amide II vibrations, indicating the presence of nitrogen or oxygen containing aromatic compounds such as alkaloids, proteins, or polyphenols.

Overall, the FTIR analysis of Sample 1 confirmed the presence of functional groups such as hydroxyl, carbonyl, and aromatic systems which are features typical of plant-based corrosion inhibitors. These findings align with the study of [18] who reported similar spectral profiles in *Azadirachta indica* extract, recognized for its corrosion-inhibiting potential. Minor differences in peak intensity could be due to variations in solvent extraction, plant maturity, or drying conditions.

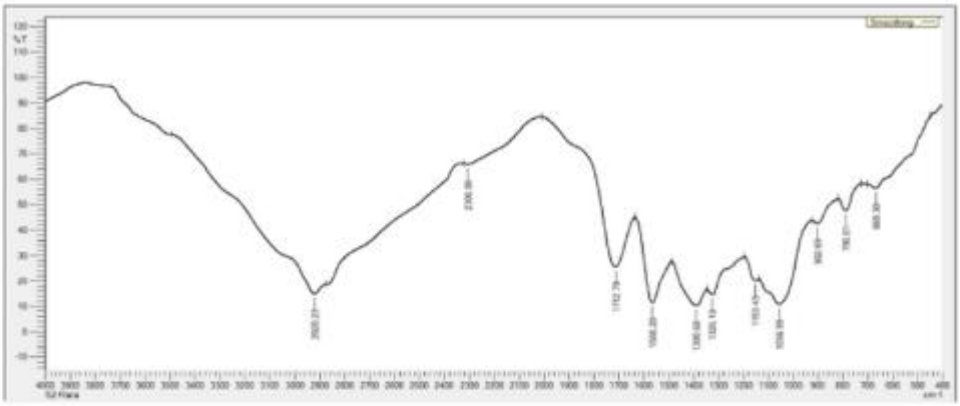


Figure 4 Image of the IR spectrum of D. seguine (Jacq.) Schott Root at 400-4000 cm-1

Table 2 FTIR Spectral Interpretation of *Dieffenbachia seguine* (Jacq.) Schott Root Extract (Sample 2)

	Functional Group	**Intensity**	**Interpretation**	**Potential Phytochemical Class**
2920.23	C–H stretch (asymmetric) (alkane group)	Strong	Aliphatic $-CH_2/-CH_3$ stretching vibrations indicating the presence of long-chain hydrocarbons, fatty acids, or waxy materials	Lipids, Fatty acids, Steroids
2306.86	C≡N stretch / CO_2 asymmetric stretch	Weak to Medium	May indicate nitrile (C≡N) functional group or absorbed atmospheric CO_2; possible presence of nitrogen-containing compounds or trace amines	Alkaloids, Amines
1712.79	C=O stretch (carbonyl group)	Strong, Sharp	Characteristic of ester, aldehyde, or carboxylic acid functional groups; indicates presence of fatty acid esters, organic acids, or terpenoids	Fatty acid esters, Organic acids, Terpenoids
1566.20	Aromatic C=C stretch / N–H bend (amide II band)	Medium	Associated with aromatic ring vibrations or amide II; indicates presence of aromatic compounds, polyphenols, or proteinaceous substances	Alkaloids, Flavonoids, Tannins, Proteins

The FTIR spectrum of Dumb Cane roots (Sample 2) shows distinct absorption bands at 2920.23 cm^{-1}, 2306.86 cm^{-1}, 1712.79 cm^{-1}, and 1566.20 cm^{-1}, each corresponding to functional groups associated with phytochemical constituents. The strong band at 2920.23 cm^{-1} is attributed to C–H asymmetric stretching vibrations of aliphatic $-CH_2$ and $-CH_3$ groups, indicating the presence of lipids or sterols. Long aliphatic chains are known to form hydrophobic barrier films on steel surfaces, reducing the diffusion of aggressive species to the metal surface [27].

The weak absorption at 2306.86 cm^{-1} corresponds to C≡N stretching vibrations, suggesting the presence of alkynes or nitriles. As [22] discussed, such compounds contribute to corrosion inhibition by promoting π-electron interactions with metal atoms, strengthening the adsorption layer. A sharp peak at 1712.79 cm^{-1} corresponds to C=O stretching of carbonyl compounds such as esters, ketones, or carboxylic acids. Phytochemicals containing carbonyl groups, particularly flavonoids and tannins, can form stable complexes with iron ions on metal surfaces, thereby reducing corrosion activity [22]. The peak at 1566.20 cm^{-1} represents aromatic C=C stretching or amide II vibrations, indicating the presence of aromatic or nitrogen-containing compounds such as alkaloids, flavonoids, tannins, and proteins.

Overall, the FTIR spectrum of Sample 2 indicates the presence of hydroxyl, carbonyl, and aromatic functional groups that enhance adsorption and corrosion inhibition. These results are consistent with findings from [25], who observed similar functional group patterns in *Glycyrrhiza glabra* root extracts with strong inhibition efficiency on mild steel. The correlation between the observed functional groups and literature confirms that Dumb Cane roots, like its leaves and stem, contain bioactive compounds capable of acting as plant-based corrosion inhibitors.

3.2. Inhibition Efficiency through Weight Loss

The corrosion behavior of mild steel in seawater, inhibited by ethanolic extracts of Dumb Cane (*Dieffenbachia seguine)*, was evaluated using weight loss measurements. Mean values and standard deviations are presented in Table 3.

Weight-loss values decreased as inhibitor concentration increased for both stem/leaf and root extracts. The uninhibited blank specimen showed a mean weight loss of 0.19 ± 0.08 g, while the negative control (ethanol) resulted in 0.10 ± 0.03 g. In comparison, specimens treated with Dumb Cane extracts exhibited substantially lower weight losses: 0.03 g at 0.2–0.4 g/L, 0.01 g at 0.6 g/L, and nearly zero (0.00 g) at 0.8 g/L for both plant parts.

Table 3 Weight Loss results

Dumb cane part	Concentration (g/L)	Mean (g)	Standard Deviation
Stem/Leaf	0.2	0.030	0.01
	0.4	0.030	0.01
	0.6	0.010	0.01
	0.8	0.000	0.00
Root	0.2	0.030	0.01
	0.4	0.030	0.01
	0.6	0.010	0.01
	0.8	0.000	0.00

Notes. Results are the mean of triplicate determinations Blank – 0.19 ± 0.08 g; Negative control (ethanol) - 0.10 ± 0.03 g

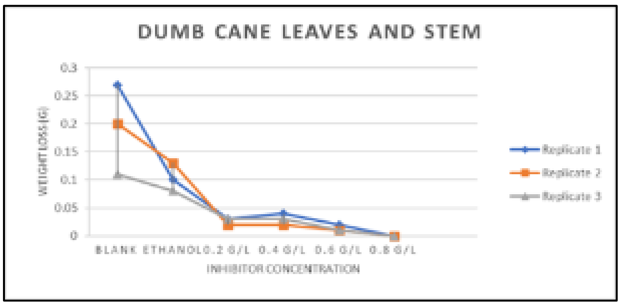


Figure 5 Result of the weight loss of different corrosion inhibitors (stem/leaf)

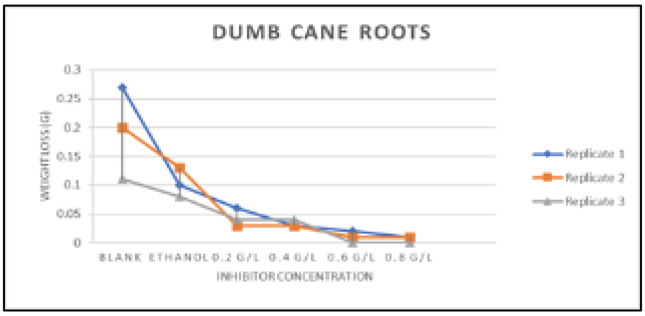


Figure 6 Result of the weight loss of different corrosion inhibitors (roots**)**

These results indicate a concentration-dependent inhibition effect, with corrosion decreasing as inhibitor concentration increases. The absence of measurable weight loss at 0.8 g/L suggests nearly complete surface protection. This observation is consistent with the formation of a stable adsorbed inhibitor film that restricts metal dissolution and electrolyte diffusion. Similar behavior has been reported for other green inhibitors, including extracts of *Cuminum cyminum* and *Glycyrrhiza glabra* [28,24].

Table 4 summarizes the results of the two-way ANOVA. The analysis confirmed that concentration had a statistically significant effect on corrosion rate, $F(3, 16) = 19.98$, $p < .001$. In contrast, the effect of plant part was not significant, $F(1, 16) = 2.88$, $p = .109$, and the interaction between plant part and concentration was also non-significant, $F(3, 16) = 1.47$, $p = .260$. These findings indicate that both stem/leaf and root extracts exhibit a similar concentration-dependent inhibition trend. The model accounted for 80.8% of the total variance (adjusted $R^2 = .724$).

The results of the post-hoc Tukey HSD comparisons are presented in Table 5. The analysis showed that mean weight losses at 0.6 g L^{-1} and 0.8 g L^{-1} were significantly lower than those at 0.2 g L^{-1} and 0.4 g L^{-1} ($p < .05$), whereas the difference between 0.6 g L^{-1} and 0.8 g L^{-1} was not significant ($p = .348$). Therefore, 0.6 g L^{-1} was identified as the optimum concentration, beyond which inhibition reached a saturation point. This behavior is attributed to complete surface coverage by inhibitor molecules [9,24].

Table 4 Two-way ANOVA results for weight loss

Source	***df***	**MS**	**F**	***p***
Plant Part	1	0.000	2.882	0.109
Concentration	3	0.001	19.980	0.000*
Plant Part · Concentration	3	0.000	1.471	0.260

Note. df – degrees of freedom; MS – Mean square; *Statistically significant at 5% level of significance ($p < 0.05$)

Table 5 Post-hoc comparisons using Tukey's test of the differences for concentration (weight loss, g)

Comparison (I – J)	**Mean Difference (g)**	***SE***	***p***
0.2-0.4	0.400	0.003	0.901
0.2-0.6	.0233*	0.005	0.001
0.2-0.8	.0317*	0.005	0.000
0.4-0.6	.0200*	0.005	0.004
0.4-0.8	.0283*	0.005	0.000
0.6-0.8	0.008	0.005	0.348

Note. SE – standard error; *Statistically significant at 5% level of significance ($p < 0.05$)

The percentage inhibition efficiency (%IE) results, as presented in Table 6, exhibit a concentration-dependent trend consistent with the weight-loss data. For the stem/leaf extract, %IE increased from 80.93% at 0.2 g/L to 100% at 0.8 g/L. The root extract demonstrated 75.47% inhibition at 0.2 g/L and 97.10% at 0.8 g/L.

The negative control (ethanol) exhibited only 58.25 ± 6.90 % inhibition, indicating that ethanol alone offers minimal corrosion protection. The substantially higher efficiencies observed for Dumb Cane extracts indicate that phytochemicals within the plant, rather than the solvent, are primarily responsible for corrosion inhibition.

Table 6 Inhibition efficiency (%) results

Dumb cane part	Concentration (g/L)	% IE	Standard Deviation
Stem/Leaf	0.2	80.93	13.12
	0.4	82.64	8.91
	0.6	92.83	2.06
	0.8	100.00	0.00
Root	0.2	75.47	10.87
	0.4	79.18	13.60
	0.6	95.86	3.78
	0.8	97.10	2.59

Notes. Results are the mean of triplicate determinations; Negative control (ethanol) – 58.25 ± 6.90%

The similar inhibition efficiencies observed for stem/leaf and root extracts suggest the presence of comparable bioactive constituents in both plant parts. As the concentration increases, inhibitor molecules compete for active sites on the steel surface, achieving complete monolayer coverage and thereby minimizing metal–solution contact [25,27].

Regression analysis of inhibition efficiency versus concentration is summarized in Table 7. The analysis revealed a strong positive relationship for both extracts, with R^2 values of 0.942 for the stem/leaf extract and 0.888 for the root extract. The linear models, IE = 72.25 + 33.70C for stem/leaf and IE = 66.51 + 40.79C for root, account for more than 88 % of the observed variability. These high coefficients of determination indicate that inhibition efficiency is directly proportional to the inhibitor concentration.

Table 7 Linear Regression Analysis of Inhibition Efficiency (%) Versus Inhibitor Concentration (g/L)

Plant Part	Regression Equation	R^2	F	p
Stem/Leaf	IE=72.25+33.70 C	0.942	32.297	0.030
Root	IE=66.51+40.79 C	0.888	15.887	0.058

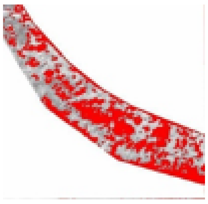
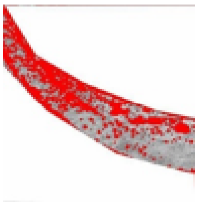
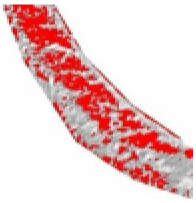
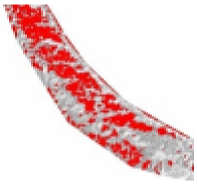
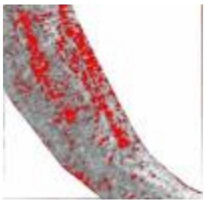
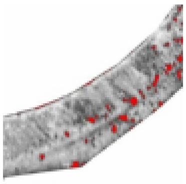
Note. The inhibition efficiency increased significantly with concentration for both extracts ($p < .05$).

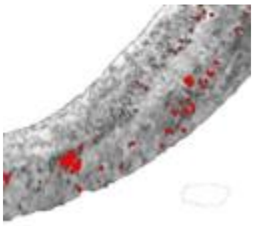
3.3. Image Analysis

Table 8 presents the percentage rust coverage of mild-steel surfaces, as determined by ImageJ analysis, following exposure to seawater with and without *Dieffenbachia seguine* extracts. The data demonstrate that corrosion severity decreased as inhibitor concentration increased for both plant parts. The blank specimen exhibited the highest rust coverage (42.57%), indicating extensive corrosion in the absence of any inhibitor, while the ethanol control showed a nearly identical value (42.61%), confirming that the solvent alone had a negligible protective effect. In contrast, specimens treated with Dumb Cane extracts exhibited substantially lower corrosion coverage, with values decreasing from 12.35% at 0.2 g/L to 3.21% at 0.8 g /L for the stem/leaf extract, and from 9.48% to 2.54% for the root extract. This progressive reduction in the rusted area is consistent with the statistical findings from the two-way ANOVA (Table 4), which indicate a significant influence of inhibitor concentration on the corrosion rate ($p < .001$).

These results also complement the FTIR findings (Figures 2–3; Tables 1–2), which identified functional groups such as hydroxyl and carbonyl capable of adsorbing onto the metal surface to form a protective film. The low rust coverage at higher concentrations visually confirms that these phytochemicals adsorbed onto and covered the steel surface, thereby minimizing exposure to chloride ions. Comparable concentration-dependent reductions in surface corrosion have been reported for plant-based inhibitors such as *Cuminum cyminum* [28] and *Glycyrrhiza glabra* [24]. Thus, the rust coverage data in Table 8 provide clear morphological validation of the adsorption-controlled inhibition mechanism established by both FTIR and statistical analyses.

Table 8 Rust coverage analysis of mild steel samples determined using ImageJ

Treatment	ImageJ Process Image of Mild Steel	Rust Coverage (%)
Blank		42.57
Negative Control		42.61
DCLS (0.2 g/L)		36.67
DCLS (0.4 g/L)		34.19
DCLS (0.6 g/L)		16.87
DCLS (0.8 g/L)		3.21
DCR (0.2 g/L)		3.99

DCR (0.4 g/L)		3.73
DCR (0.6 g/L)		3.86
DCR (0.8 g/L)		2.54

The surface morphology of mild steel specimens after seawater immersion was examined to confirm the protective effects of *Dieffenbachia seguine* extracts. Quantitative and qualitative analyses were conducted using ImageJ and 3D surface profiling. The data in Table 8 and the images in Figure 4a–c provide visual evidence supporting the statistical and spectroscopic results.

The uninhibited specimen (Figure 4a) showed a rough, irregular surface with extensive rust formation and deep corrosion pits. ImageJ analysis indicated about 42% rust coverage, consistent with the high mean weight loss (0.19 ± 0.08 g) in the blank sample (Table 3). This confirms rapid metal dissolution and chloride attack in the absence of an inhibitor.

In contrast, specimens treated with Dumb Cane extracts showed smoother, more uniform surfaces (Figures 4b–4c). The stem/leaf extract at 0.8 g L^{-1} reduced rust coverage to 3.21%, while the root extract achieved the lowest coverage at 2.54%, indicating slightly better protection. These results align with the two-way ANOVA (Table 4), which showed a significant effect of concentration ($F(3, 16) = 19.98$, $p < .001$) but no significant effect of plant part ($p = .109$). This indicates that both extracts were similarly effective, with the root extract showing marginally smoother surfaces.

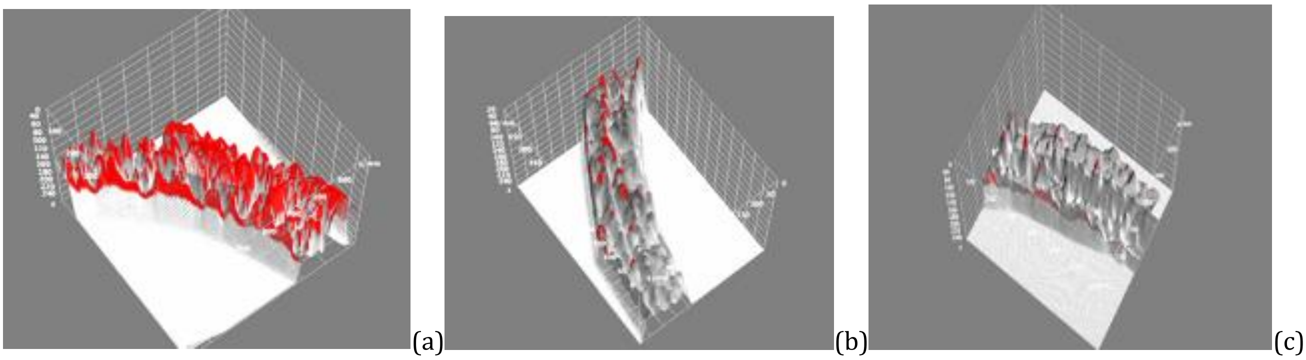


Figure 7 Comparative 3D Surface Topography of Mild Steel after Immersion in Seawater with and without Dumb Cane Extracts: (a) Uninhibited mild steel (blank), (b) mild steel treated with ethanolic stem/leaf extract, and (c) mild steel treated with ethanolic root extract of *Dieffenbachia seguine*.

The morphological differences between untreated and treated surfaces are consistent with the FTIR results (Figures 2–3; Tables 1–2). Both extracts showed absorption bands for O–H, C–H, C=O, and C–O groups, corresponding to hydroxyl, carbonyl, and ether linkages found in flavonoids, phenols, and tannins. These compounds adsorb onto metal surfaces through lone pairs and π-electron interactions, forming a compact protective film that reduces anodic and cathodic reactions [22,18,23].

The smoother surfaces of treated specimens confirm this adsorption-based mechanism. High inhibition efficiencies at 0.6 and 0.8 g L^{-1} (above 95%; Table 6) indicate near-complete surface coverage. This trend agrees with regression results (Table 7), which show a strong correlation between concentration and inhibition efficiency (R^2 = .888–.942). The plateau beyond 0.6 g L^{-1} suggests surface saturation and monolayer formation.

These findings are consistent with studies on plant-based inhibitors. Similar surface improvements were observed with *Glycyrrhiza glabra* [24] and *Cuminum cyminum* [28], where phytochemical adsorption formed stable protective films. Other studies [29,30] also report increased efficiency with concentration until adsorption equilibrium is reached.

The 3D surface plots (Figure 7a–c) show the transition from severe corrosion in the blank sample to smoother, minimally corroded surfaces after treatment. The blank specimen exhibits pronounced peaks and valleys from rust and pitting, while treated samples show reduced roughness. The root extract (Figure 7c) produced the smoothest surface, consistent with its slightly higher inhibition efficiency (97.10%) and lower rust coverage.

Overall, the results confirm that corrosion inhibition by Dumb Cane extracts occurs through adsorption of oxygen- and nitrogen-containing phytochemicals, forming a dense protective film on steel. The consistency between surface morphology, FTIR data, and statistical analysis supports an adsorption-controlled mechanism, similar to other green inhibitors [9,31].

4. Conclusion

The findings confirm that ethanolic extracts of Dumb Cane (*Dieffenbachia seguine)* stems, leaves, and roots act as effective green corrosion inhibitors for mild steel in seawater. Statistical analysis shows that inhibitor concentration significantly affects corrosion inhibition, while plant part does not, indicating comparable performance. Regression results demonstrate a strong positive relationship between concentration and inhibition efficiency, with effectiveness increasing until a saturation point is reached.

FTIR analysis identified functional groups such as hydroxyl, carbonyl, and amide, which promote adsorption onto the metal surface. These oxygen- and nitrogen-containing phytochemicals—mainly flavonoids, tannins, and alkaloids—interact with iron through electron donation and hydrogen bonding, forming a stable protective film. ImageJ analysis supports this, showing reduced rust coverage and smoother surfaces in treated samples.

Overall, the results show that corrosion inhibition by *D. seguine* extracts is adsorption-controlled, involving both chemisorption and physisorption. Both stem/leaf and root extracts were similarly effective, with the root extract offering slightly better protection, supporting its use as a sustainable corrosion inhibitor in chloride-rich environments like seawater.

Compliance with ethical standards

Acknowledgments

First and foremost, the researchers express their deepest gratitude to Almighty God, the source of wisdom, knowledge, and strength, for His continuous blessings, protection, and guidance throughout the completion of this study.

Heartfelt appreciation is extended to the research adviser, Mr. Christian James L. Castro, for his guidance, encouragement, and patience, as well as to the other research advisers for their valuable suggestions and constructive criticisms that improved this paper. Moreover, the researchers extend their deepest appreciation to their parents and families for their unconditional love, understanding, and moral and financial support, which made this endeavor possible.

Lastly, the researchers thank all individuals who contributed their assistance, time, and encouragement, dedicating the success of this study to everyone who supported and believed in them.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest concerning the publication of this paper.

Statement of ethical approval

The present research work did not involve the use of animals/humans, by any of the authors. Neither did it involve information about individual(s) by way of case study, survey or interview.

References

[1] Harsimran, S., Santosh, K., & Rakesh, K. (2021). OVERVIEW OF CORROSION AND ITS CONTROL: A CRITICAL REVIEW. Proceedings on Engineering Sciences, 3(1), 13–24. https://doi.org/10.24874/pes03.01.002

[2] Mazumder, M. A. J. (2020, June 2). Global Impact of Corrosion: Occurrence, Cost and Mitigation. Global Journal of Engineering Sciences. https://irispublishers.com/gjes/fulltext/global-impact-of-corrosion-occurrence-cost-and-mitigation.ID.000618.php

[3] Ken, J. (2024). Corrosion of Metals: Factors, Types and Prevention Strategies. 14(1), 7987.https://www.researchgate.net/publication/377534338_Corrosion_of_Metals_Factors_Types_and_Prevention_Strategies

[4] Verma, N., Kumar, T., Vinod Kumar Vashistha, Das, D. K., Yadav, S., Rajasekhar VSR Pullabhotla, & Sharma, G. (2024). Anticorrosion properties of flavonoids for rust-free building materials: a review. Corrosion Reviews, 0(0). https://doi.org/10.1515/corrrev-2024-0024

[5] Al-Amiery, A. A., Isahak, W. N. R. W., & Al-Azzawi, W. K. (2023). Corrosion Inhibitors: Natural and Synthetic Organic Inhibitors. Lubricants, 11(4), 174. https://doi.org/10.3390/lubricants11040174

[6] Eno, I. P., & Ubi, G. M. (2021, January 1). Toxic Effect of the Floristic Dumb Cane (Dieffenbachia amoena) Phytochemicals and Anti Nutritional Factors on household.https://www.researchgate.net/publication/383231300_Toxic_Effect_of_the_Floristic_Dumb_Cane_Dieffenbachia_amoena_Phytochemicals_and_Anti_Nutritional_Factors_on_household

[7] Ahmed, M. A., Amin, S., & Mohamed, A. A. (2024). Current and emerging trends of inorganic, organic and eco-friendly corrosion inhibitors. RSC Advances, 14(43), 31877–31920. https://doi.org/10.1039/D4RA05662K

[8] Wang, X., Chen, L., Yang, F., Xiang, Q., & Liu, J. (2023). Corrosion inhibition mechanism and extraction technology of plant corrosion inhibitors: a review. Journal of Adhesion Science and Technology, 37(21), 2919–2943. https://doi.org/10.1080/01694243.2023.2172993

[9] Khan, M. A., Farooq, M., & Ashraf, M. (2021). Corrosion protection of mild steel using coatings and inhibitors: An updated review. Coatings, 11(5), 579.

[10] Sonawane, J. M., Yadav, A., Ghosh, P. C., & Adeloju, S. B. (2016). Recent advances in the development and utilization of modern anode materials for high performance microbial fuel cells. Biosensors and Bioelectronics, 90, 558–576. https://doi.org/10.1016/j.bios.2016.10.014

[11] Nguyen, Q.-V., Huyen, B., Thi, B., Tran, M.-Đ., Nguyen, M.-T., Doan, M.-D., Nguyen, A.-D., Minh Le, T., Tran, V.-C., & Pham, T.-N. (2022). Impact of Different Drying Temperatures on In Vitro Antioxidant and Antidiabetic Activities and Phenolic Compounds of Wild Guava Leaves Collected in the Central Highland of Vietnam. Natural Product Communications, 17(4), 1934578X2210953. https://doi.org/10.1177/1934578x221095349

[12] Wang, C., Wang, W., Wang, N., & Zhang, X. (2025). Durable and multifunctional superhydrophobic composite coating based on activated PAL for active protection of aluminum alloy. Applied Surface Science, 716, 164717. https://doi.org/10.1016/j.apsusc.2025.164717

[13] Crăciun, A. L., & Gutt, G. (2023). Optimization of Experimental Parameters in the Solvent Extraction of Trans-Resveratrol from Pruning Waste of Vitis vinifera, Fetească Neagră Variety. Applied Sciences, 13(2), 823. https://doi.org/10.3390/app13020823

[14] Sarkar, A., & ghosh, uma. (2017). Effect of extraction temperature and technique on phenolic compounds and antioxidant activity of. Research Journal of Applied Sciences, 06(02), 10–15. https://www.researchgate.net/publication/313342184_Effect_of_extraction_temperature_and_technique_on_phenolic_compounds_and_antioxidant_activity_of_Tamarindus_indica_seed

[15] Yao, L., Baharum, A., Yu, L. J., Yan, Z., & Badri, K. H. (2025). Bio-based polyurethane as a sustainable coating material for controlled-release fertilizer. Discover Sustainability, 6(1). https://doi.org/10.1007/s43621-025-01756-y

[16] Oloyede, G. K., Onocha, P. A., & Abimbade, S. (2012). Phytochemical, toxicity, antimicrobial and antioxidant screening of extracts obtained from Dieffenbachia picta (Araceae) Leaves and Stem. 11(1), 31–43. https://www.researchgate.net/publication/262329938_Phytochemical_toxicity_antimicrobial_and_antioxidant_screening_of_extracts_obtained_from_Dieffenbachia_picta_Araceae_Leaves_and_Stem

[17] Royani, A., Prifiharni, S., Priyotomo, G., Triwardono, J., & Sundjono. (2019). Corrosion of carbon steel in synthetic freshwater for water distribution systems. IOP Conference Series: Earth and Environmental Science, 399(1), 012089. https://doi.org/10.1088/1755-1315/399/1/012089

[18] Enekwe, C. B., Igwilo, C. N., Ude, C. N., Omotioma, M., Onoh, I. M., & Nwobu, D. N. (2024). Impact of neem (Dogonyaro) leaf extract as a green inhibitor to control corrosion of mild steel in HCl acid medium. Ebonyi State College of Education, Ikwo Journal of Educational Research (EBSCOEIJER), 9(2), 59–68. https://ebscoeijer.org/index.php/self/article/view/59/54

[19] Qiang, Y., Zhang, S., Tan, B., & Chen, S. (2018). Evaluation of Ginkgo leaf extract as an eco-friendly corrosion inhibitor of X70 steel in HCl solution. Corrosion Science, 133, 6–16. https://doi.org/10.1016/j.corsci.2018.01.008

[20] Skotnicki, W., & Jędrzejczyk, D. (2024). Comparative analysis of coatings applied for Anti-Corrosion protection of public transport vehicles' structural parts. Materials, 17(15), 3763. https://doi.org/10.3390/ma17153763

[21] Verma, V., Patel, P., Ryan, K. M., Hudson, S., & Padrela, L. (2022). Production of hydrochlorothiazide nanoparticles with increased permeability using top-spray coating process. The Journal of Supercritical Fluids, 192, 105788. https://doi.org/10.1016/j.supflu.2022.105788

[22] Umoren, S. A., & Solomon, M. M. (2017). Synergistic corrosion inhibition effect of metal cations and mixtures of organic compounds: A Review. Journal of Environmental Chemical Engineering, 5(1). https://doi.org/10.1016/j.jece.2016.12.001

[23] Al-Moubaraki, A. H., Abdelkarim Chaouiki, Alahmari, J. M., Al-Hammadi, W. A., Noor, E. A., Al-Ghamdi, A. A., & Young Gun Ko. (2022). Development of Natural Plant Extracts as Sustainable Inhibitors for Efficient Protection of Mild Steel: Experimental and First-Principles Multi-Level Computational Methods. Materials, 15(23), 8688–8688. https://doi.org/10.3390/ma15238688

[24] Salleh, S. Z., Yusoff, A. H., Zakaria, S. K., Taib, M. a. A., Seman, A. A., Masri, M. N., Mohamad, M., Mamat, S., Sobri, S. A., Ali, A., & Ter Teo, P. (2021). Plant extracts as green corrosion inhibitor for ferrous metal alloys: A review. Journal of Cleaner Production, 304, 127030. https://doi.org/10.1016/j.jclepro.2021.127030

[25] Parthipan, P., Cheng, L., & Rajasekar, A. (2021). Glycyrrhiza glabra extract as an eco-friendly inhibitor for microbiologically influenced corrosion of API 5LX carbon steel in oil well produced water environments. Journal of Molecular Liquids, 333, 115952. https://doi.org/10.1016/j.molliq.2021.115952

[26] Chigondo, M., & Chigondo, F. (2016). Recent natural corrosion inhibitors for mild steel: An overview. Journal of Chemistry, 2016, 1–7 https://doi.org/10.1155/2016/6208937

[27] Sheydaei, M. (2024). The use of plant extracts as green corrosion Inhibitors: A review. Surfaces, 7(2), 380–403. https://doi.org/10.3390/surfaces7020024

[28] Desai, P. S., & Desai, F. P. (2023). An overview of sustainable green inhibitors for aluminum in acid media. AIMS Environmental Science, 10(1), 33–62. https://doi.org/10.3934/environsci.2023003

[29] Kumari, A., Kaur, N., Chahal, S., & Kaur, T. (2025). Sustainable corrosion prevention of mild steel in acidic media with Rumex Nepalensis herb extract. RSC Advances, 15(2), 924–937. https://doi.org/10.1039/d4ra07958b

[30] González-Parra, J. R., & Di Turo, F. (2024). The Use of Plant Extracts as Sustainable Corrosion Inhibitors for Cultural Heritage Alloys: A Mini-Review. Sustainability, 16(5), 1868. https://doi.org/10.3390/su16051868

[31] Sheydaei, M. (2024). The use of plant extracts as green corrosion Inhibitors: A review. Surfaces, 7(2), 380–403. https://doi.org/10.3390/surfaces7020024